


The thematic assessment report on

THE SUSTAINABLE USE OF WILD SPECIES

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THE IPBES THEMATIC ASSESSMENT REPORT ON THE SUSTAINABLE USE OF WILD SPECIES

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IPBES is an independent intergovernmental body comprising about 140 member Governments. Established by Governments in 2012, IPBES provides policymakers with objective scientific assessments about the state of knowledge regarding the planet's biodiversity, ecosystems and the contributions they make to people, as well as options and actions to protect and sustainably use these vital natural assets.

The Assessment of the Sustainable Use of Wild Species was initiated by a decision from the IPBES Plenary at its sixth session (IPBES 6, Medellin, Colombia, 2018), based on the scoping report approved by the Plenary at its fifth session (IPBES 5, Bonn, Germany, 2017). It was considered by the IPBES Plenary at its ninth session (IPBES 9, Bonn, Germany, 2022), which approved its summary for policymakers, and accepted its chapters. All material can be found here: https://ipbes.net/sustainable-use-assessment

FOREWORD

A key objective of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is to provide Governments, the private sector and civil society with scientifically credible and independent up-to-date assessments of available knowledge for better evidence-informed policy decisions and action at the local, national, regional and global levels.

The Assessment of the Sustainable Use of Wild Species is part of a series of reports whose production was initiated during the "first work programme of IPBES, 2014–2018" and concluded during the current "IPBES rolling work programme up to 2030". This Assessment has been carried out by close to 100 experts selected from all regions of the world, including early career fellows, assisted by about 200 contributing authors. More than 6,000 scientific publications were analyzed as well as a substantive body of indigenous and local knowledge. Its chapters were accepted, and its summary for policymakers was approved, by the IPBES Plenary composed of 139 member States at its ninth session held from 3rd to 9th July 2022 in Bonn, Germany.

The Sustainable Use of Wild Species Assessment builds on the landmark IPBES Global Assessment of Biodiversity and Ecosystem services published in 2019. The Global Assessment concluded that for terrestrial and freshwater ecosystems, the direct exploitation, in particular overexploitation, of animals, plants and other organisms, mainly via harvesting, logging, hunting and fishing ranked second, immediately following land-use change, in terms of having the largest relative negative impact on nature since 1970; and that the reverse was true for marine ecosystems, with direct exploitation of organisms (mainly fishing) having the largest relative negative impact on nature. This Assessment focuses on the sustainability of the use of wild species and does not review the status of wild species nor the impacts of human uses on wild populations, which were recently assessed by the IPBES Global Assessment.

The Sustainable Use of Wild Species Assessment shows how billions of people around the world rely on over 50,000 wild species for food, energy, medicine, and other uses in low as well as in high-income countries, and that 70% of the world's poor are directly dependent on wild species.

The Assessment finds that status and trends in the use of wild species vary depending on types and scales and social-ecological contexts. Globally, 34% of marine wild fish are

overfished; populations of many terrestrial animals are declining due to unsustainable use; and the survival of 12% of wild trees species is threatened by unsustainable logging.

The Assessment investigates the causes of unsustainable use and finds that global trade is a major driver of unsustainable use and has expanded substantially over the past 40 years. Illegal harvesting and trade in wild species is another driver of unsustainable use.

The Assessment concludes that policy and tools are most effective, among others, when they pay attention to the social and cultural contexts in which they are applied, in addition to the ecological context; when they support fairness, rights and equity; and when they are supported by robust and adaptive institutions which are inclusive and include participatory mechanisms.

The Assessment notes that indicators of sustainable use of wild species are poorly represented in global goals, such as the Sustainable Development Goals; that they fail to capture key social-ecological linkages recognized as key to sustainable use; and that scientific monitoring is limited or lacking for many extractive and non-extractive practices, thus strongly limiting the impact of regulations.

Finally, the report also observes that indigenous peoples and local communities manage fishing, gathering, and terrestrial animal harvesting in about 40% of terrestrial conserved areas in 87 countries, and have developed an extensive knowledge regarding wild species, such as on monitoring practices. It further concludes that policy options would be strengthened by recognising and supporting multiple forms of knowledge, including indigenous and local knowledge.

As the Chair and the Executive Secretary of IPBES, we wish to recognize the leadership and dedication of the co-chairs, Dr. John Donaldson (South Africa), Dr. Marla R. Emery (United States of America/Norway), and Dr. Jean-Marc Fromentin (France) and the hard work and commitment of all the coordinating lead authors, lead authors, review editors, fellows, contributing authors and external reviewers, and to warmly thank them for contributing their time and ideas freely to this important report. We would also like to recognize the leadership and dedication of Agnès Hallosserie, head of the technical support unit for this Assessment, and the hard work of the other members of the unit including Dr. Marie-Claire Danner and Daniel Kieling.

Our thanks go also to the current and former members of the Multidisciplinary Expert Panel (MEP) and of the Bureau who provided guidance as part of the management committee for this report, and to members of the IPBES secretariat including those of other technical support units within the IPBES secretariat, who have supported the production of this report, and its successful launch in the media. We would also like to thank all Governments and other institutions that provided financial and in-kind support for the preparation of this Assessment.

We are profoundly aware that work was made more challenging over the past couple of years because of the COVID-19 pandemic which prevented the experts from meeting and connecting in-person as planned, and which created very difficult personal circumstances for many. We express again our deepest thanks and recognition to all involved, on behalf of IPBES.

This Assessment was requested by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and by the Convention on Biological Diversity (CBD), in addition to individual governments and others. We hope that Parties to CITES will see this Assessment as a major resource toward meeting its two 2030 commitments: the CITES strategic vision for a world where all international trade in wild fauna and flora is legal, sustainable and traceable, and the United Nation's Sustainable Development Goals. We also hope that the Assessment will form a significant contribution to the implementation of the new Global Biodiversity Framework of the Convention on Biological Diversity and inform action by Governments and a diversity of actors at national and local scales.

Ana María Hernández Salgar
Chair of IPBES

Anne Larigauderie
Executive Secretary of IPBES

STATEMENTS FROM KEY PARTNERS

Today one million species are at risk of extinction. And the unsustainable, illegal and unregulated use of species is a large part of the problem. For example, the illegal wildlife trade is a 23-billion-dollar annual business that lines the deep pockets of a few unscrupulous individuals. These people get rich at the expense of nature and ecosystems. This trade also robs countries, indigenous people and local communities of access to their own resources and safe livelihoods.

This is because an important value of nature lies in its sustainable use for food, medicine, income generation and livelihoods for millions of people.

It is critical to ensure sustainable use, and fair and equitable sharing of its benefits – particularly to most vulnerable populations and the communities that are the stewards of nature. Sustainable use can provide a strong incentive for conservation and living in harmony with nature.

The Sustainable Use of Wild Species Assessment from IPBES, whose secretariat is hosted by UNEP, is a vital contribution to global efforts to ensure this happens.

Inger Andersen
Under-Secretary-General of the United Nations and Executive Director,
United Nations Environment Programme (UNEP)

The IPBES Assessment Report on the Sustainable Use of Wild Species is a stark reminder that human beings are interdependent with all living beings. Millions of people are living in harmony with nature in UNESCO designated sites worldwide, from Biosphere reserves to World heritage sites.

This is a wealth of experience and solutions to reconcile and make peace with nature. It is not too late to act, and UNESCO is fully committed to mobilize the full force of education, science and culture to lead this global transformative change.

Audrey Azoulay
Director-General,
United Nations Educational, Scientific and Cultural Organization (UNESCO)

The sustainable use of wild species is important to the world's agrifood systems. It is fundamental to the forestry and fisheries sectors, and it contributes directly to livelihoods, food security and nutrition, particularly in developing regions and indigenous people. Wild species provide a huge range of products, diversify diets, provide multiplies options for income generation, and are part of the cultural and social life of many communities.

We must ensure that the use of wild species is sustainable. Failure to do so will compromise the future of agrifood systems and jeopardize efforts to meet the Sustainable Development Goals.

It will also undermine the supply of essential ecosystem services, increase the risk of infectious disease outbreaks, drive inequity and conflict, and diminish our capacity to mitigate and adapt to threats of the climate crisis.

This Report heightens our understanding of how wild species are used and how they can be sustainably managed to benefit the people and habitats that depend on them.

Dr QU Dongyu
Director-General,
Food and Agriculture Organization of the United Nations (FAO)

"The IPBES continues to strengthen the role of science in public decision-making on biodiversity and ecosystem services, ultimately helping to restore the delicate balance between people and our natural world. As part of these efforts, this new IPBES assessment report, the Sustainable Use of Wild Species Assessment, shows how billions of people depend on more than 12,000 wild species for food, medicine, energy, and livelihoods. Crucially, it provides policymakers with a framework for sustainable management, one that includes data and analytics to track and trace wild species. Leveraging insights from 420 of the world's leading experts in this field, the assessment's latest science, evidence and analysis will help countries to implement the post-2020 Global Biodiversity Framework. It also aims to contribute to a chain reaction of bold action on protecting, restoring, and sustainably managing nature towards the Sustainable Development Goals. Doing so will help the world to break through to a greener, more inclusive, and more sustainable future for all."

Achim Steiner
Administrator,
United Nations Development Programme (UNDP)

"The IPBES Assessment of the Sustainable Use of Wild Species is an important tool and source of knowledge for all members of the biodiversity community. In our world faced with biodiversity decline including as a result of the overexploitation of wild species, we need to better understand the ways forward for sustainable use. The need to better ensure the sustainable harvesting, trade and use of wild species while ensuring benefits to nutrition, food security, medicines, and livelihoods for people especially for the most vulnerable from the sustainable use of wild species has been well recognized in the discussions around the post-2020 Global Biodiversity Framework.

In examining the feasibility of and options for the sustainable use of wildlife on land, in freshwater and in the oceans, by people around the world, this report is in fact linked to the draft version of the Global Biodiversity Framework. We expect that this Assessment can also be one of the tools to assist implementation of the Global Biodiversity Framework, expected to begin after its adoption at COP 15.

Let me congratulate IPBES and its community of experts for this work. I look forward to its active use by all Parties and stakeholders to the Convention."

Elizabeth Maruma Mrema
Executive Secretary,
Convention on Biological Diversity (CBD)

Over half this Assessment was conducted against the backdrop of the COVID-19 pandemic. As Co-Chairs, we wish to thank the many individuals and institutions who persevered through those extraordinary circumstances to bring this Assessment into being.

Firstly, we acknowledge with gratitude the tremendous efforts and dedication of the people who researched, wrote, and reviewed the full Assessment including its summary for policymakers. Many abruptly lost access to their offices, research databases, childcare, health care and, even, consistent sources of food. Several lost family members, became ill themselves or cared for loved ones who contracted coronavirus. We rejoice that most were able to find workarounds that allowed them to continue contributing to the work and saddened that this was not possible for all. Our tremendous technical support unit – Agnès Hallosserie, Marie-Claire Danner, and Daniel Kieling – remained steady, professional, and encouraging throughout, exhibiting near miraculous creativity in their efforts to support the work of our experts, especially those in the most difficult circumstances. The fruits of their labor are evident throughout the Assessment.

The sudden necessity to switch to exclusively virtual meetings was both a challenge and an opportunity. We are indebted to the technical support unit for their technical expertise, which made those meetings possible with a minimum of disruptions. Our thanks go to those experts who consistently participated despite schedules that required them to do so late at night or in the early hours of the day.

Integration of indigenous and local knowledge was central to this Assessment. Dialogue workshops were an essential component of that effort and we are profoundly grateful to the many individuals and organizations representing indigenous peoples and local communities who participated in them. Our thanks to UNESCO, notably Nigel Crawhall, for hosting the first workshop in Paris, and to Eric Vachon and Isabel Julian for their warm welcome of the second workshop at the Biosphere Environmental Museum in Montreal. One silver lining of the pivot to virtual meetings was the expanded number of indigenous peoples and local communities who were able to participate in the third dialogue workshop. Special appreciation to Gabriela Lichtenstein and Maite Lascuarin Rangel for helping to organize and facilitate a session in Spanish. This essential work would not have been possible without the indigenous and local knowledge

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Jean-Marc Fromentin, Marla R. Emery, and John Donaldson
Co-Chairs

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SUMMARY FOR POLICYMAKERS

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Key Messages

A Sustainable use of wild species is critical for people and nature

A.1 Billions of people in all regions of the world rely on and benefit from the use of wild species for food, medicine, energy, income and many other purposes.

A.2 Sustainable use of wild species is central to the identity and existence of many indigenous peoples and local communities.

A.3 Ensuring sustainability of the use of wild species, including by promoting sustainable use and halting overexploitation, is critical to reverse the global trend in biodiversity decline.

B Status and trends in uses of wild species

B.1 Status and trends in uses of wild species vary depending on types and scales of use, and social-ecological contexts.

B.2 The sustainability of the use of wild species is influenced negatively or positively by multiple drivers.

B.3 Key elements of sustainable use of wild species have been identified in relevant international and regional standards, agreements and certification schemes, but indicators are incomplete, most notably for social components.

C Key elements and conditions for the sustainable use of wild species

C.1 Policy instruments and tools are most successful when tailored to the social and ecological contexts of the use of wild species and support fairness, rights and equity.

C.2 Policy instruments and tools are more effective when they are supported by robust and adaptive institutions and are aligned across sectors and scales. Inclusive, participatory mechanisms enhance the adaptive capacity of policy instruments.

C.3 Effective monitoring of social, including economic, and ecological outcomes supports better decision-making. Scientific evidence is often limited, and indigenous and local knowledge is underutilized and undervalued.

D Pathways and levers to promote sustainable use and enhance the sustainability of the use of wild species in a dynamic future

D.1 The sustainability of the use of wild species in the future is likely to face challenges due to climate change, increasing demand and technological advances. Addressing and meeting these challenges will require transformative changes.

D.2 To address current and projected future pressures, concerted interventions will be needed to implement and scale up policy actions that have been shown to support the sustainable use of wild species.

D.3 The world is dynamic and to remain sustainable, use of wild species requires constant negotiation and adaptive management. It also requires a common vision of sustainable use and transformative change in the human-nature relationship.

Introduction

The thematic assessment of the sustainable use of wild species of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) evaluates the sustainable use of wild species through the lenses of practices, environmental and spatial contexts, human communities, policies, governance systems and institutions. The aim of the assessment is to consider various approaches to enhance the sustainability of the use of wild species besides their existence values and identify challenges and opportunities that ensure and promote the sustainable use of wild species, in order to reduce and eventually eliminate unsustainable and illegal uses of wild species within the ecosystems that they inhabit, and to strengthen related practices, measures, capacities and conservation approaches that arise from such uses. The assessment builds on previous IPBES assessments, most recently the *Global Assessment Report on Biodiversity and Ecosystem Services,*[2] which evaluated the status of wild species worldwide and documented the impacts of human uses on wild populations.

For purposes of the assessment, sustainable use and wild species are interpreted and defined as follows:

- **Sustainable use** was defined in article 2 of the Convention on Biological Diversity[3] in 1992 as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations." The assessment notes that sustainable use is also an outcome of social-ecological systems {1.1.1} that aim to maintain biodiversity and ecosystem functions in the long term, while contributing to human well-being. It is a dynamic process as wild species, the ecosystems that support them and the social systems within which uses occur change over time and space {1.3.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5}. The assessment takes

2. IPBES (2019): Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E. S., Settele, J., Díaz, S., and Ngo, H.T. (editors). IPBES secretariat, Bonn, Germany. Available at https://doi.org/10.5281/zenodo.3831673.

3. United Nations, *Convention on Biological Diversity* (Rio de Janeiro, Brazil, 1992).

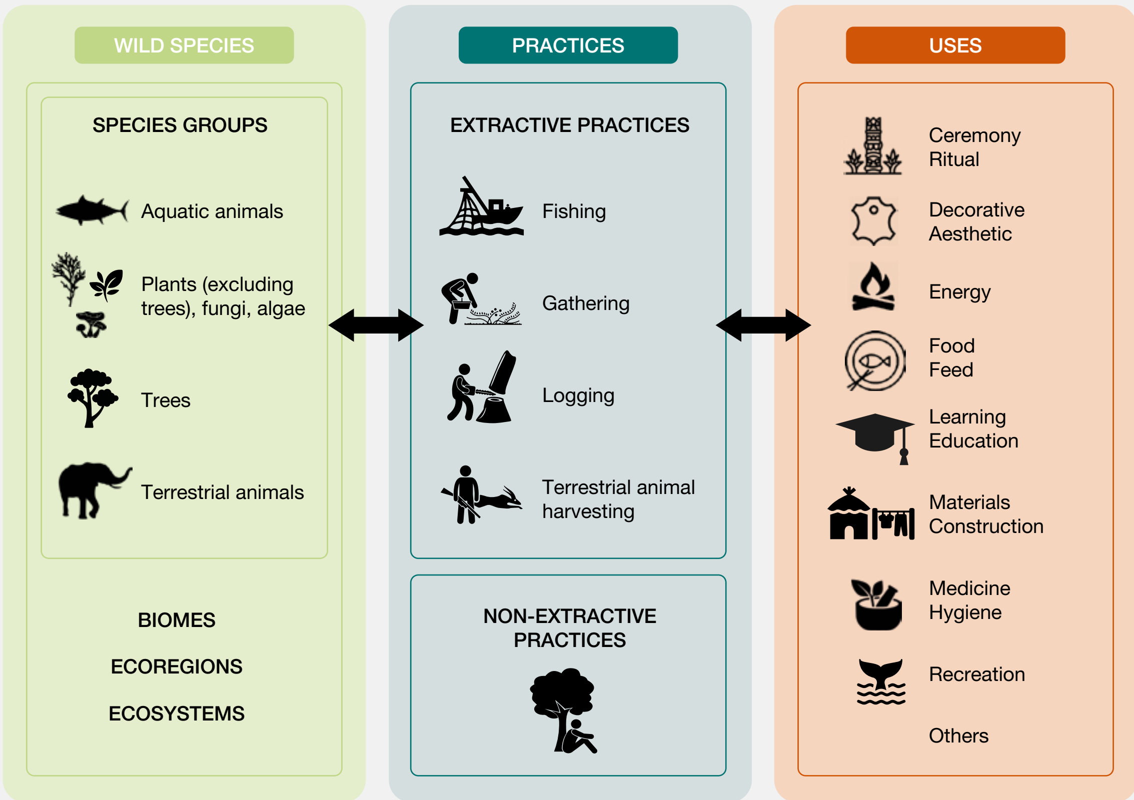

Figure SPM 1 **Organizing structure of the sustainable use assessment.**

© Logging pictogram: Gan Khoon Lay from the Noun Project

into account the social, economic and environmental dimensions of sustainability, as identified by the 2030 Agenda for Sustainable Development and its Sustainable Development Goals.

- **Wild species** refers to populations of any species that have not been domesticated through multigenerational selection for particular traits, and which can survive independently of human intervention that may occur in any environment. This does not imply a complete absence of human management and recognizes various intermediate states between wild and domesticated {1.3.2}.

Use of wild species involves both the practices associated with harvest or other direct interactions with wild species, as well as the end purpose for which the species is used. Practices and uses are defined in chapter 1 of the assessment. All other technical terms used in the present summary for policymakers, and in particular definitions of different practices and uses, are further defined in the glossary of the assessment and appendix 3 to the present annex. For the assessment, four main groups of wild species inhabiting different types of biomes, ecoregions or ecosystems, four extractive practices, one non-extractive practice and nine types of use are considered **(Figure SPM.1)** {1.3.4}.

A. Sustainable use of wild species is critical for people and nature

The use of wild species is widespread and occurs across almost all aquatic and terrestrial ecosystems, in subsistence to global economies, and is embedded in local and global systems, including for food, medicine, hygiene, energy and many other uses. Addressing the causes of unsustainable use and promoting and ensuring the sustainable use of wild species are critical for people and to address biodiversity decline.

A1 Billions of people in all regions of the world rely on and benefit from the use of wild species for food, medicine, energy, income and many other purposes.

(A.1.1) The use of wild species directly contributes to the well-being of billions of people globally on a day-to-day basis and is particularly important to people in vulnerable situations *(well established)* (see appendix 1) {1.5, 3.2.1, 3.3.1, 3.3.4.4.2}. Wild species contribute to human well-being through many different types of uses **(Figure SPM.1)**, which can be continuous, daily or irregular. In many cases, a single species may have multiple uses and contribute to human well-being in multiple ways *(well established)* {1.3.4, 3.4.3.1, 4.3.4}. For example, wild plants, algae and fungi provide food, nutritional diversity and income for an estimated one in five people around the world, in particular women, children, landless farmers and others in vulnerable situations *(well established)* {3.3.2}. 2.4 billion people (approximately one third of the global population) rely on fuelwood for cooking and an estimated 880 million people globally log firewood or produce charcoal, particularly in developing countries *(established but incomplete)* {3.3.4.4.2}. Small-scale fisheries are strongly anchored in local communities' ways of life on all continents and support over 90 per cent of the 120 million people engaged in capture fisheries globally. About half of the people involved in small-scale fisheries are women *(well established)* {3.4.3.1}. People in vulnerable situations are often most reliant on wild species and are most likely to benefit from more sustainable forms of use of wild species to secure their livelihoods *(well established)* {1.5, 1.6, 3.2.1, 4.2.3.5}. An estimated 70 per cent of the world's poor depend directly on wild species and on businesses fostered by them *(well established)* {3.2.1}.

(A.1.2) About 50,000 wild species are used for food, energy, medicine, materials and other purposes through fishing, gathering, logging and terrestrial animal harvesting globally. People all over the world directly use about 7,500 species of wild fish and aquatic invertebrates, 31,100 species of wild plants, of which 7,400 species are trees, 1,500 species of fungi, 1,700 species of wild terrestrial invertebrates and 7,500 species of wild amphibians, reptiles, birds and mammals *(well established)* {3.2.1.3, 3.3, 3.3.2.3.4}. Among the wild species that are used, more than 20 per cent (over 10,000 species) are used for human food, making the sustainable use of wild species critical to achieving food security and improving nutrition in rural and urban areas worldwide *(well established)* {3.3}. Fisheries constitute a major source of food from wild species, with a total annual harvest of 90 million tons over recent decades, of which about 60 million tons go to direct human consumption, with the rest used as feed for aquaculture and livestock *(well established)* {3.2.1.1}. Terrestrial animal harvesting (which includes hunting) contributes to the food security of many people living in rural and urban areas worldwide, especially in developing countries *(well established)* {3.3.3.3.3}. Wild aquatic and terrestrial animals constitute key sources of protein, fat, and micronutrients, such as calcium, iron, zinc and fatty acids, for the global human population *(well established)* {3.3.1.5.1, 3.3.2.3.4, 3.3.3.3.3}.

(A1.3) Wild species are important sources of subsistence resources and income. Uses of wild species form the basis for economically and culturally important activities worldwide *(established but incomplete)* {3.3.2}. Trade in wild plants, algae and fungi is a billion-dollar industry and the establishment of supply chains can fuel economic development and diversification *(well established)* {3.3.2.1}. People in economically disadvantaged urban and rural areas rely on wild plants, algae and fungi as sources of essential calories, micronutrients and medicine *(well established)* {3.3.2, 3.3.2.2.2}. Fishing, terrestrial animal harvesting, logging and nature-based tourism are vital to regional and local employment and economies in many developing and developed countries and further contribute to public infrastructure, development and provisioning of related goods and services *(well established)* {3.3}. The use of wild species also provides non material contributions by enriching people's physical and psychological experiences, including their religious and ceremonial lives *(well established)* {1.3.4, 3.3.5.2.1}.

(A.1.4) Gathering wild plants, fungi and algae takes place in both developed and developing countries worldwide. Such a practice is closely associated with cultural and subsistence practices, and can also supply global markets *(established but incomplete)* {3.3.2}. Gathering is often assumed to be an activity more prevalent in the global South. However, estimates of individuals and households participating in gathering in Europe and North America range from 4 to 68 per cent, with the highest rates of gathering by households in Eastern Europe *(established but incomplete)* {3.3.2.2.1}, often irrespective of economic status *(established but incomplete)* {3.3.2.2.3}. Gathering is not confined to rural areas, with dozens to hundreds of wild plant and fungi species gathered for food, medicine, firewood, decoration and cultural practices in urban ecosystems worldwide *(well established)* {3.3.2.2.2}. Gathering wild products is often a gendered activity in many parts of the world, with roles depending on cultural rules, on the type of harvested wild plants, fungi or algae and the places where they are harvested. In many countries, women perform the bulk of gathering and processing wild plants for food, medicine, fuel and handicrafts for subsistence purposes and sale in local markets *(well established)* {3.3.2.2.3, 4.2.3.6.2}.

(A.1.5) Wild tree species are currently the major source for wood and wood products and will continue to be so in the coming decades *(well established)* {3.3.4.1}. Logging is an important source of subsistence resources and income for millions of people worldwide *(well established)* {3.3.4.3}. Globally, wild tree species provide two thirds of industrial roundwood {3.3.4.3.3} and half of all wood consumed for energy *(established but incomplete)* {3.3.4.4.2}. Logging is carried out by smallholders, communities and industrial entities *(established but incomplete)* {3.3.4.3}. For example, logging by smallholders provides thousands of jobs in Central African countries *(well established)* {3.3.4.3.1}. An estimated 15 per cent of global forests are managed as community resources by indigenous peoples and local communities, often with a strong focus on multiple use management *(established but incomplete)* {3.3.4.3.2}, while industrial logging occurs in over one quarter of the world's forests *(well established)* {3.3.4.3.3}.

(A.1.6) Nature-based tourism, including wildlife watching, supports mental and physical well-being, raises awareness and facilitates connections to nature, in addition to bringing local benefits such as direct income generation to local communities *(well established)* {3.3.5}. Although non-extractive practices using wild species are common across all human societies, the nature of the practice differs among cultures and locations *(well established)* {3.3.5}. Wildlife watching generates substantial revenue, contributing US$ 120 billion in 2018 to global gross domestic product (five times the estimated value of the illegal wild species trade) and sustaining 21.8 million jobs *(well established)* {3.3.4.2.3}. Prior to the coronavirus disease (COVID-19) pandemic, globally, protected areas received 8 billion visitors and generated US$ 600 billion per year, with species-rich countries experiencing the highest increases in rates of tourism visitation *(established but incomplete)* {3.3.5.2.3}. Wildlife watching is crucial for local livelihoods, provides employment and promotes development of tourism-related infrastructure, particularly in some remote locations *(well established)* {3.3.5.2.3, 3.4.4.2}.

(A.1.7) Potential contributions from sustainable use of wild species to meeting the Sustainable Development Goals are substantial, but largely overlooked *(established but incomplete)* {1.6}. Measures to ensure and promote the sustainable use of wild species will make direct contributions to meeting many of the Sustainable Development Goals. While the contributions of the sustainable use of wild species have been identified for Goal 14 (life below water) and Goal 15 (life on land), there is untapped potential for contributions to the rest of the Sustainable Development Goals **(Figure SPM.2)** *(established but incomplete)* {1.6}. Further attention to ways in which the sustainable use of wild species can support good quality of life for people and the planet will contribute to realizing these global goals *(well established)* {1.6, 2.2.10}.

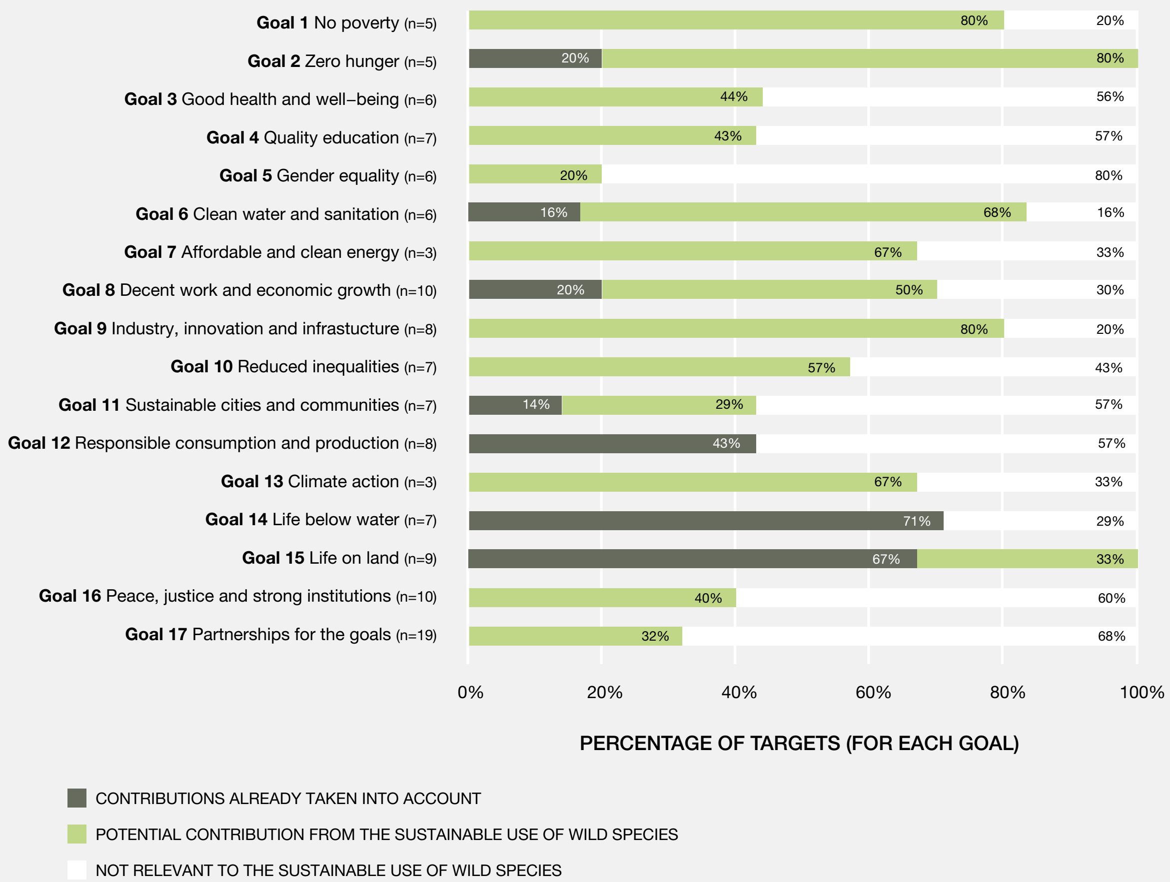

Figure SPM 2 **Sustainable use of wild species has unacknowledged potential to contribute to the achievement of many targets of the Sustainable Development Goals.**

This figure shows the untapped potential of including the sustainable use of wild species in strategies to achieve the Sustainable Development Goals. The potential contribution of the sustainable use of wild species to achieve each Goal was assessed based on the wording of the "outcome targets" (n=x) under each Goal and the evidence documented in the Thematic Assessment of the Sustainable Use of Wild Species.[4] The percentages showed in the figure refer to the number of targets related to the sustainable use of wild species that are "already taken into account" (grey bar), have "potential relevance" (green bar), or have "no relevance" (white bar) to achieve each Goal. Supporting information and details on assessments for each Goal are available in chapter 1 {1.6}. A data management report for this figure is available at https://doi.org/10.5281/zenodo.6036273.

4. IPBES (2022). Thematic Assessment Report on the Sustainable Use of Wild Species of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Fromentin, J.M., Emery, M.R., Donaldson, J., Danner, M.C., Hallosserie, A., and Kieling, D. (eds.). IPBES secretariat, Bonn, Germany. Available at https://doi.org/10.5281/zenodo.6448567.

A2 Sustainable use of wild species is central to the identity and existence of many indigenous peoples and local communities.

(A.2.1) Wild species play essential roles in the well-being of many indigenous peoples and local communities. Loss of opportunity to engage in sustainable use of wild species represents an existential threat to indigenous peoples and local communities *(well established)* {1.4, 2.2.4, 3.3.1.4, 3.3.2., 3.3.3, 3.3.4.3.1, 4.2, 6.5, 6.6}. Uses of wild species are central to the identities, cultural expressions and livelihoods of many indigenous peoples and local communities **(Figure SPM.3)**. While all wild species in use are important, some have special significance as cultural keystone species **(Box SPM.1)**; that is, they provide multiple benefits that define key elements of a people's tangible and intangible cultural heritage. Continued ability to engage in sustainable use of wild species and the cultural practices associated with them is essential for indigenous

Box SPM 1 **Cultural keystone species: wild rice.**

Wild rice *(Zizania palustris)* is a cultural keystone species, providing physical, spiritual and cultural sustenance for many indigenous peoples in the Great Lakes region of North America. Remarkable for its high protein and micronutrient profile when processed correctly, this aquatic grain can be stored for long periods of time, which represents a particularly important property in a region characterized by severe winters and short growing seasons. The significance of wild rice to the identities of indigenous peoples in the region can be seen in nomenclatures and traditions. The name of the Menominee Indian Tribe of Wisconsin (United States of America) means "wild rice people". When the Anishinaabe peoples migrated from the Atlantic coast and the north-east of North America, oral tradition instructed that they should move westward until they arrived at "the place where food grows on water". Wild rice remains a healthy staple in the diets of indigenous peoples in the Great Lakes region and is an important part of many feasts and ceremonies {1.4.1}.

Harvesting wild rice, a cultural keystone species for indigenous peoples in the Great Lakes region of North America.
Photo credit: CO Rasmussen/GLIFWC

peoples and local communities to survive and thrive *(well established)* {1.4, 2.2.4, 2.2.8, 3.2.1, 3.3.3, 3.3.4, 4.2.2.2.5, 4.2.3.4, 4.2.3.5, 4.2.2.6, 6.5.2}.

(A.2.2) Sustainable use of wild species contributes to the livelihoods of indigenous peoples and local communities through subsistence, as well as trade in informal and formal markets *(well established)* {4.2.4.3.2}. Subsistence uses of wild species are important sources of food, medicine, fuel and other livelihood resources for indigenous peoples and local communities in both developed and developing countries. Often, wild species are considered superior to cultivated species or other substitutes, as identified in discussions with indigenous peoples and local communities. Many wild foods have nutritional benefits over processed foods and there may be no culturally acceptable alternative for ceremonial and ritual materials *(well established)* {3.3.1.7.1, 3.3.2.3.4, 3.3.3.3.3, 3.3.3.4.2, 3.3.5.2.1}. Wild species also provide a basis for culturally meaningful employment *(well established)* {1.6, 3.3.3.2.1, 3.3.5.2.3}. Indigenous peoples and local communities have engaged in long-distance trade of wild species and materials derived from them for millennia. Trade continues to be an important source of goods and monetary income for many indigenous peoples and local communities *(well established)* {4.2.4.3.2}.

(A.2.3) Knowledge, practices and worldviews guide sustainable uses of wild species by many indigenous peoples and local communities *(well established)* {1.4.1, 2.2.4, 2.2.5, 4.2.5.2.4}. For many indigenous peoples and local communities, sustainable uses of

INDIGENOUS PEOPLES AND LOCAL COMMUNITIES AND THE SUSTAINABLE USE OF WILD SPECIES

Figure SPM 3 **Sustainable use of wild species is essential to the well-being of many indigenous peoples and local communities.**

In turn, sustainable use also contributes to maintaining abundant, healthy populations of wild species. Photos, clockwise from top. **Well-being and health:** fishing by Mayangna communities in Nicaragua. **Language:** Inuit language encodes knowledge necessary for successful hunting, fishing and trapping in the Canadian Arctic. **Art, crafts and music:** animal motifs engraved on an ostrich egg by a Khomani San artist from the Kalahari, South Africa. **Ritual and ceremony:** spring festival in the Kedarnath Valley, India. **Animals and plants as kin, totems and spirits:** vicuñas are revered by peoples of the Andean altiplano. **Community institutions and governance:** the Karamojong people of Uganda make decisions about uses of wild species in a sacred meeting place. **Livelihoods and economy:** in the Solomon Islands, fishing is central to local livelihoods. Fishing is organized around customary sea tenures and fish are distributed through a kinship-based system. **Clothing, fuel, fodder and shelter:** the bark of Himalayan nettle is used as fibre for clothing, ropes and sacks by indigenous peoples and local communities in Nepal. **Food:** in the Brazilian Amazon a local fisherman carries a pirarucú, an important food fish. **Traditional medicines:** a Roma woman gathers *Hypericum sp*. in the Carpathians. **Learning and knowledge transmission:** in Canada, an Inuk boy learns how to skin a caribou.

Photo credits: P. Gros / D. Nakashima / G. Kruiper / S. Dhyani / B. Vilá / I. Ocen / E. Hviding / R. P. Chaudhary / R. Oliveira / A. Peter Molnar.

wild species are embedded in and maintained through indigenous and local knowledge, practices and spirituality. While indigenous and local knowledge and the cultures of indigenous peoples and local communities are diverse, common values with respect to sustainable use of wild species include an obligation to engage nature with respect, reciprocate for what is taken, avoid waste, manage harvests and ensure fair and equitable distribution of benefits from wild species for community well-being *(well established)* {1.4, 2.2.4, 4.2.5.2.4}. These values are frequently upheld by community institutions and governance *(well established)* {2.2.4.2, 4.2.2.4}.

A3 Ensuring sustainability of the use of wild species, including by promoting sustainable use and halting overexploitation, is critical to reverse the global trend in biodiversity decline.

(A.3.1) Effective management systems that promote the sustainable use of wild species can contribute to broader conservation objectives *(established but incomplete)* {1.1.1, 3.3.3.3.4, 3.3.3.4.1, 3.3.4.3.2, 3.3.5.2.3, 4.2.4.3.1}. Based on the assessment of 10,098 species from 10 taxonomic groups documented for the International Union for Conservation of Nature Red List of Threatened Species, at least 34 per cent of the wild species assessed are used sustainably *(established but incomplete)* {3.2.1, 3.2.2, 4.2.4.3.1}. This includes 172 threatened or near-threatened species. Effective management systems that promote sustainable use, supported by policies linked to land tenure and rights of access, have contributed to the conservation of ecosystems such as forests at the local level *(well established)* {3.3.2.3.4, 4.2.2.2.4, 4.2.2.6}. Revenues from the sustainable use of wild species can make a substantial contribution to the conservation of landscapes and seascapes *(established but incomplete)* {4.2.3.3.5, 4.2.4.3.1, 4.2.4.3.3, 4.2.5.2.3}. Revenues from non-extractive practices, notably tourism in protected areas, can make a significant contribution to overcoming funding shortfalls for protected areas if the revenue is used to support protected area management *(established but incomplete)* {4.2.4.3.1}. Revenues from the extractive use of wild animals, including hunting and fishing licenses and concession fees, provide an important and substantial income stream for conservation agencies and local communities in some countries *(well established)* {3.3.3.2.4}. Large areas of land that are managed for recreational hunting (e.g., approximately 1.4 million km^2 in Africa) could contribute to conservation objectives and spatial conservation targets, but their unique biodiversity values as well as their ecological and social durability have mostly not been evaluated *(established but incomplete)* {3.3.3.2.4}.

(A.3.2) Overexploitation has been identified as the main threat to wild species in marine ecosystems and the second greatest threat to those in terrestrial and freshwater ecosystems *(well established)* {1.1, 3.3.1.4}. Addressing the causes of unsustainable use and reversing the trend will result in better outcomes for these wild species. Many uses of wild species occur within the context of declining wild species populations and ranges. For example, unsustainable fishing is the main cause of the increased extinction risk of sharks and rays over the past half-century *(well established)* {3.3.1}. Among the 1,250 shark and ray species identified today, 1,199 have been recently assessed and 449 (37.5 per cent) have been assessed as threatened *(well established)* {3.3.1.3}. Unsustainable hunting has been identified as a threat for 1,341 wild mammal species, including 669 species that were assessed as threatened, and declines in large-bodied species with low intrinsic rates of population increase have been linked to hunting pressure *(well established)* {3.3.3}. Negative impacts of hunting have also been reported for bird species *(well established)* {3.3.3.2.5, 3.3.3.2.6, 3.3.3.3.4}. An estimated 12 per cent of wild tree species are threatened by unsustainable logging {3.2.1.4} and unsustainable gathering is one of the main threats for several plant groups, notably cacti, cycads and orchids *(well established)*, as well as other plants and fungi harvested for medicinal purposes {3.2.2, 3.3.2.3.2, 4.2.4.3.1}. Overall, unsustainable harvesting contributes towards elevated extinction risk for 28–29 per cent of near-threatened and threatened species from 10 taxonomic groups assessed on the International Union for Conservation of Nature Red List of Threatened Species {3.2.1, 3.2.2}.

(A.3.3) Indigenous peoples manage fishing, gathering, terrestrial animal harvesting and other uses of wild species on more than 38 million km^2 of land in 87 countries *(well established)* {1.3.2}. This area coincides with approximately 40 per cent of terrestrial conserved areas, including many with high biodiversity value *(well established)* {1.3.2, 1.4}. Globally, deforestation is generally lower on indigenous territories, in particular where there is security of land tenure, continuity of knowledge and languages and alternative livelihoods *(well established)* {4.2.2.2.5}. The long history of sustainable uses of wild species in these areas has played a role in maintaining and increasing local levels of biodiversity while supporting indigenous peoples' well-being and livelihoods *(well established)*. Examples of customary provisions to promote the sustainable use of wild species include rest periods, spatial and temporal prohibitions on use, and designation of areas and species for exclusive use by kinship groups *(well established)* {1.1.2, 1.4, 3.3, 4.2.5.2}.

B. Status and trends in uses of wild species

Status and trends in uses of wild species display strong disparities according to the social and ecological contexts in which they occur. Although common principles of sustainable use have been identified, methods and tools to assess the sustainability of the use of wild species are constrained by lack of a comprehensive set of indicators, especially regarding non-extractive use and social components of extractive uses.

B1 Status and trends in uses of wild species vary depending on types and scales of use, and social-ecological contexts.

(B.1.1) Recent global estimates indicate that approximately 34 per cent of marine wild fish stocks are overfished and 66 per cent are fished within biologically sustainable levels, but this global picture displays strong heterogeneities *(well established)* {3.2.1.1}. In countries or regions implementing robust fisheries management,[5] stocks are increasing in abundance and tend to be above target levels **(Figure SPM.4)** *(well established)* {3.3.1}. These countries provide roughly half of the fisheries landings reported to the Food and Agriculture Organization of the United Nations and mostly concern large-scale fisheries *(well established)* {3.3.1}. For countries and regions with low-intensity fisheries management measures, the status of stocks is often poorly known *(well established)* {3.3.1.2}, but generally believed to be below the abundance that would maximize sustainable food production *(established but incomplete)* {3.3.1}. For small-scale fisheries that have been assessed around the world, many have been considered to be unsustainable or only partially sustainable, especially in Africa for both inland and marine fisheries and in Asia, Latin America and Europe for coastal marine fisheries *(established but incomplete)* {3.3.1.4.1}. The diversity of contexts in which small-scale fisheries operate have often made conventional data-driven fisheries management inadequate and unsuccessful, but when the involvement, participation and empowerment of indigenous peoples and local communities are maintained or promoted, the sustainability of small-scale fisheries can be achieved *(well established)* {6.5.1.1, 6.5.3.1}.

(B.1.2) Unintentional bycatch of threatened and/or protected marine species is unsustainable for many populations, including wild sea turtles, seabirds, sharks, rays, chimaeras, marine mammals and some bony fishes. Reducing unintentional bycatch and discards is progressing, but still insufficient *(well established)* {3.3.1.1}. While fishing of target species may be sustainable, the conservation status of bycatch species and other associated and dependent species is often poorly known. Bycatch is a well-known issue for several large-scale fisheries, such as shrimp or bottom-trawl fisheries, but it is also a concern for several small scale fisheries *(well established)* {3.3.1.1, 3.3.1.5}. There have been recent advances in monitoring and managing fishing mortality of marketable incidental species and discarded bycatch species, however global uptake of effective bycatch management measures is severely lagging in a majority of marine capture fisheries *(well established)* {3.3.1.5}. For example, nearly all (99 per cent) shark and ray species are officially declared to be taken unintentionally, but are valuable and are retained for food. Consequently, shark species have been declining steeply since the 1970s, especially in tropical and subtropical coastal shelf waters *(well established)* {3.3.1.3}.

(B.1.3) Trade in wild plants, algae and fungi for food, medicine, hygiene, energy, and ornamental use is increasing (Figure SPM.4) *(well established)* {3.3.2}. There is a growing demand for wild foods in the food and aromatics industries including among fine dining and haute cuisine establishments, and among urban populations *(well established)* {3.3.2.2.2, 3.3.2.3.4}. There is also a growing interest and ongoing demand for products produced at least in part from harvested wild plants and fungi, to complement chemical medicines in many developed and developing countries *(well established)* {3.3.2.3.5}. Trade in ornamental plants has increased rapidly over the past 40 years. Although much of the trade is in cultivated plants, poaching of ornamental species from the wild continues to occur, and can threaten the survival of species *(well established)* {3.3.2.3.2}. Harvests that have been sustainable in the past due to smaller markets and sustainable harvesting practices may become unsustainable if, for example, harvesting is undertaken without following established techniques and protocols *(well established)* {3.3.2.3.4}, or new technologies are employed which increase the volume of harvest or result in damage to or death of the organism, for example when entire trees are felled rather than climbed to harvest ripe fruits *(established but incomplete)* {3.3.2}.

(B.1.4) Terrestrial animal harvesting takes place in a variety of governance, management, ecological and socio-cultural contexts, which affect the outcomes for sustainable use. Globally, populations of many terrestrial animals are declining due to unsustainable use, but the impacts of use on wild

5. Robust fisheries management is understood here as an organizational scheme which regularly evaluates the status of fished populations and the performance of fisheries, sets management regulations consistent with the best knowledge available and has the capacity to monitor catches and effort, constrain effort and impose effective deterrents for non-compliance.

Practice	Use category	20-year global trends: use	20-year global trends: sustainable use	Comments	Chapter section
FISHING	Food Feed	↓	↑	Corresponds to large-scale fisheries with intensive management, data rich	3.3.1.2
		↗	✥	Corresponds to large-scale fisheries with weak management, data limited	3.3.1.2
		✥	✥	Corresponds to small-scale fisheries, based on a range of sources	3.3.1.5.1
	Medicine Hygiene	↑	✥	Based on stock status and total weight of products	3.3.1.4.2
	Recreation	↑	⊘	Data limited	3.3.1.5.3
GATHERING	Food Feed	↗	→	Based on a range of sources	3.3.2.3.4
	Medicine Hygiene	↑	✥	Based on population trends, threatened categories and CITES listing	3.3.2.3.5
	Decorative Aesthetic	↗	→	Based on threatened categories and CITES listing	3.3.2.3.2
LOGGING	Materials Construction	↑	✥	Based on total legal wood removal	3.3.4.4.3
	Energy	↑	✥	Based on a range of sources	3.3.4.4.2
TERRESTRIAL ANIMAL HARVESTING	Recreation	✥	→	Based on population trends, threatened categories and CITES listing	3.3.3.2.4
	Food Feed	✥	↓	Based on increasing demand for wild meat in commercial markets, population trends	3.3.3.3.3
NON-EXTRACTIVE PRACTICES	Recreation	↑	✥	Based on amount of tourism revenue generated	3.3.5.2.4
	Ceremony Ritual	✥	⊘	Data limited	3.3.5.2.1
	Medicine Hygiene	✥	⊘	Data limited	3.3.5.2.3

- WELL ESTABLISHED
- ESTABLISHED BUT INCOMPLETE
- UNRESOLVED
- INCONCLUSIVE

- ↑ ↗ STRONGLY OR SLIGHTLY INCREASING
- ↓ ↘ STRONGLY OR SLIGHTLY DECREASING
- → STABLE
- ✥ HIGH VARIABILITY IN TRENDS

Figure SPM 4 **Global trends in use and sustainable use of wild species from 2000 to the present.**

The figure shows only the top two to three use categories for each practice, selected based on which uses were most documented in the systematic literature reviews conducted as part of chapter 3 analysis. Additional use categories are included in chapter 3 {3.3}. Trends in use refer to an assessment of the overall state of use for wild species in relation to the specified practice, i.e., has overall use increased strongly, increased, stayed the same, decreased or decreased strongly. The multi-directional arrow depicts highly variable trends across areas or sectors for a given category of practice-use. The colours of the arrows refer to the confidence levels associated with those trends. Trends in sustainable use specifically refer to whether the intensity and form of use have been deemed sustainable over the 20-year period. For additional explanations see the definition of sustainable use in the glossary of the assessment. Data supporting global trends and regional variations come from practice-based systematic reviews of over 1,600 scientific texts. Use of indicators and other variables in the analysis varied widely across the five practice categories. The search for appropriate indicators demonstrated knowledge gaps in existing global data sets and indicators sets {3.2}. Thus, the comments column contains brief reference to how the trend was determined, with further explanations in chapter 3 as referenced in the final column. In some categories a subdivision demonstrates the ways in which the practice is understood and analysed in the available literature. For a definition of the practices, see appendix 3 of the present summary, and for an explanation of knowledge gaps, see appendix 2. *Abbreviations:* CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora.

species and society can be neutral or positive in some places (Figure SPM.4) *(well established)* {3.3.3}. Hunting (a sub-category of terrestrial animal harvesting, see appendix 3) for food, medicine and recreation is a prominent practice in terms of number of species and biomass of harvested animals *(well established)* {3.3.3.2}. Sustainability of hunting for food, especially in tropical areas, has been negatively affected by profound socio economic changes, which have resulted in shifts from local-level subsistence towards more intensive wild meat trade *(well established)* {3.3.3.2.3}. The impacts of hunting on the abundance of wild species vary worldwide depending on the biological characteristics of the animals as well as the management systems but are generally lower for species with high population growth rates, or high ecological adaptability, and where hunting is well managed *(well established)* {3.3.3.2.4}. There is considerable variation in the way recreational hunting is governed and administered in different regions, which makes any generalization about its sustainability or unsustainability difficult {3.3.3.2.4}. Some species are recovering from small population sizes under management systems that allow regulated recreational hunting, usually as a way to generate revenue and increase the land area for population expansion *(established but incomplete)* {3.3.3.2.4}. Harvesting live animals for a variety of purposes, including the pet trade, affects thousands of wild species. There are more than 1,000 species of birds, reptiles, fish and mammals legally and illegally traded for personal and commercial use as pets. While the total dollar value of species traded as pets is less than 1 per cent of the total trade of wild species, the number of individuals traded is in the millions *(established but incomplete)* {4.2.4.1}. For example, about 12 million live parrots were recorded in international trade between 1980 and 2015 *(established but incomplete)* {3.3.3.3}. Harvesting of vicuña (*Vicugna vicugna*) fibre is a good example of sustainable non lethal use of wild animals, associated with an increase of populations across its range, especially in areas where communities benefit from sustainable use projects *(well established)* {4.2.4.4.1}.

(B.1.5) Large-bodied mammals are the most targeted species for subsistence and commercial hunting, as these animals provide more meat for consumption and sale to generate more economic benefits for hunters' households *(well established)* {3.3.3.2.3}. Large mammals alone comprised 55 per cent to 75 per cent of total wild meat biomass hunted annually in different regions of the world, although hunters may target smaller animals when large animals become scarce and some traditional small band societies (e.g., the San, the Hadza, the Ache, Native American groups) harvest small game as a primary source of protein and daily nutrition *(well established)* {3.3.3.2.3}. Selective hunting of particular species, individuals or populations which have particular attributes (e.g., large-sized or large horns) can impact ecosystem structure and processes, and cause changes to the genetic structure of affected populations {3.3.3.2.4}, shifts in the distribution of species across multiple trophic levels and shifts in ecosystem functions *(well established)* {3.3.3.3.1, 3.3.3.3.3}.

(B.1.6) Logging for energy is prevalent globally, but reliance on wood for heating and cooking is highest in developing countries *(well established)* {3.3.4}. Logging for energy accounts for 50 per cent of all wood consumed globally, and accounts for 90 per cent of timber harvested in Africa. Fuelwood use is declining in most regions but is increasing in sub-Saharan Africa *(established but incomplete)* {3.3.4.4.2}. Fuelwood demand can be met at a global and national scale when comparing supply-demand balances, but localized fuelwood shortages and associated forest and woodland degradation occur in areas where people have few alternatives for cooking and heating *(established but incomplete)* {3.3.4.4.2}. Sustainable fuelwood logging remains a renewable energy opportunity that provides income, heating and cooking in developing countries where 1.1 billion people do not have access to electricity or alternative energy sources *(established but incomplete)* {3.3.4.4.2}, provided air pollution (indoor and outdoor) and climate change emissions are mitigated.

(B.1.7) Destructive logging practices and illegal logging threaten sustainable use of natural forests *(established but incomplete)* {3.3.4}. The outcomes of logging affect forest ecology, as well as other forest based uses of wild species, such as gathering, terrestrial animal harvesting and observing wild species *(well established)* {3.3.4}. Demand for wood and, therefore, logging are expected to increase *(well established)* {3.3.4.1}. Although there is an expected increase in production of plantation wood, there is also a projected increase in timber demand that will not be matched by plantation wood *(well established)* {3.3.4.1, 3.3.4.1.2}. Inventory-based management plans, selective logging and reduced-impact logging practices could reduce the impacts of logging, including threats to non-target species, but logging sustainability depends on the planning, techniques and implementation used to minimize damage to the residual forest stand, as well as forest soils, flora and fauna *(well established)* {3.3.4.2}. About 20 per cent of the world's tropical forests (3.9 million km^2) are currently subject to selective logging *(well established)* {3.2.1.4, 3.3.4.2}. A geographic shift has been observed in illegal logging and related timber trade. Illegal logging has declined in parts of the tropical Americas, as well as parts of the tropical and mountainous regions of Asia due to improved monitoring and collaborative transboundary collaborations. However, illegal logging and trade have increased in other regions, including Southeast Asia, Northeast Asia and parts of Africa *(established but incomplete)* {3.3.4.2}.

(B.1.8) Nature-based tourism is an important non-extractive practice and recreational use of wild species. Demand for media (e.g., documentaries) and *in situ* observing (e.g., wildlife watching tourism) related to wild species was growing up to 2020 (Figure SPM.4) *(well established)* {3.3.5.2.3}. Wildlife watching tourism generates significant revenues and has the potential, when it is regulated and well-managed, to make positive contributions to the conservation of wild species, community development and livelihoods *(well established)* {3.3.5.2.3}. Although non-extractive practices are frequently less directly harmful to wild species and ecosystems than extractive ones, wildlife watching may have unintended detrimental impacts through changes to species behaviour, physiology, the health of species, ecosystems or humans, or damage to habitats *(well established)* {3.3.5.2.3}. Lack of effective institutions, enforcement, regulatory measures and governance structures often make it challenging to address negative outcomes *(well established)* {2.2.3}. Many of the unsustainable impacts of the tourism industry could be mitigated through context-based understanding, implementation of best practice guidelines for observing, education of tourists and tour operators, collaborative engagement with all stakeholders and sector-specific regulation *(well established)* {3.3.5.2.3}.

B2 The sustainability of the use of wild species is influenced negatively or positively by multiple drivers.

(B.2.1) Multiple drivers affect the sustainability of the use of wild species and these interact with one another (Figure SPM.5) *(well established)* {4.3, 4.4}. Outcomes for a particular species and a particular practice can be simultaneously impacted by multiple drivers, some positive, some negative, as well as mediating factors that may mitigate or amplify impacts on multiple scales. As a result, to be effective, governance responses address the multiple drivers affecting use and are flexible enough to accommodate differences among species, practices, sites and scales. For instance, the sustainability of wild meat hunting is increasingly driven by socio economic changes, recreation, entertainment, trade, or trafficking, rather than solely by hunting for subsistence *(well established)* {3.3.3}.

(B.2.2) Drivers such as landscape and seascape changes, climate change, pollution and invasive alien species impact the abundance and distribution of wild species, and can increase stress and challenges for the human communities who use them *(well established)* {4.2.1.2., 4.2.1.4, 4.2.1.5, 4.2.1.6}. The prevailing trend is a reduction in species' abundance and shifts in their

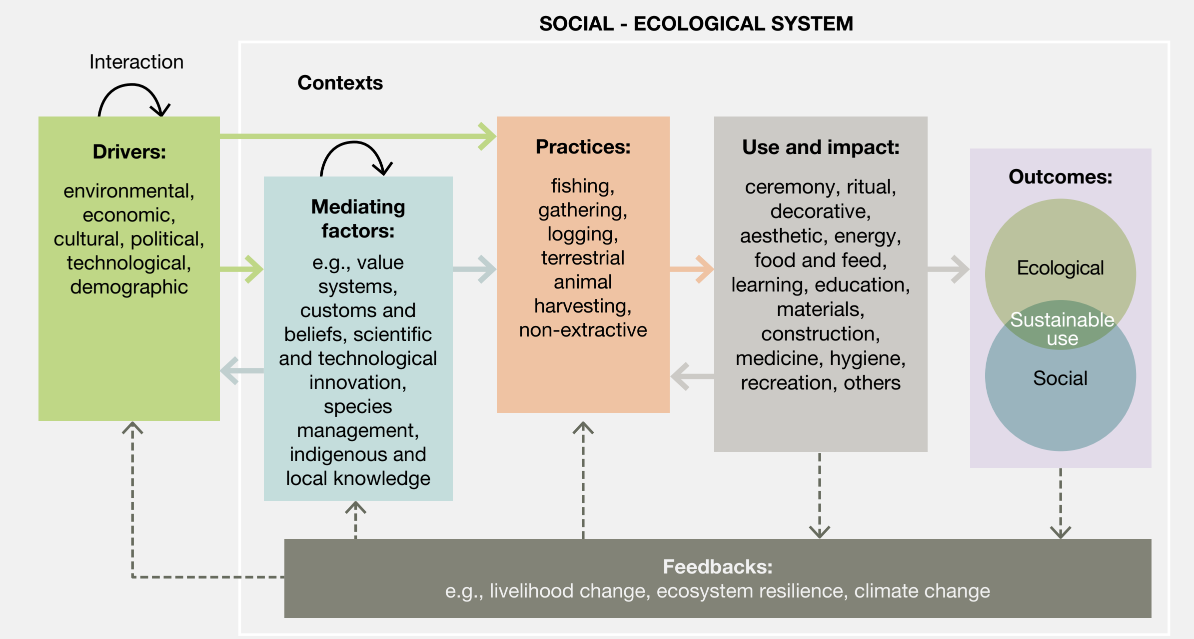

Figure SPM 5 **Conceptual approach to the drivers of sustainable use of wild species.**

Diagram showing relationships between different components of the social-ecological systems relating to the direct use of wild populations, as they have been conceptualized in the *Thematic Assessment on the Sustainable Use of Wild Species*. The diagram shows how these systems are affected by a combination of drivers (green) and mediating factors (blue) that affect practices (orange) and uses (grey). The complex nature of these interactions means that it is often not possible to separate the effects of direct drivers from those of indirect drivers as defined in the IPBES conceptual framework spatial distributions, although landscape and seascape changes, climate change, pollution and invasive alien species may positively affect some species. These drivers also place pressure on the capacity of systems to sustain extractive harvests at previous levels and may increase the need to use wild species to meet basic needs. Efforts to directly address such drivers can also have positive outcomes for sustainable use *(established but incomplete)* {4.2.1.2., 4.2.1.5.}.

(B.2.3) Climate change is an increasingly strong driver affecting sustainable use, creating many challenges *(well established)* {4.2.1.2}. Climate change strongly affects the use of wild species through, for example, changes to mean temperature and precipitation, the impacts of increased frequency and intensity of hydro-meteorological events and changes in spatial distribution, productivity and habitats of wild species under use *(well established)* {4.2.1.2}. For example, climate-related impacts on logging include changing forest composition and productivity as a result of increased intensity and frequency of floods, droughts and wildfires. While cultural burning and prescribed fire will continue to be important forest management tools, repeated intense wildfires have the potential to degrade landscapes, reduce local population density of important understory and overstory species and support proliferation of invasive alien species *(established but incomplete)* {4.2.1.2.5}. These effects are compounded and complicated by interactions of climate change with other environmental, sociocultural, political and economic drivers and associated underlying causes. Developing effective responses is also challenged by incomplete knowledge of climate change patterns and by many gaps in understanding of how climate change affects sustainability of uses *(established but incomplete)* {4.2.1.2}.

(B.2.4) Regulations, together with market forces, have resulted in a shift from wild species to specimens derived from farmed stocks *(established but incomplete)* {4.2.4.3.1}. Over the past 40 years, trade in many wild populations has been replaced or supplemented by trade from farmed stocks of the same species of plants or animals *(well established)* {4.2.2.2.1, 4.2.4.3.1}. Such farming is notable for fish, birds, amphibians and plants where more than 50 per cent of recorded trade is from farmed sources *(well established)* {3.2.1.1, 3.3.1.5.1}. This shift has been attributed to multilateral agreements and associated legislation restricting trade in wild harvested specimens, combined with market forces relating to quality and consistency of supply {3.2.1.1, 4.2.2.2}. Shifts to farmed stocks can reduce harvest impacts on wild populations where there is no specific demand for specimens of wild origin and where laundering of illegally harvested wild specimens into trade can be avoided *(established but incomplete)* {4.2.2.2.1}. However, the impacts of a shift to farmed stocks on livelihoods, equitable sharing of benefits, conservation of habitat, welfare of farmed animals, potential introduction of invasive alien species and potential transmission of zoonotic diseases need to be considered as part of the individual evaluations of sustainable use *(established but incomplete)* {4.2.1.4}.

(B.2.5) Throughout the world, where people living in poverty rely on the use of wild species, environmental degradation and resource depletion threaten their livelihoods and well-being *(well established)* {4.2.3.5}. Rural populations in developing countries rely disproportionally on the use of wild species and comprise nearly 3.5 billion people, or 45 per cent of the human population *(established but incomplete)* {4.2.3.3.5, 4.2.3.5.2}. A great diversity of wild species (aquatic and terrestrial animals, plants, fungi and algae) is harvested for subsistence purposes in the Americas, Asia and Africa, as an affordable and easily accessible resource *(well established)* {4.2.3.5}. Drivers related to economics and governance can contribute towards unsustainable use *(well established)* {4.2.3.3, 4.2.3.5}. The lack of complementary alternatives for people living in poverty, which can be driven by many factors, may lead them to intensify their use of wild species, further depleting the resource in decline and creating negative feedback that exacerbates poverty, resource depletion and environmental degradation. However, economic and political systems that perpetuate poverty and inequity are the underlying drivers of such unsustainable uses *(well established)* {4.2.3.3, 4.2.3.5}. Effective policies consider levels of poverty, inequality and food insecurity, that affect developing countries in particular, as well as social, including economic, conditions and cultural preferences *(well established)* {4.2.2.7.1, 4.2.3.5}.

(B.2.6) Multiple drivers threaten indigenous peoples' and local communities' ability to maintain and restore practices associated with sustainable use of wild species *(well established)* {4.2.2.4, 4.2.3.4, 4.2.4.3.1}. International instruments that support the rights of indigenous peoples and local communities to access lands, territories and customary sustainable resource uses have not always been fully implemented in national policies. Lack of data and indicators to monitor progress in this regard undermines opportunities to support the sustainable use of wild species by indigenous peoples and local communities *(well established)* {2.2.9.3, 2.3.3, 4.2.2.4, 4.2.3.4}. Sectoral policies, such as those related to forestry, agriculture, energy, infrastructure and resource extraction, as well as conservation policies, also frequently compromise access of indigenous peoples and local communities to traditional lands and resources *(well established)* {6.4.4.1}. Other factors that threaten sustainable use of wild species by indigenous peoples and local communities include loss of indigenous and local languages *(established but incomplete)*

{3.3, 4.2.5.1, 4.2.5.2.1}, education programmes divorced from local, cultural and environmental conditions *(well established)* {4.2.6.4.2, 6.4.3.2}, and lack of attention to gendered roles, including those in matrilineal and matriarchal cultures *(well established)* {4.2.3.5}. Many indigenous peoples and local communities identify integration into monetized and commodified economic systems as undermining values toward nature and sustainable use of wild species *(well established)* {3.3.2.3.5, 3.3.3.3.4, 4.2.5, 6.4.4.4}.

(B.2.7) Land tenure and resource rights can contribute to sustainable use *(well established)* {4.2.2.6}. Tenure arrangements that foster secure rights over land and resource use and trade can incentivize resource conservation, sustainable use, and diverse livelihoods, in part because there are more opportunities for effective regulation of use patterns *(established but incomplete)* {4.2.2.3} and they allow for longer-term planning. In regions where tenure insecurity has been reduced there is evidence of improved food security and positive conservation outcomes for wild species *(well established)* {4.2.2.6}. However, illegal seizures of land violate the rights of indigenous peoples, diminishing food security and positive conservation outcomes for wild species *(established but incomplete)* {4.2.6.2.3}.

(B.2.8) Inequitable distribution of costs and benefits from the use of wild species often undermines sustainability *(well established)* {4.2.2.5}. Allocation of usage rights and benefits can be influenced by existing inequities within and between communities and companies and between generations {4.2.2.6.1}, across levels of government, among jurisdictions with shared governance of cross-boundary species, and others. These inequities can be expressed both at the site of wild species' use and at all scales of trade, particularly when products are sold outside the community *(well established)* {4.2.2.7}.

(B.2.9) Gender is seldom taken into account in the governance of wild species, leading to inequities in the distribution of costs and benefits from their use. There are often gender inequities in how the costs and benefits of wild species' uses are distributed, with women bearing more of the costs and receiving fewer benefits of use *(well established)* {3.3.4.2.2., 4.2.3.6, 6.4.3, 6.4.4}. Many institutions and policies governing wild species' use do not take gender into account, resulting in women being excluded from decision-making processes, which further exacerbates burdens on women and those of diverse gender identities {4.2.3.6.3, 6.5.4.1}. Frequently, these inequities result from disparities in the security of land tenure and access *(well established)* {4.2.2.6}. Securing women's participation in decision-making leads to better resource governance outcomes, sustainable livelihoods and resilience.

(B.2.10) Urbanization is a dominant global trend which has negative impacts or indirect positive influences on sustainable use *(well established)* {4.2.3.3.4}. The shift from rural to urban lifestyles can reduce the use of some wild species, notably those linked to subsistence livelihoods, but this effect varies among contexts and interacts with other factors, such as infrastructure development and cultural and economic conditions *(established but incomplete)* {4.2.3.2, 4.2.3.3.4}. Furthermore, this transition is often characterized by the growth of peri-urban areas. In such areas, densities are urban, but economic infrastructure and services are still rural-oriented, resulting in ongoing demand for wild species that leads to overexploitation and unsustainable use. Similarly, urbanization and development are associated with increased demand for some wild species, such as wild meat and seafood products *(established but incomplete)* {4.2.1.5, 4.2.3.3.4, 4.2.4.3.1}.

(B.2.11) Global trade in wild species is a major driver of increased use. When not effectively regulated, it can become a driver of unsustainable use. Global trade in wild species has expanded substantially over the past 40 years in terms of volumes, value and trade networks *(well established)* {4.2.4.4.1, 4.2.2.2.1}. Global trade in wild species, both live or of their parts and derivatives, provides an important income source for exporting countries, often higher income for harvesters, and can diversify sources of supply to allow pressure to be redirected from species being used unsustainably *(well established)* {4.2.2.2.1}. However, global trade in wild species also decouples the consumption of wild species from the place of origin, introduces structures and dynamics that are different from those that govern local trade relations and practices, and can shift governing strategies from collective action to individual-based strategies *(established but incomplete)* {4.2.1.4, 4.2.4.4.1}. Without effective regulations operating across the supply chain (from local to global), global trade in wild species generally increases pressure, leading to unsustainable use and sometimes to wild population collapses (e.g., shark fin trade) *(well established)* {4.2.4.3.1, 4.3.2.2}. International trade has also been recognized as an important and rapidly growing source of introduction of invasive alien species {4.2.1.7}. Sustainable, legal and traceable trade of wild species is important for biodiversity-dependent communities, especially indigenous peoples and local communities and people in vulnerable situations in developing countries and has the potential to contribute to reversing biodiversity decline *(well established)* {4.2.3.3.5, 4.2.4.2.2}.

(B.2.12) Illegal harvesting and trade in wild species occur across all practices, involving numerous species, and often lead to unsustainable use *(established but incomplete)* {4.2.4.3.1}. Illegal trade in wild species is regarded as the third largest class of illegal trade, with estimated annual values of between US$ 69 billion and US$ 199 billion {4.2.4.4.1}. Volumes and value of illegal trade in wild species are greatest for timber and fish, but even lower levels of illegal trade strongly affect the sustainable use of rare species. Illegal trade is not governed by traditional or institutional safeguards and often results in harvests that exceed biological limits of sustainability *(well established)* {4.2.2.2, 4.2.4.3.1}. Illegal trade is further associated with social injustices and the involvement of criminal networks and can lead to violent conflicts *(well established)* {4.2.4.3.1, 4.2.4.3.2}. International cooperation is often required to address illegal harvest and trade *(established but incomplete)* {3.3.4.2}.

(B.2.13) Conflict, including armed conflict, can have significant and diverse impacts on sustainable use. Indigenous peoples and local communities and other people in vulnerable situations can be displaced from territories, severing their relationships to valued species. This can result in unsustainable use in other areas due to the migration and settlement of displaced peoples *(established but incomplete)* {4.2.2.8}. Overexploitation of species by armed forces is also a major issue in many regions experiencing conflict *(established but incomplete)* {4.2.2.8.2}. The disruption of institutional structures and processes (informal and formal) governing wild species, as well as the disruption of economies, investment and development (leading to fewer livelihood alternatives to wild species' use) can also amplify these impacts of conflict *(established but incomplete)* {4.2.2.8.3}.

(B.2.14) Culture, comprising language, knowledge, religion, food habits, values and philosophies, influences people's interactions with wild species and the extent to which particular practices and uses are acceptable and sustainable *(well established)* {4.2.5}. Culture is dynamic and actions that influence culture, such as education and awareness-raising, have the potential to drive changes in behaviour towards more sustainable uses of wild species, but the outcomes are uncertain *(established but incomplete)* {4.2.6.4}. Use and relationships between people and nature are often mediated and managed by diverse customary rules and norms. For instance, many religious beliefs, myths and taboos pertaining to the use of certain wild plants and the hunting of wild animals have fostered sustainable use in several cases (e.g., sacred groves), but it has also been documented that some beliefs have facilitated the unsustainable use of wild species *(well established)* {4.2.5.2.2}.

(B.2.15) Education, communication and public awareness are key drivers of sustainable use as they provide knowledge and capacity for improved decision-making regarding the sustainability of wild species' uses *(established but incomplete)* {4.2.6.4}, but are seldom prioritized as policy options *(established but incomplete)* {6.4.3.2}. Education efforts are more effective when they promote time outside in nature, when they respect the cultures and languages of indigenous peoples and local communities and include those living in vulnerable situations, notably elders, youth, women and girls *(established but incomplete)* {3.3.5, 4.2.6.4}. Learning in and from nature, for example through citizen science and social learning, fosters a sense of responsibility and stewardship, and can change attitudes and behaviour via increased ecological knowledge *(well established)* {3.3.5.2.4, 4.2.6.4, 4.2.6.3.2, 4.2.6.4.5}. Changes in educational programmes to include place-based knowledge, environmental ethics, cultural competency, and intragenerational and intergenerational transmission of knowledge can foster sustainable use of wild species and conservation of biodiversity *(established but incomplete)* {4.2.6.4}. Recognizing and embedding indigenous and local knowledge into education systems would support sustainable use of wild species *(established but incomplete)* {6.4.3, 6.4.4.2, 6.6.2}. However, education and outreach remain underutilized as policy options and aligning national educational policies with those for sustainable use can enhance sustainable use of wild species *(established but incomplete)* {6.4.3.2, 6.4.2.1}.

(B.2.16) Science, research and technology create conditions that can support or undermine sustainable use of wild species, and local livelihoods based on them by, for example, setting quotas or harvest levels *(established but incomplete)* {4.2.6.2}. Advances in fields such as gene sequencing and data networks are creating new ways to identify, characterize, manage, and monitor species by, for example, providing a better understanding of genetic variability in species populations and assisting identification of illegally harvested and traded species, as well as those that may be mislabelled or listed as threatened or rare. Advances in miniaturization and spatial data technologies facilitate the monitoring of terrestrial and aquatic animals, while information and communications technologies such as smartphones and applications supporting citizen science allow the collection of large volumes of data that can be analysed with new computational methods. However, diffusion of these technologies remains unequal and may further exacerbate existing inequities in access to wild species and markets for them *(established but incomplete)* {4.2.6.2}. Biotechnologies and industrial processes based on them may provide alternatives for unsustainably harvested species, thereby reducing pressure on wild populations, but they can also negatively impact small-scale producers and harvesters who depend on this income, lowering local motivation to conserve the ecosystems on which those species depend *(established but incomplete)* {4.2.6.2}.

B3 Key elements of sustainable use of wild species have been identified in relevant international and regional standards, agreements and certification schemes but indicators are incomplete, most notably for social components.

(B.3.1) Conceptualizations of sustainable use are evolving over time. Nevertheless, statements in international and regional agreements continue to maintain a common emphasis on not causing irreversible harm to biodiversity and supporting the material and non-material contributions of biodiversity to human well-being *(well established)* {2.2.2, 2.2.3.7, 2.2.5, 2.2.7}. Sustainable use of wild species is therefore best operationalized through a set of specific targets or indicators in the ecological and social domains. These targets and indicators will require periodic revision, as knowledge and experience grow and public policy dialogue progresses *(well established)* {2.3.1, 2.3.4}. Ideally, indicators are developed jointly by all the actors in the social-ecological system *(well established)* {1.3.1, 1.5} and additional efforts are undertaken by all actors in order to address existing knowledge gaps (see appendix 2).

(B.3.2) Available indicators provide a fragmented view of wild species' use in social-ecological systems across the globe and within each practice, impeding both full evaluation of sustainability of practices in many instances and comparisons of sustainability across practices *(well established)* {3.2}. Of the hundreds of indicators codified in relevant multilaterally agreed goals and targets, for example the Sustainable Development Goals and the Aichi Biodiversity Targets, only a small percentage relates specifically to the sustainable use of wild species *(well established)* {3.2.1, 3.2.2}. Further, although there are widely accepted sustainability indicators in fishing and logging, global and regional indicator frameworks for gathering, non extractive practices and terrestrial animal

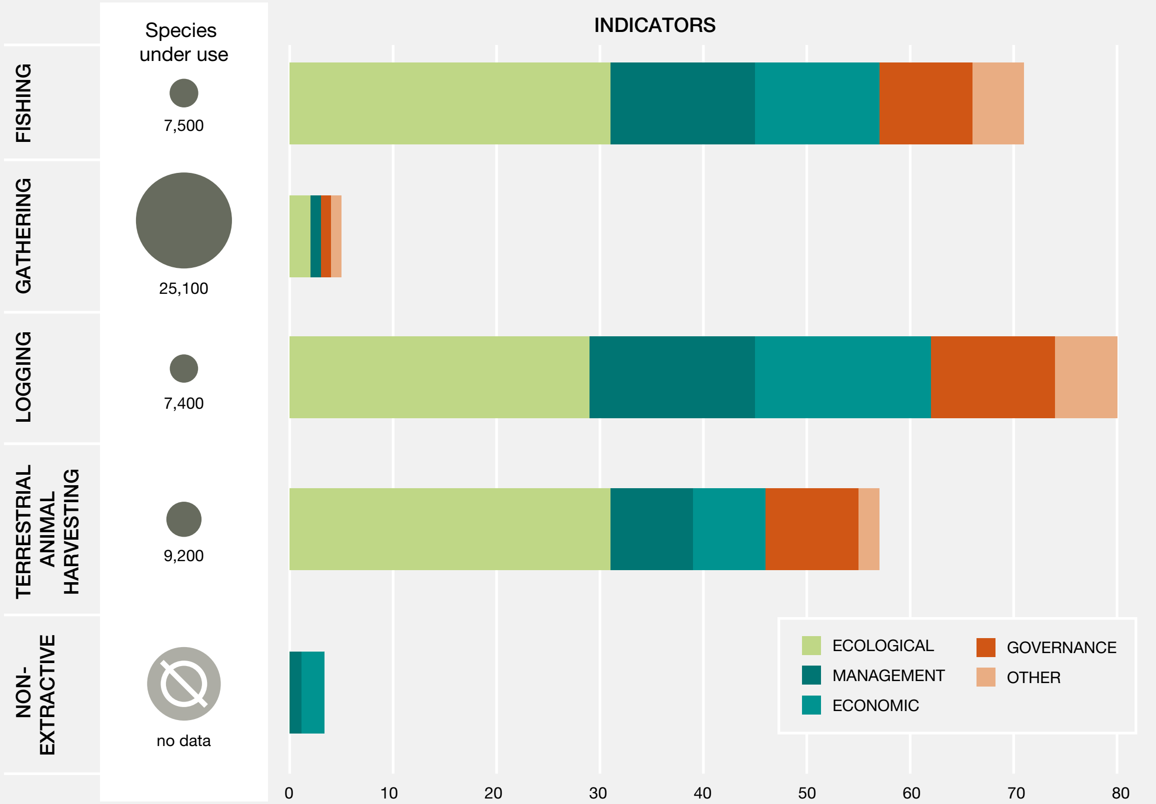

Figure SPM 6 **Wild species used worldwide compared with indicators of sustainable use by practice.**

This figure displays the approximate number of wild species used, categorized by practice type, in comparison with the number of widely used global indicators of sustainable use of wild species by practice type. The terrestrial animal harvesting group is based primarily on a large regional indicator set due to the paucity of global indicators. Data for this analysis are from chapter 2 {2.3.2.2.2} and chapter 3 {3.2.1, table 3.1 and box 3.1 in 3.2.2}. A data management report for this figure is available at https://doi.org/10.5281/zenodo.6452576.

harvesting are lacking **(Figure SPM.6)** *(established but incomplete)* {2.3, 3.2.1.2}. For all practices, there are few social indicators of sustainable use in global and regional indicator sets *(established but incomplete)* {2.3}.

(B.3.3) Many of the ecological, economic and governance indicators in global and regional indicator sets have low sensitivity or specificity for the sustainability of individual practices, thus requiring substantial contextual information to be interpreted reliably *(established but incomplete)* {2.3.4}. Very few indicators capture the social-ecological linkages now globally recognized to be important to sustainable use. Monitoring by many indigenous peoples and local communities focuses on interlinked social and ecological elements and can inform the development of local and global indicators that recognize these linkages at different scales *(well established)* {2.3.4}.

C. Key elements and conditions for the sustainable use of wild species

Policy instruments and tools are most successful when they pay attention to and fit both the ecological and social contexts in which they are applied. Many policy instruments for the sustainable use of wild species have been successful in some circumstances, but have failed in others.

C1 Policy instruments and tools are most successful when tailored to the social and ecological contexts of the use of wild species and support fairness, rights and equity.

(C.1.1) Conceptualizations of sustainable use of wild species influence policymaking by determining the ecological and social elements that are considered, monitored, assessed and used in policy (Box SPM.2) *(established but incomplete)* {2.3.2, 2.3.3, 2.3.4, 2.2.10}. Sustainable use of wild species is increasingly understood as inextricably social and ecological. Voluntary agreements often invoke both dimensions. However, national frameworks and international instruments largely continue to emphasize ecological dimensions, as well as some social, including economic, and governance dimensions, while cultural contexts receive little attention *(well established)* {2.2.3, 2.2.4, 2.2.8, 2.2.10, 6.4.1.2}. Adverse effects of these conceptual oversights include reduced effectiveness and inequities *(well established)* {2.2.10, 2.3.4}, in particular a lack of recognition of the sustainable use practices of indigenous peoples and local communities and support for their tenure and access rights *(well established)* {6.4.4.1}.

(C.1.2) Policy instruments and tools commonly fail when they are not tailored to local ecological and social contexts (Figure SPM.7) *(established but incomplete)* {1.4, 4.2.2, 6.5.2.3}. The use of wild species takes place in landscapes and seascapes with diverse ecologies, cultures, politics and histories, all of which affect policy outcomes. Policies and regulations that fail to recognize and account for the diversity of uses and benefits associated with a practice can lead to negative social and ecological outcomes. Such adverse outcomes are especially pronounced in cases where there are differences between large-scale commercial actors and subsistence or small-scale actors *(well established)* {6.4.3.1}. Similarly, multiple pre-existing policies and instruments often apply to a species, practice or place *(well established)* {6.5}. Where customary governance is ignored, new policies may undermine previously successful approaches to sustainable use. New policy instruments that do not account for the history and current conditions of use also may exacerbate pre-existing tensions and create conflict, even where other enabling conditions are present *(well established)* {6.5.4.2}. The need for policy which is "fit for purpose" is widely acknowledged but incompletely pursued *(well established)* {6.5.2.1, 6.5.4.2}. For example, community-based and nature-based tourism standards that combine legal and regulatory approaches with social and information-based approaches provide livelihood benefits to communities while protecting indigenous and local cultures and environments *(established but incomplete)* {6.4.1.3, 6.4.4.5}. Many of the unsustainable impacts of the tourism industry could be mitigated through context-based understanding, implementation of best practice guidelines for observing, communication, education and public awareness of tourists and tour operators, collaborative engagement with all stakeholders and sector-specific regulation *(well established)* {3.3.5.2.3}.

(C.1.3) Fairness, rights and equitable distribution of benefits are essential to ensure the sustainable use of wild species (Figure SPM.7) *(well established)* {6.6.3}. People's perceptions of fairness and justice shape their willingness to comply with regulations that govern sustainable use {6.4.3}. Inequitable distribution of benefits from the use of wild species can undermine sustainability by encouraging over-harvesting, short-term gains over

Box SPM 2 The Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Biological Diversity.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora was established in 1973 to protect wild species from overexploitation associated with international trade and to avoid utilization that is incompatible with their survival. As at April 2021, the Convention had 183 parties. The assessment found that the Convention has been an important instrument for driving global coordination of regulations and enforcement regarding international trade in wild species, as well as the establishment of institutions and tools to ensure sustainable use *(well established)* {4.2.2.2}. As a result of those efforts, 101 countries now have the legislation and institutions in place to fully implement the Convention and a further 43 countries are in a position to partially implement it. Tools for assessing whether trade is detrimental to the survival of a species in trade (termed non-detriment findings) have been developed for a wide range of taxa with different life histories and vulnerabilities to trade. As at 2021, over 38,700 species were listed in the appendices to the Convention and subjected to regulation by the parties. Based on these operational indicators, the Convention on International Trade in Endangered Species of Wild Fauna and Flora is a successful policy instrument. Nevertheless, based on trends of continuing decline in the status of species affected by international trade, these species continue to be affected by unsustainable levels of use and illicit trade *(established but incomplete)* {4.2.2.2}. The Convention focuses on regulating international trade but other factors affecting the use of wild species fall outside the scope of the Convention and can continue to drive unsustainable and/or illegal trade both from the supply and demand sides of trade. These issues also affect domestic trade in wild species, which can be significant, and so species can continue to decline despite international trade restrictions. Successful outcomes for the species listed in the appendices to the Convention have often been linked to complementary actions that either reduce demand for wild species, achieve greater coherence between domestic policies and the decisions of the Convention, involve local communities affected by decisions relating to international trade, or reduce illegal trade *(established but incomplete)* {4.2.2.2}. Durable outcomes from Convention decisions are more likely if there is a good fit between the regulatory options available to the Convention and the specific contexts in which they are applied. There is a growing body of evidence that can support better outcomes for species and complement biological information to inform decisions, including for economics, consumer behaviour, the structure of legal and illicit markets, impacts on livelihoods and the role of communities in promoting sustainable use and combating illegal trade.

The Convention on Biological Diversity is an international treaty with 196 parties as at April 2021 that lists among its three objectives the sustainable use of biological diversity, including a specific provision "to protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements" {2.2.2, 5.9.2}. In 2010, the Convention established the Aichi Biodiversity Targets to guide action to 2020, including targets for sustainable use {2.2.2, 3.2}. A new post-2020 Global Biodiversity Framework is expected to be adopted at the fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity {5.9.1}.

long-term sustainable management, poaching and unsustainable mining of natural resources by companies *(well established)* {3.3, 4.2.2.5}. Small producers, who lack political or economic power, can easily lose out if measures are drafted in a way that primarily promotes the interests of the advantaged **(Box SPM.3)** *(well established)* {6.5.2}. In contrast, secure rights of access to and use of wild common property resources, along with social capital, participation in governance mechanisms and accountability, positively influence the sustainability of uses of wild species *(well established)* {4.2.3.2, 6.4.4, 6.5.1}. Equitable distribution of benefits from the sustainable use of wild species is a stated goal of many governance and institutional frameworks, but their implementation is often incomplete *(well established)* {2.2.6, 6.5.2.1, 6.6.3}. Further efforts are required to realize these goals and ensure sustainable use policies are aligned {4.2.2, 6.4.1.1, 6.4.3.1}.

(C.1.4) Effectiveness of market-based incentives, such as certification and labelling, is mixed and mostly limited to high-value markets *(established but incomplete)* {6.4.3.1}. Certification and labelling schemes operate on the premise that providing information to consumers will result in a market shift that favours sustainable products, thereby incentivizing and rewarding sustainable practices by producers through price premiums and increased market share *(well established)* {6.4.3.1, 6.5.1.2}. In general, certification and labelling, when carefully designed and implemented, can promote ecological, economic and to a lesser extent social sustainability, but benefits have largely been for large-scale operations and where there is high market demand *(established but incomplete)* {6.4.3.1, 6.5.1.3}. Certification and labelling are widely used in large scale commercial fishing, logging and non-extractive recreational practices. In the cases of fishing and logging, certification and labelling frequently have been successful in securing and increasing market share, but it is unclear how often certification supports transitions from unsustainable to sustainable practices *(established but incomplete)* {6.4.3.1}. Certification may also lead to specialization around a few value chains. Furthermore, market-based incentives have generally not delivered price premiums for producers *(well established)* {6.4.3.1}. Relatively high costs to obtain certification, satisfy ongoing reporting requirements and

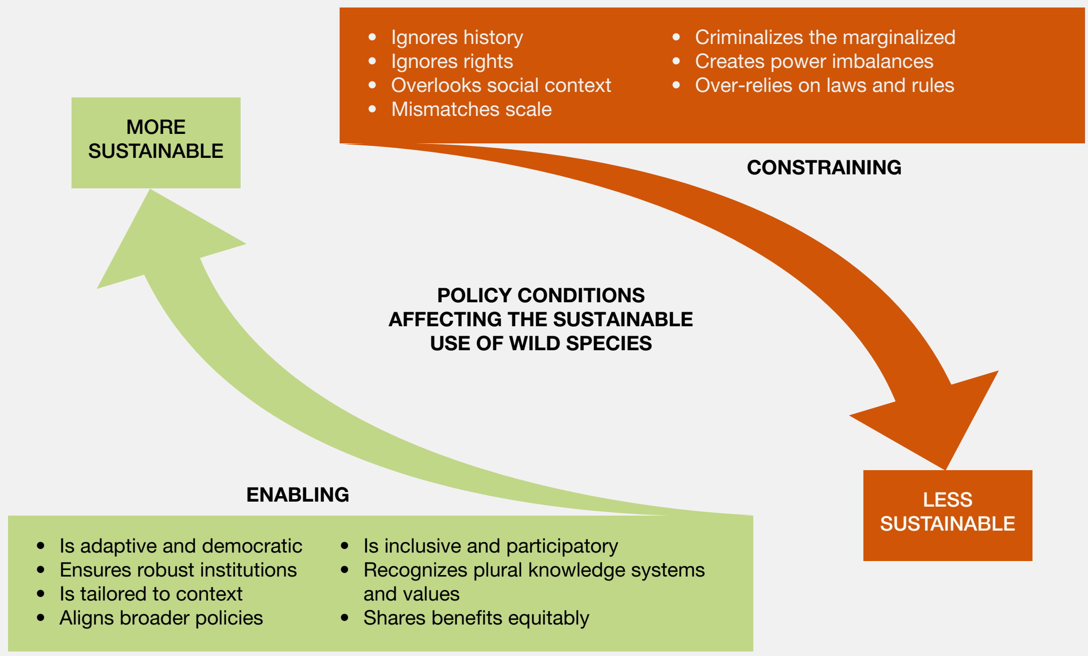

Figure SPM 7 **Conditions that enable (green) or constrain (red) sustainable use policies.**

realize market benefits often place certification beyond the reach of small-scale producers, including indigenous peoples and local communities *(established but incomplete)* {6.4.3.1, 6.5.2}. The viability of market-based incentives such as certification and labelling also depends on appropriate design, in line with international trade regulations *(established but incomplete)* {6.4.3.1}.

C2 Policy instruments and tools are more effective when they are supported by robust and adaptive institutions and are aligned across sectors and scales. Inclusive, participatory mechanisms enhance the adaptive capacity of policy instruments.

(C.2.1) Robust governance systems tend to be adaptive to changes in social and ecological conditions and include participatory mechanisms *(well established)* {6.6.1}. The social and ecological conditions under which uses of wild species occur are always dynamic. Consequently, policy instruments and management tools are most effective when they address the causes of unsustainable use and adapt to changing circumstances *(well established)* {6.5.2}. Adaptive processes are enhanced by collaborative learning and governance. Successful co-learning is characterized by comprehensive, continuous, iterative and transparent engagement between key actors, including governance institutions and those who depend on wild species for their livelihoods and well-being **(Box SPM.4)** *(well established)* {6.5}. Collaborative governance arrangements that meaningfully engage these key actors, such as biosphere reserves designated by the United Nations Educational, Scientific and Cultural Organization, can ensure that policy decisions on sustainable use are equitable *(well established)* {4.2.2.2, 4.2.2.3, 6.5}. Such participatory mechanisms are more effective when implemented through inclusive processes that integrate customary and statutory laws, include participation of indigenous peoples and local communities in policy design, recognize gendered differences in the knowledge and practices of uses of wild species and include close follow-up through monitoring **(Box SPM.4)** *(well established)* {6.5.2.2}. Conservation instruments such as protected areas or other effective conservation measures can also contribute to the sustainability of the use of wild species *(well established)* {6.5.1.1}. However, to be effective, protected areas should be inclusive of indigenous peoples and local communities and other people involved, avoid displacing indigenous peoples, local communities and dependent livelihoods, be embedded in larger planning processes, and have a full implementation strategy *(well established)* {4.2.2.2, 4.2.2.3, 4.2.3.2.2, 6.5, 6.5.1.1}.

(C.2.2) Aligning and coordinating policies across sectors and scales of governance can create enabling conditions for sustainable use of wild species *(well established)* {6.5.1.2, 6.5.2.2}. Policies enacted to govern diverse sectors, including, but not

Box SPM 3 **Distribution of benefits from vicuña fibre.**

The vicuña *(Vicugna vicugna)* is one of the rare success stories of international conservation, with significant social outcomes though still limited economic outcomes. This camelid has one of the most valuable and highly priced animal fibres on the international market. Luxury garments made from vicuña fibre are sold in the most exclusive fashion houses around the world. Vicuña fibre is produced mainly by extremely low income indigenous communities from the Andes, who "pay the cost" of vicuña conservation by allowing vicuñas to graze on communal or private land. The production of fibre also relies on substantial investments borne primarily by state institutions and local communities. However, it is almost impossible for a remote Andean community to negotiate with an international textile company or large trading company on equal terms or directly place its product in the international market. As a consequence, most of the benefits of the global trade in vicuña fibre are captured by traders and international textile companies. Limited economic returns are a disincentive for community participation. Efforts to increase the benefits accrued by poor rural communities focus on explicitly redressing access asymmetries, strengthening producer associations and the provision of added value at the local level *(well established)* {4.2.3.5}.

Distribution of benefits from vicuña fibre harvest in Sajama, Bolivia (Plurinational State of). *Photo credit: D. Maydana.*

limited to, agriculture, energy and transportation, often also affect uses of wild species. The interaction of such policies can support or undermine sustainable use. For example, sectoral policies designed to advance national economies and territorial connections can escalate the exploitation of wild species, displace local uses and exacerbate poverty *(well established)* {4.2.3.5}. Further, laws are often built incrementally and, as a result, may come to lack coherent objectives and strategies *(well established)* {6.5.3}. If well designed, strategic combinations of policies can simultaneously alleviate multiple drivers of unsustainable use and create a supportive environment for sustainable use of wild species *(well established)* {6.5.3, 6.6.4}. Similarly, policies that align at international, national, regional, subnational, and local levels are more effective at supporting sustainable use of wild species, with fewer negative and unintended consequences. When attention is paid to coordinated interactions between approaches, actors, and scales, outcomes are more effective *(well established)* {6.5}.

(C.2.3) Policies that support secure tenure rights and equitable access to land, fisheries and forests, as well as poverty alleviation, create enabling conditions for sustainable use of wild species *(well established)* {6.4.4.1}. When national sectoral policies are aligned with targeted policies to support local tenure of land, fisheries and forests, the resulting synergy creates enabling conditions for the sustainable use of wild species. Sustainable use of wild species can also be enhanced by well-designed holistic approaches that co-address poverty and environment in policy design, and acknowledge that poverty is a multidimensional driver *(well established)* {4.2.3.4}. For example, policies that alleviate poverty can also empower local customary institutions that, in turn, support sustainable use of wild species *(well established)* {6.5.1} (see also B.2.5).

(C.2.4) Strengthening customary institutions and rules often contributes to the sustainable use of wild species *(well established)* {6.4.4.2}. Attention to customary institutions and rules governing uses of

Box SPM 4 **Moving from unsustainable to sustainable fishing at local and large scales.**

Local scale

Pirarucú is among the largest freshwater fishes in the Amazon, playing an important role in the Amazonian economy and culture since the sixteenth century. As for many fisheries worldwide, the introduction of modern technologies occurred during the second half of the twentieth century and rapidly induced an uncontrolled increase in fishing pressure, which led to the overfishing of pirarucú stocks in most parts of the Amazon. Official protective measures were first introduced in the 1980s by Brazilian government agencies but had little effect due to the lack of enforcement capacity of local authorities. In 1998, community-based management was introduced in small riverine communities at Mamirauá Reserve (Brazil). The governance system adopted was based on a local management committee with the capacity to approve and enforce rules, conduct and oversee the activity and equitably distribute the benefits generated. Fishermen provided their traditional knowledge and were responsible not only for protecting the fishing grounds but also for submitting an annual management plan to the government authorities. Local scientific projects were also conducted on the biology of the species, as well as the technical, social and economic aspects of the fishery. The results of these ongoing surveys and evaluations allow the improvement of the technical guidelines in a truly adaptive management approach. Nowadays, community-based management of pirarucú is performed within a hundred small local communities in the Brazilian Amazon and in other Amazonian countries. After two decades, pirarucú fisheries management has demonstrated that conservation of the species can be reconciled with its sustainable use, generating positive social, economic and ecological results *(well established)* {6.5.1.1}.

Large scale

Atlantic bluefin tuna has been sustainably exploited for two millennia by traditional fisheries, but the rise of the sashimi market during the 1980s generated new and strong demand, which sharply increased the value of the fish and led to uncontrolled international overcapacity in the fishing fleet and critical overexploitation in the 1990s and 2000s, including a severe problem of illegal catch. The failure of bluefin tuna management at that time was partly due to the multilateral nature of the International Commission for the Conservation of Atlantic Tunas. The scientific body of the Commission had alerted the management body about the critical status of Atlantic bluefin tuna stocks in the 1990s, but the scientific advice carried little weight against fisheries lobbies and national interests, which were most influential in maintaining high quotas. During the 2000s, however, environmental non-governmental organizations became more powerful and efficiently used communication tools to call the attention of the public to the poor stock status of bluefin tuna. Following a shift in public opinion, the management body of the Commission started to pay more attention to scientific advice and implemented a first rebuilding plan in 2007, which was reinforced in the following years. The final Atlantic bluefin tuna rebuilding plan included a reduction in the length of the fishing season for the main fleets, an increase in the minimum catch size, new tools to monitor and control fishing activities and a strong reduction in fishing capacity and annual quotas. As a result of this plan, the Atlantic bluefin tuna population has been rebuilt and is now exploited within biologically sustainable levels *(well established)* {6.5.3.3}.

Purse seiner fishing Atlantic bluefin tuna. *Photo credit: J.-M. Fromentin.*

wild species can reduce conflicts and increase policy effectiveness *(well established)* {6.5}. Customary approaches can lower transaction costs for monitoring and enforcement compared with formal governance systems. For example, taboos limit the use of individual species. Such customary approaches can support the ecological and economic dimensions of sustainability and are particularly effective at supporting its social dimensions. However, historical and cultural systems, such as taboos, have seldom been incorporated into policies for managing the use of wild species *(well established)* {6.4.4.3}.

C3 Effective monitoring of social, including economic, and ecological outcomes supports better decision-making. Scientific evidence is often limited, and indigenous and local knowledge is underutilized and undervalued.

(C.3.1) Monitoring of the ecological and social, including economic, aspects of uses of wild species is critical for sustainable use *(well established)* {3.2.4, 3.3.3.3.4}. The lack of ongoing monitoring of population dynamics may make the most adaptive of regulations insufficient to prevent species decline *(well established)* {4.2.2.2.3}. Where governance systems are informed by monitoring of species health and use, equitable participation by those dependent on wild species (particularly for food) and the inclusion of strong mechanisms for dispute resolution, there is evidence of sustainable use *(well established)* {4.2.2.2}. Scientific monitoring is limited or lacking for many extractive and non-extractive practices *(well established)* {3.3.1, 3.3.3, 3.3.5} and is identified as a critical knowledge gap for sustainable use {3.5}. Many indigenous peoples and local communities have well-developed monitoring practices that contribute to sustainable use through stewardship and adaptive and innovative learning *(well established)* {4.2.2.2, 4.2.2.4.}. Examples of traditional measurement observations include the amount of caribou back fat observed by hunters or the changing flavour of fish. For some communities, knowledge of species trends and dynamics has been passed from generation to generation, resulting in knowledge that exceeds the time frames of most scientific studies. Increasingly robust networks of indigenous peoples and local communities dedicated to monitoring with a hybrid of traditional and scientific methods are generating important information about the status of wild species and their uses *(well established)* {2.3.3, 3.4, 4.2}.

(C.3.2) Policy instruments and tools are more effective when they are inclusive of plural knowledge systems *(well established)* {1.1.2, 1.4, 2.2.6, 2.2.8, 6.6.2}. Bringing together scientists and holders of indigenous and local knowledge improves decision-making *(well established)* {2.2.3, 3.4, 4.2}. Co-production of knowledge by indigenous peoples and local communities and scientists can create robust information about social and ecological conditions and enhance decision-making *(well established)* {1.1.2, 1.4, 2.2.6, 2.2.8, 4.2.2.2, 6.5.1.1, 6.5.1.2}. While there is global recognition of the importance of indigenous and local knowledge in sustainable management of wild species, national policy initiatives often do not involve indigenous peoples and local communities in decision-making. Inclusion of indigenous peoples and local communities in the development and implementation of policies for sustainable use of wild species requires sustained commitment and recognition of both indigenous and local knowledge and science as authoritative; doing so can be mutually beneficial. It is also important that engagement with indigenous peoples and local communities ensure free, prior and informed consent and follows international protocols on access and benefit sharing, for example based on the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity *(well established)* {1.1.2, 1.4, 2.2.6, 6.4.4.2, 6.5.3.3}. Legal and regulatory instruments are more effective when they take into account indigenous and local knowledge and science *(well established)* {6.5.3.3}.

D. Pathways and levers to promote sustainable use and enhance the sustainability of the use of wild species in a dynamic future

There is an urgent need to implement and scale up policy instruments that work, while recognizing the need for adaptive management and transformative changes to address current and future pressures and challenges. Scenarios point to a future where the sustainability of the use of wild species will become increasingly vulnerable to pressures associated with climate change, technological advances and increasing consumption.

D1 The sustainability of the use of wild species in the future is likely to face challenges due to climate change, increasing demand and technological advances. Addressing and meeting these challenges will require transformative changes.

(D.1.1) According to most scenarios and models, climate change is expected to lead to multiple changes, such as changing wild species distribution and population dynamics, increasing frequency of extreme events and altering nutrient cycles, as well as ecological changes, which will affect wild species and their use across all practices, through multiple impacts. There is uncertainty however about future trajectories. Climate change may further exacerbate social, including economic, vulnerabilities and inequalities *(well established)* {5.2.1.2, 5.2.1.5, 5.4}. Climate change has implications for all extractive and non-extractive practices, including effects on the population dynamics of targeted wild species and the ecosystems they inhabit *(well established)* {5.4}. For example, climate change projections in high-emission scenarios up to 2100 from the Intergovernmental Panel on Climate Change show a decrease in global ocean biomass; the global catch is projected to be potentially reduced in all systems and more substantially in tropical systems, while a poleward shift in marine species could create new opportunities in mid- to high-latitude oceans *(established but incomplete)* {4.2.1.2.2, 5.4.2.5, 5.4.2.8}.

(D.1.2) For many practices, demand is linked to demographic trends and consumption patterns. Growing human populations and consumption will result in greater pressure on wild species *(well established)* {5.4.3.1, 5.4.4.4, 5.4.6.8, 5.9.4}. For example, global fish demand is expected to almost double by mid-century and will increase in all regions of the world, while the demand for gathered wild plants, algae, and fungi is increasing both at the local level, where most products are consumed, as well as in international markets *(well established)* {5.4.2.2, 5.4.2.8, 5.4.3.4}. Demand for wood-based bioenergy is expected to increase, while at the same time there are continuing reductions in global forest cover due to increased logging and mortality resulting from climate change. Forest plantations may meet some of the growing demand but there are likely to be trade-offs between the management of natural forests to meet demand for wood and biodiversity conservation *(well established)* {5.4.5.1}. Non-extractive practices including nature-based tourism are also likely to grow and potentially generate negative environmental trends resulting from, for example, increasing waste. Projections of increasing tourism growth suggest that significant additional efforts will be necessary to mitigate these negative impacts *(well established)* {5.4.6}.

(D.1.3) Technological advances will affect future uses of wild species both negatively and positively *(well established)* {5.4.2.3, 5.4.3.3, 5.4.4.3, 5.4.5.3}. Technological advances are likely to make many extractive practices more efficient, such as the ability to exploit resources more rapidly and more intensively. However, this may have potentially negative consequences *(well established)* {5.4.2.3, 5.4.5.3}. At the same time, technological advances are also likely to enhance monitoring, surveillance, and enforcement *(well established)* {5.4.2.3, 5.5.4.8}. Progress in information and communication technologies has the potential to profoundly modify wild species observation through improved virtual wildlife watching *(established but incomplete)* {5.4.6.3}. According to scenarios for a specific area, technological innovations could support sustainable use of natural forests through multiple routes. Uptake of technologies for sustainably advancing agricultural intensification, particularly in working lands of producer countries, could enable land to be spared for forest conservation, conditional on the type of governance in place and that the negative effects be overcome *(established but incomplete)* {5.4.5.3}. Technologies in wood manufacturing can improve the efficiency of uses of wood for construction materials and energy production *(established but incomplete)* {5.4.5.3}. Technological innovations that enhance efficiency and reduce waste may help the sustainable use of wild species *(well established)* {5.4.5.3}. Consideration of customary uses and land tenure, access and resource rights in accordance with national legislation may also help *(established but incomplete)* {5.4.5.3, 5.4.5.8, 5.8}.

(D.1.4) Scenarios projecting the future use of wild species are few in number *(well established)* {5.3}, but they indicate that transformative changes are needed to ensure sustainable use and to enhance the sustainability of the use of wild species *(established but incomplete)* {5.8}. In most scenarios, transformative changes that enable sustainable use of wild species under future conditions share common characteristics. These characteristics include concerted action on leverage points, integration of plural value systems, equitable distribution of costs and benefits, changes in social values, cultural norms and preferences and effective institutions and governance systems *(established but incomplete)* {5.8}. Ambitious goals are necessary but not sufficient to drive transformative change. Translating high-level goals into meaningful and inclusive action at multiple scales will require coordination between multilateral institutions, multiple arms of government, business and civil society *(well established)* {5.9.2}.

Scenarios identify actions that will be needed to assure the future sustainability of each practice. In the case of fishing, most scenarios indicate that future sustainable use may require fixing current inefficiencies, reducing illegal, unreported, and unregulated fishing and suppressing harmful financial subsidies that contribute to overcapacity and overfishing in marine systems *(established but incomplete)* {5.4.2.4}, supporting small-scale fisheries, adapting to changes in oceanic productivity due to climate change and proactively creating effective transboundary institutions *(established but incomplete)* {5.4.2.8}. Sustainable logging may be supported by the management and certification of forests for multiple uses, technological innovations to reduce waste in the manufacturing of wood products and economic and political initiatives that recognize the rights of indigenous peoples and local communities, including land tenure *(well established)* {5.4.5.3, 5.4.5.6, 5.4.5.8}. At the same time, development and improvement of sustainable forest management practices would provide tools to support sustainable economic activities and wild species-based products, thus reducing pressure on forest resources *(established but incomplete)* {3.3.4.5.1, 4.2.3.3.3, 5.4.5.4}. Wild meat is a primary objective of terrestrial animal harvesting. Projected future demand for wild meat shows differing regional trends, with increases in some areas and declines in others due to changing cultural norms, social acceptability and preferences. Increased regulation or bans on wild meat trade could be viable in some regions, while similar regulations would lead to food insecurity in other regions *(established but incomplete)* {5.4.4.4}.

D2 To address current and projected future pressures, concerted interventions will be needed to implement and scale up policy actions that have been shown to support the sustainable use of wild species.

(D.2.1) Key elements (sets of policy actions) that support sustainable use of wild species have been identified (see section C, Figure SPM.8). However, with the exception of fishing, these key elements are poorly integrated into binding agreements and this limits progress towards their implementation (Table SPM.1) *(established but incomplete)* {2.2.6, 2.2.7}. The following seven key elements have been shown to enhance the sustainability of the use of wild species **(Table SPM.1)**: inclusive and participatory decision-making, inclusion of multiple forms of knowledge and recognition of rights, equitable distribution of costs and benefits, policies tailored to local social and ecological contexts, monitoring of social and ecological conditions and practices, coordinated and aligned policies, and robust customary and statutory institutions *(well established)* {6.6}. Integration of these key elements into binding agreements, voluntary agreements and certification schemes differs strikingly among practices. Binding agreements for fishing display the strongest integration of these seven key elements, although two key elements (inclusive and participatory decision making, acknowledgement of rights and equitable distribution of benefits) remain largely absent **(Table SPM.1)** *(established but incomplete)* {2.2.6}. Certification schemes for gathering and logging integrate most of these key elements, but do not address alignment of policies or coordination of interactions with other practices. These two prior key elements are only reflected in voluntary agreements for gathering, terrestrial animal harvesting and non-extractive practices **(Table SPM.1)** *(well established)* {2.2.6}. All types of agreements related to logging and non-extractive practices entirely overlook one or two key elements **(Table SPM.1)**. Integrating all seven key elements into binding agreements, voluntary agreements and certification schemes for all practices is a prerequisite for the future of sustainable use of wild species *(established but incomplete)* {6.6}.

(D.2.2) These seven key elements have been deployed in limited contexts and could be used as levers of changes to promote sustainable use and enhance the sustainability of the use of wild species in the future if they are scaled up across practices, regions and sectors *(well established)* {6.6}.

1. **Policy options that are inclusive and participatory will strengthen sustainable uses of wild species *(well established)* {6.5.1.1, 6.6.1}.** Stakeholder diversity promotes buy-in and collaboration, and expands the knowledge base for decision-making (e.g., co-management), provided that power imbalances and conflicts are managed *(well established)* {4.2.2.2.3, 6.5.4, 6.6.2, 6.6.8}. Specific actions to promote inclusive and participatory processes include enacting policies with clear guidance on procedures for decision-making and representation (e.g., specifying membership roles and responsibilities) and building capacity that enables all parties to participate fully *(well established)* {6.5.1.1, 6.6.1}.

2. **Policy options that recognize and support multiple forms of knowledge will enhance the sustainability of the use of wild species *(well established)* {6.6.2}.** Sustainable use of wild species will be enhanced by policy processes that protect indigenous and local knowledge and draw on diverse forms of knowledge, bringing scientists, indigenous peoples and local communities and other relevant actors together in a co-learning process *(well established)* {6.6.2}. Measures to ensure that indigenous and local knowledge holders have provided free, prior and informed consent for, and receive benefits from, the use of their knowledge are important, for example, through the enactment of access and benefit-sharing mechanisms {6.5.2.4}.

3. **Policy instruments and tools will only be effective if they ensure fair and equitable distribution of costs and benefits from sustainable use of wild species *(well established)* {6.4.3.1, 6.5.3.3, 6.6.3}.** Policies that overlook social equity increase the risk of unsustainable use of wild species *(established but incomplete)* {6.5.3.3}. Specific actions and plans could include enacting guidelines on access and benefit sharing that are currently common in voluntary agreements, and applying governance and institutional frameworks that ensure fair and equitable distribution of costs and benefits. This may ensure that policies do not inadvertently criminalize or deprive local communities or marginalized individuals of access and equitable distribution of costs and benefits, and identify measures that may ensure preventing the misappropriation of genetic resources and associated traditional knowledge *(well established)* {6.4.4, 6.6.3}.

4. **Context-specific policies are needed to ensure the sustainable use of wild species *(well established)* {6.5.2.1, 6.5.3.2, 6.6.4}.** Effective policies are purpose-built to local, social and ecological conditions in which uses take place *(well established)* {4.2, 5.5}. Actions to

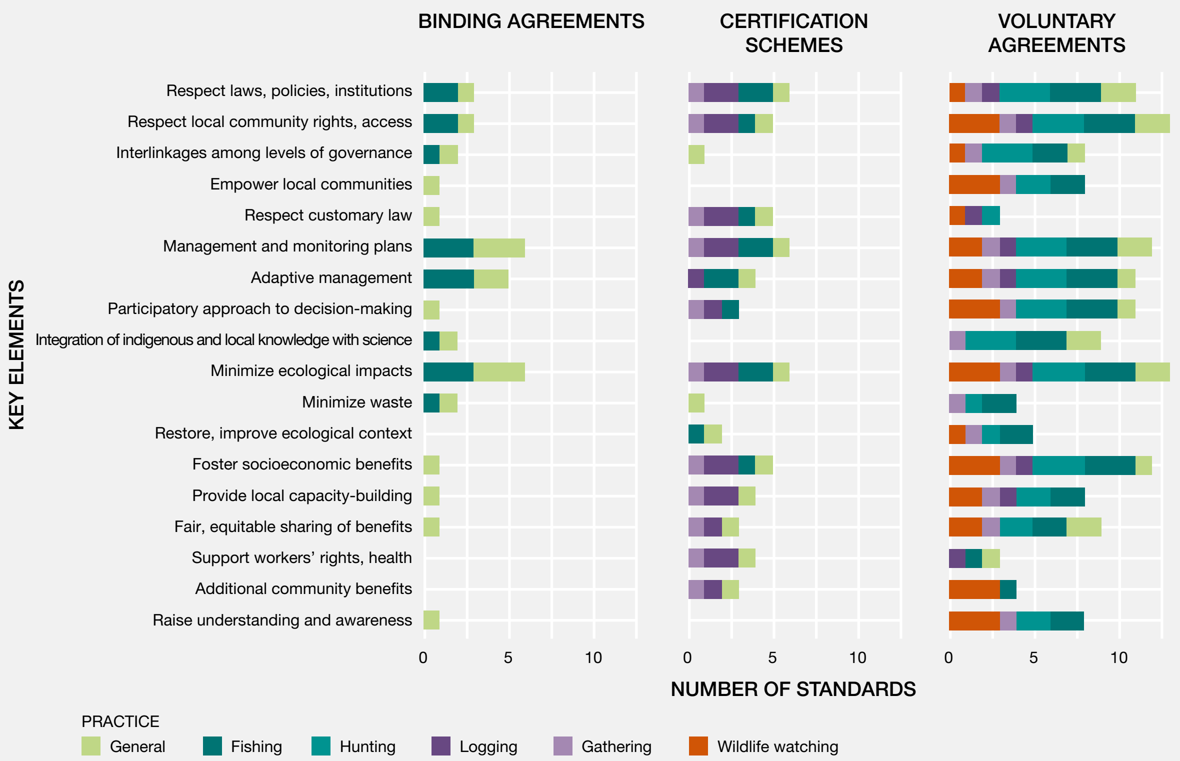

Figure SPM 8 **Themes in key elements of sustainable use of wild species in international and regional agreements, including binding agreements (n=6), certification schemes (n=6) and voluntary agreements (n=13).**

A data management report for this figure is available at https://doi.org/10.5281/zenodo.6473133.

empower indigenous peoples and local communities and respect their rights, access and customary rules are fundamental to the development of context-specific policies.

5. **Monitoring wild species and practices is crucial to prevent species decline *(well established)* {4.2.2.2.3}.** Monitoring is resource intensive and will require more support and investment in all countries to overcome the capacity, financial, technical and institutional challenges that generate strong limitations to monitoring wild species, which are more pronounced in developing countries. Monitoring efforts that are inclusive of indigenous peoples, local communities and scientific approaches, and facilitate equitable participation of all key actors, can better inform decision-making *(well established)* {3.2.4, 3.3.3, 3.3.5}.

6. **Policy instruments that are aligned at international, national, regional and local levels, and that maintain coherence and consistency with existing international obligations and take into account customary rules and norms, will be more effective *(well established)* {6.5.1.2, 6.5.2, 6.6.6}.** Policy outcomes will also be more effective and will lead to fewer negative and unintended consequences when attention is paid to coordinated interactions between approaches, actors, and scales *(well established)* {6.5.1.2, 6.6.3}.

7. **Robust institutions in terms of sustainable use of wild species, including customary institutions, will be essential to future sustainable use of wild species *(well established)* {6.5.1.3, 6.6.7}.** Institutions that support collaborative and decentralized learning and shared interests in sustainable use are more effective than centralized systems aimed only at top-down governance *(established but incomplete)* {4.2.2.6}. Adaptive and dynamic institutions capable of adjusting to changing circumstances will be needed to face current and future challenges to sustainable use of wild species *(well established)* {6.5.1.1, 6.5.1.3, 6.5.3.2, 6.6.7}. The integration of conflict resolution

Table SPM 1 **Seven key elements of effective policy for sustainable use of wild species, their presence in current international agreements and examples of policy options.**

Colour coding based on the data drawn from analysis of chapter 2 {figure 2.3 in 2.2.6.2}. Pictograms represent (from left to right): fishing, gathering, logging, terrestrial animal harvesting and non extractive practices.

Key elements						Policy options
Inclusive and participatory decision-making						Enact policies with clear guidance on transparent processes for decision-making and representation
						Build the capacity of all actors
						Develop national, regional, and international contact points, platforms and community facilitators, mediators
Inclusion of multiple forms of knowledge and recognition of rights						Ensure that decision-making processes are mandated to draw on diverse forms of social and ecological knowledge
						Develop measures to gain free, prior and informed consent for the use of knowledge and to ensure knowledge holders benefit
						Promote the obligation to secure the substantive and procedural rights that are guaranteed by law for all potentially affected persons
Equitable distribution of costs and benefits						Incorporate the contents of voluntary guidelines on fair and equitable sharing of benefits into legally binding agreements
						Distribute costs of management through social safety nets while ensuring that costs of management do not exceed benefits
						Apply governance and institutional frameworks that promote equitable benefit-sharing
						Ensure that policies do not inadvertently remove access for indigenous peoples, local communities or marginalized individuals
Policies tailored to local social and ecological context						Develop science- and evidence-based policies according to specific local ecological and social contexts, and follow the precautionary approach as appropriate
						Respect local communities' rights and access and customary rules
						Empower local communities
Monitoring of social and ecological conditions and practices						Incorporate guidelines and tools in project and programme planning to ensure social and ecological monitoring and evaluation of all interventions and their implications for the rights of people involved
						Invest resources in coordinated social and ecological monitoring programmes
						Support scientific and community-based social and ecological monitoring programmes
Coordinated and aligned policies						Coordinate international, regional, national and subnational policies and governance
						Integrate policies across sectors
						Coordinate policies across practices
Robust institutions, from customary to statutory						Design adaptive and dynamic institutions capable of adjusting to ecological and social changes
						Develop conflict resolution mechanisms and manage conflicts
						Integrate transparency measures into formal, legally mandated accountability policies
						Ensure all relevant customary and statutory policies, laws and institutions are respected in national and international agreements

VOLUNTARY AGREEMENTS

VOLUNTARY AGREEMENTS AND CERTIFICATION SCHEMES

NOT PRESENT

VOLUNTARY AGREEMENTS, CERTIFICATION SCHEMES AND LEGALLY BINDING AGREEMENTS mechanisms will make institutions more effective, while transparency initiatives connected to legally mandated measures of accountability will enhance trust in institutions.

D3 The world is dynamic and to remain sustainable, use of wild species requires constant negotiation and adaptive management. It also requires a common vision of sustainable use and transformative change in the human-nature relationship.

(D.3.1) Successful adaptation and negotiation require attention to the dynamics of both the social and ecological contexts of uses *(well established)* {2.2.3.7}. Because the species under use, the ecosystems that support them and the social systems within which uses occur are dynamic and change over time and space, the sustainable use of wild species is an ongoing adaptive process, which may be depicted as follows: (i) assess status and trends in wild species under use; (ii) identify drivers of (un)sustainability; (iii) adapt uses and management; and (iv) re-assess after a given time interval and re-adapt use and management, if needed *(well established)* {1.3, Box 2.3, 4.2.2.2, 4.2.2.4, 6.5.1.3}. Continuous long-term monitoring is needed to inform such adaptive management processes and benefit from approaches that integrate complementary information from science and indigenous and local knowledge *(well established)* {2.2.6, 2.3.3, 2.3.4}.

(D.3.2) Intensification of existing uses and/or the emergence of new uses for wild species have often led to the rapid and substantial reconfiguration of trade-offs and synergies within and among practices, with negative impacts on the sustainability of the use *(well established)* {3.4}. They can also create novel interfaces that influence disease risk, but the link with the intensification of the use of wild species and zoonotic diseases is unresolved *(established but incomplete)* {4.2.1.7}. Such changes can be fast and profound. For instance, rapid development of new markets can produce rapid changes in resource exploitation and overwhelm the ability of institutions to respond *(established but incomplete)* {4.2.2.2}. Intensification of uses can reinforce negative impacts, such as land degradation or the introduction of invasive alien species, modifying the spillover risk of novel or known pathogens from wild species hosts to domestic animals and humans *(established but incomplete)* {4.2.1.7.2.}. Transparency and effective institutions informed by evidence, and robust management and governance, will likely help tackle threats to ecosystems and health by recognizing the interconnection between humans, domestic and wild animals, plants, and the wider environment, contributing to sustainable development, and ultimately reducing the risk of future spillover events *(well established)* {4.2.1.7}. Governance that supports the involvement of multiple sectors at varying levels of society in decision-making, (e.g., One Health), can limit risk from zoonotic disease and provide positive ecological and social outcomes *(established but incomplete)* {4.2.1.4}.

(D.3.3) Achieving transformative change relating to the use of wild species requires moving towards a common vision while recognizing different value systems and conceptualizations of sustainable use *(established but incomplete)* {1.3.3, 1.4.1}. This could be achieved, at least at a local level, by promoting participatory and inclusive approaches to the use of scenarios and models to explore the different uses of wild species and identify pathways to sustainable use, while helping different actors think through decision options from a variety of value perspectives *(established but incomplete)* {5.7}.

(D.3.4) The sustainable use of wild species will benefit from a transformative change in the prevailing conceptualization of nature, shifting from the human-nature dualism deeply rooted in many (but not all) cultures, to a more systemic view that humanity is part of nature *(well established)* {1.3.3, 1.4}. Views of the human-nature relationship that separate nature (understood as existing by itself) from culture (produced by humans) have a profound influence on perceptions of the functioning of the biosphere and the language used to understand and describe it. Although many cultures consider nature and humans to be indivisible, a conceptual separation between people and nature is pervasive and may be found in most national and international instruments and policies *(well established)* {1.4}. This human-nature dualism further fosters the illusion that humanity could exist apart from or in control of the rest of nature, to such an extent that humans' use of nature ad libitum ultimately led to major environmental crises, such as climate change and biodiversity decline *(well established)* {1.3.3}. Considering humanity to be part of nature (i.e., a member or a citizen of nature, among others) would lay the foundation for a more respectful and sustainable relationship, as shown by indigenous peoples' and local communities' traditional practices and uses *(well established)* {1.4}.

APPENDIX 1

Communication of the degree of confidence

Figure SPM A 1 **The four-box model for the qualitative communication of confidence.**

Confidence increases towards the top-right corner, as suggested by the increasing strength of shading. Source: IPBES (2016).[6] Further details of the approach are documented in the *IPBES Guide on the Production of Assessments*.[7]

In the thematic assessment of the sustainable use of wild species, the degree of confidence in each main finding is based on the quantity and quality of evidence and the level of agreement regarding that evidence **(Figure SPM.A1)**.

The evidence includes data, theory, models and expert judgement.

- **Well established:** there is a comprehensive meta-analysis or other synthesis or multiple independent studies that agree.
- **Established but incomplete:** there is general agreement, although only a limited number of studies exist; there is no comprehensive synthesis, and/or the studies that exist address the question imprecisely.
- **Unresolved:** multiple independent studies exist but their conclusions do not agree.
- **Inconclusive:** there is limited evidence and a recognition of major knowledge gaps.

6. IPBES (2016): Summary for policymakers of the Assessment Report on Pollinators, Pollination and Food Production of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S.G. Potts, V. L. Imperatriz-Fonseca, H. T. Ngo, J. C. Biesmeijer, T. D. Breeze, L. V. Dicks, L. A. Garibaldi, R. Hill, J. Settele, A. J. Vanbergen, M. A. Aizen, S. A. Cunningham, C. Eardley, B. M. Freitas, N. Gallai, P. G. Kevan, A. Kovács-Hostyánszki, P. K. Kwapong, J. Li, X. Li, D. J. Martins, G. Nates-Parra, J. S. Pettis, R. Rader, and B. F. Viana (eds.)., secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. Available at http://doi.org/10.5281/zenodo.2616458.
7. IPBES (2018): IPBES Guide on the Production of Assessments. Secretariat of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. Available at https://ipbes.net/guide-production-assessments.

APPENDIX 2

Knowledge gaps table

Table SPM A 1 **Knowledge gaps table for the thematic assessment of the sustainable use of wild species.**

Sector	Knowledge gaps (in data, indicators, inventories, scenarios)
Data and information availability and access	• Data and information on wild species and their uses at the same scales as those used for their management {2.1} • Context-specific information on practices and uses and their outcomes {1.4, 3.3, 4.2, 6.5} • Long-term temporal and spatial studies, particularly for non-fishing practices {4.5} • Consistency among worldwide and regional databases concerning the harvest of wild species and the social components of their use {3.2.1.5} • Databases containing information on policies adopted at different levels of governance addressing sustainable use of wild species {3.2.1} • Information about the interlinkages among different taxonomic groups of wild species, specific ecosystem functions, nature's contributions to people and human well-being {3.2.4, 3.5, 3.6.2} • Information on sources, quality assurance, safety and efficiency of traditional uses of wild species {3.5} • Robust indicators at multiple temporal and spatial scales, particularly for gathering, logging and non-extractive practices {3.2.1, 3.3.2, 3.3.4, 3.3.5} • Indicators reflecting the social components of uses of wild species (for all practices) {2.2, 2.3, 3.2, 6.4} • Strengthen the consistency, breadth and depth of documentation of threats and use and trade classification schemes in the International Union for Conservation of Nature Red List of Threatened Species assessments {3.2.1, 3.2.2}
Assessment methods, models and scenarios	• Studies on the effectiveness of various policy instruments and tools (including certification schemes and other market mechanisms) {5.6} • Studies of ecosystem resilience and how resilience is affected by uses of wild species, particularly for practices other than fishing {4.5} • Studies addressing the interactions of multiple drivers of unsustainable uses {3.2.2, 6.5} • Methods which combine information from multiple knowledge systems {3.2} • Evaluation of the impacts of changes in social-ecological systems (especially their social components) on sustainable use of wild species {4.5, 5.3, 6.7} • Scenario studies for gathering, terrestrial animal harvesting and non-extractive practices {5.3, 6.5.2} • Scenario studies focusing on cultural, rights and equity aspects of use of wild species {5.6} • Archetype scenarios exploring uses of wild species {5.6}
Indigenous and local knowledge	• Methods co-developed with indigenous peoples and local communities for weaving science and indigenous and local knowledge {3.5, 4.5} • Documentation of indigenous and local knowledge regarding sustainable use of wild species, ensuring free, prior and informed consent {3.5} • Monitoring processes and indicators co-produced with indigenous peoples and local communities {3.5, 4.5} • Scenarios co-produced with indigenous peoples and local communities, based on indigenous and local knowledge and values {5.11} • Approaches to support and revitalize indigenous and local knowledge and customary governance {4.5} • Capacity-building and support for indigenous peoples and local communities to conduct research, monitoring and governance, to support and enhance the sustainability of the use of wild species {3.5, 4.5}
Multiple uses and interactions of uses with other pressures	• Interactions between ecological and social components of uses of wild species {3.4.3, 5.4, 6.5} • Interactions among practices, such as logging, gathering, terrestrial animal harvesting and non extractive practices {3.4} • Interactions between pollution, climate change, urbanization and human consumption of wild species {4.5} • Impacts of climate change on wild species distribution, the ecosystems they inhabit and policies addressing their use {3.5, 4.5} • Impacts of invasive alien species on sustainable uses of wild native species {4.5}

Sector	Knowledge gaps (in data, indicators, inventories, scenarios)
Practices	**Fishing** • Assessments of small-scale fisheries in coastal and inland areas {3.3.1} • Assessments of all types of fisheries in South and East Asia, Latin America and Africa {3.3.1} • Consistent differentiation between wild and non-wild species, especially for production, consumption and trade statistics {3.3.1, 3.3.4} • Life histories information for wild species {3.3.1} • Documentation on bycatch and discards {3.3.1} • Long time series for population status and harvest volumes {3.3.1} • Information on trade in ornamental fishes {3.3.1} • Studies on the social components of fishing, especially governance and equity considerations {5.4.2} **Gathering** • Information on the uses of wild plants, algae and fungi {3.2} • Information on trade in wild plants, algae and fungi {3.3.2, 3.5} • Studies of the effects of harvest techniques on wild plants, algae and fungi {3.3.2} • Information on urban gathering, especially for Asia and the Pacific {3.3.2} • Information on formal and informal governance systems {4.5} • Impacts of the use of wild plants, algae and fungi on human health and food security {3.3.1, 3.3.2, 3.3.5} • Projections and scenarios on the gathering of wild plants, algae and fungi {5.4.3} • Projections and scenarios on the impacts of climate change on distributions of wild plants, algae and fungi in use and the traditional territories of indigenous peoples and local communities that rely on them {5.4.3, 5.5} **Logging** • Information on timber trade, especially species, sources (naturally regenerating *versus* plantation forests) and the legality (legal *versus* illegal) of wild species entering markets {1.4.1, 3.3.4} • Consistent differentiation between naturally regenerating *versus* plantation sources of wood in production, consumption and trade statistics {3.3.1, 3.3.4} • Studies exploring interactions among multiple drivers of logging outcomes (e.g., climate change, agriculture and development) {3.3.4, 4.3.2.4, 4.5} • Studies exploring how context-specific factors affect the drivers of use of wood from naturally regenerating forests and their interactions {4.3.2.4, 4.5} **Terrestrial animal harvesting** • Information on harvest and trade of edible insects {3.3.3, 3.5} • Information on wild meat harvesting from understudied areas, especially from the Asian tropics {3.2.1, 3.3.3} • Information on the impacts of various forms of terrestrial animal harvesting in conjunction with other pressures on wild populations {3.3.3.2.4} • Empirical evidence for the link between hunting and conservation of landscapes {3.3.3.2.4} • Analyses of the identity and location of harvesting in the trade of wild reptiles {3.3.5} • Impacts and role of green hunting and trophy hunting on the sustainable use and conservation of wild species {3.3.3} • Scenarios related to environmental changes, particularly climate change {5.4.4} **Non-extractive practices** • Information on the species that are the focus of non-extractive practices across different regions {3.2} • Information on trends and sustainability of non-extractive practices {3.2} • Information on formal and informal governance systems {4.5} • Impacts of nature-based tourism on less charismatic species of wild flora and fauna {3.3.5} • Scenario studies on non-extractive practices {5.4.6}

APPENDIX 3

Definitions

Table SPM A 2 **Definitions for the thematic assessment of the sustainable use of wild species of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (see also chapter 1 and the glossary of the assessment).**

Extractive practices	Extractive practices are defined as the temporary or permanent removal of organisms, part of them or materials derived from them, and may result in mortality of the individual to be used (e.g., hunting or whole-plant harvest), but does not necessarily do so (e.g., limited collection of plant propagules or shearing and releasing of vicuña).
Fishing	Fishing is defined as the removal from their habitats of aquatic animals (vertebrates and invertebrates) that spend their full life cycle in water (e.g., fish, some marine mammals, shellfish, shrimps, squids, corals). Fishing most often results in the death of the aquatic animal, but it may not in some cases. To reflect both situations, fishing has been subdivided into a lethal and a "non-lethal" category. Lethal fishing is defined as the general and more usual meaning of fishing that leads to the killing of the animal, such as in traditional commercial fisheries. "Non-lethal" fishing is defined as the temporary or permanent capture of live animals from their habitat without intended mortality, such as in aquarium fish trade or catch and release. However, unintended mortality may occur in "non-lethal" fishing and the term "non-lethal" is therefore put in quotes. The killing of species that spend part of their life cycle in terrestrial environments (e.g., walrus, sea turtles) is encompassed by the definition of hunting.
Gathering	Gathering is defined as the removal of terrestrial and aquatic algae, fungi, and plants (other than trees) or parts thereof from their habitats. Gathering may, but often does not, result in the death of the organism. Gathering includes whole-plant harvest and removal of above and/or below ground plant parts, as well as the fruiting bodies of macrofungi. It also includes removal of non-woody portions of trees (e.g., leaves, propagules and bark). Where removal of propagules or death of an individual plant occurs (e.g., whole-plant and root removal), effects on population sustainability are contingent upon factors including timing, frequency, and intensity of harvest. The harvest of wood and woody parts of trees is encompassed by the definition of logging.
Logging	Logging is defined as the removal of whole trees or woody parts of trees from their habitat. Logging generally results in the death of the tree, but also includes cases in which it may not, such as coppicing. Logging occurs in forests that may be classified as primary, naturally regenerating, planted and plantation. This assessment does not address logging from plantation forests except as it has bearing on the practice in the other forest types. Harvest of non-woody parts of trees (e.g., leaves, propagules and bark) is here defined as gathering.
Non-extractive practices	Non-extractive practices are defined as practices based on the observation of wild species in a way that does not involve the harvest or removal of any part of the organism. The observation can imply some interaction with the wild species, such as the activities of wildlife and whale watching, or no interaction with the wild species, such as remote photography.
Social-ecological systems	Social-ecological systems are complex adaptive systems in which people and nature are inextricably linked in which both the social and ecological components exert strong influence over outcomes. The social dimension includes actors, institutions, cultures and economies, including livelihoods. The ecological dimension includes wild species and the ecosystem they inhabit.
Terrestrial animal harvesting	Terrestrial animal harvesting is defined as the removal from their habitat of animals (vertebrates and invertebrates) that spend some or all of their life cycle in terrestrial environments. As for fishing, terrestrial animal harvesting often results in the death of the animal, but it may not in some cases. To reflect both situations, terrestrial animal harvesting has been sub-divided into a lethal and a "non-lethal" category. Hunting is defined as the lethal category of terrestrial animal harvesting which leads to the killing of the animal, such as in trophy hunting. "Non-lethal" terrestrial animal harvesting is defined as the temporary or permanent capture of live animals from their habitat without intended mortality, such as pet trade, falconry or green hunting. "Non lethal" harvest of animals also includes removal of parts or products of animals that do not lead to the mortality of the host, such as vicuña fibre or wild honey. Unintended mortality may however occur in this category and the term "non-lethal" is therefore put in quotes.
Transformative change	Transformative change is defined in line with previous work of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services approved by its Plenary, as a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values,[8] needed for the conservation and sustainable use of biodiversity, good quality of life and sustainable development.

8. IPBES (2019): Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Guèze, M., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., Garibaldi, L.A., Ichii, K., Liu, J., Subramanian, S.M., Midgley, G.F., Miloslavich, P., Molnár, Z., Obura, D.,Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Roy Chowdhury, R., Shin, Y.J., Visseren-Hamakers, I.J., Willis, K.J., and Zayas, C.N. (eds.). IPBES secretariat, Bonn, Germany. Available at https://doi.org/10.5281/zenodo.3553579.

Chapter **1**

SETTING THE SCENE[1]

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Chapter **1**

SETTING THE SCENE

EXECUTIVE SUMMARY

This IPBES assessment is a comprehensive and ambitious intergovernmental effort that aims to provide policy and solution-oriented approaches towards more sustainable use of wild species, recognizing the diversity of practices, uses and contexts. The core of this assessment is therefore not to evaluate the status of wild species worldwide, nor to exhaustively document the impacts of human uses on wild populations or the various biotic and abiotic components of the ecosystems that they inhabit, as unsustainable use of wild species has been extensively covered elsewhere. This assessment focuses on: (i) how sustainable use is conceptualized by different groups, (ii) the status and trends in use of wild species and its consequence for nature and nature's contributions to people, (iii) the main drivers of change, (iv) the various scenarios for the future and finally (v) the effectiveness of policies, governance systems and institutions for managing the use of wild species.

1 **The use of wild species contributes directly to the well-being of billions of people globally.** In some countries, wild foods contribute to food and nutrition security for one third to 100% of the nation's population or select populations within it. Plants, algae and fungi provide food, income and nutritional diversity for an estimated one in five people around the world, in particular women, children, landless farmers and others in vulnerable situations. Freshwater and marine fisheries are primary sources of animal protein, nutrients and income for hundreds of millions of people worldwide, while wild meat from terrestrial animals remains a major source of protein for some rural and urban populations. The use of wild species also provides non-material contributions by enriching people's physical and psychological experiences, including their religious and ceremonial lives.

2 **Use of wild species is particularly important to people in vulnerable situations on both a day-to-day basis and in times of crisis.** The viability of wild species as livelihood resources for all people, but especially individuals and communities in vulnerable situations, depends fundamentally on their sustainable use. In many cases, a single species may have multiple uses and contribute to human well-being in multiple ways.

3 **For many indigenous peoples and local communities, the use of wild species is inextricably entwined in culture, identity and livelihoods.** Globally, lands managed by indigenous peoples and local communities display high biodiversity, including sustainable use of wild species grounded in indigenous and local knowledge systems. Unsustainable uses of wild species both contribute to and result from loss of culture and identity in indigenous and local communities. Thus, the answer to the question of how to ensure sustainable use of wild species has profound implications for the survival of indigenous peoples and local communities. Likewise, indigenous and local knowledge can play an important role in identifying and supporting existing sustainable uses of wild species and pathways to further sustainable use in the future.

4 **Overexploitation of wild species is a key driver of biodiversity decline together with other factors**, **including (but not limited to) land use/land cover change, pollution, climate change and invasive alien species.** This decline is substantial as, for instance, indicated by the International Union for Conservation of Nature Red List of Threatened Species, which classifies 28% of the species assessed to date as being threatened with extinction or by the IPBES Global Assessment Report on Biodiversity and Ecosystem Services that documented an unprecedented species extinction rate over the past decades. The adverse consequences of species decline on human well-being are receiving increasing global attention, especially in relation to food security, human health, awareness of climate crisis and rights and livelihoods of indigenous peoples and local communities.

5 **The results of human uses of wild species are not always and everywhere destructive.** Indeed, much of the biodiversity people seek to protect owes its origins to long-term relationships between the biophysical environment and the practices of indigenous peoples and local communities, including their uses of wild species. Indigenous peoples manage fishing, gathering, terrestrial animal harvesting and other uses of wild species on more than 38 million km² of land in 87 countries. This area coincides with approximately 40% of terrestrial conserved areas, including many with high biodiversity value. Cases around the world provide examples of successful efforts to restore populations of overexploited wild species to assure their long-term sustainable use at scales from the local and national to the regional and international.

6 **It is simultaneously true that: (a) unsustainable use of wild species contributes to accelerating biodiversity loss, and (b) sustainable use of wild species is an avenue for realizing conservation and development goals.** This is not a contradiction. Rather, it is

an acknowledgement that the outcomes of the use of wild species depend on social and ecological factors. These include species ecology and the status and properties of the ecosystems that they inhabit. They also depend on the history, technology, and economics of use, as well as the governance systems through which they are managed. Each of these factors are embedded in conceptualizations of the relationship between people and nature. Biodiversity loss often results from the disruption or intensification of uses that previously had been sustainable.

7 **Sustainable use of wild species may contribute in multiple ways to the achievement of the Sustainable Development Goals, but these potential contributions are most often overlooked.** Sustainable use of wild species can support better quality of life for people in the most vulnerable situations and is also an essential component of good quality of life for all. However, these potential contributions are poorly reflected in targets and indicators of several Sustainable Development Goals. While the contributions of the sustainable use of wild species has been identified for Sustainable Development Goal 14 (life below water) and 15 (life on land), there is untapped potential for contributions to the rest of the Sustainable Development Goals. Further attention to ways in which the sustainable use of wild species can support good quality of life for people and the planet will contribute to realizing these global goals.

8 **The use of wild species involves at least three components, which interact in a dynamic way.** These are (i) the wild species being used, (ii) the practices undertaken by people when they use wild species and (iii) the uses for goods and services derived from wild species.

- **Wild species** refers to populations of any species that have not been domesticated through mutigenerational selection for particular traits, and which can survive independently of human intervention that may occur in any environment.

- **Practices** have been divided into extractive (fishing, gathering, terrestrial animal harvesting, and logging) and non-extractive (observing) practices.

- **Uses** have been divided into nine categories, which are not mutually exclusive (aesthetic, construction, energy, food, learning, medicine, recreation, ritual and others).

These three components are affected by environmental, political, demographic, economic, cultural and technological drivers. The ways in which wild species, practices and uses are managed can determine whether outcomes are consistent with sustainable use.

9 **Sustainable use is an outcome of social-ecological systems** that aim to maintain biodiversity and ecosystem functions in the long term while contributing to human well-being. It is a dynamic process as wild species, the ecosystems that support them and the social systems within which their uses occur, change over time and space.

10 **The sustainable use of wild species will benefit from transformative change in the prevailing conceptualization of nature, shifting from the human-nature dualism deeply rooted in many (but not all) cultures, to a view that humanity is part of nature.** Views of the human-nature relationship that separate nature (understood as existing by itself) from culture (produced by humans) have a profound influence on perceptions of the functioning of the biosphere and the language used to understand and describe it. Although many cultures consider nature and humans to be indivisible, a conceptual separation between people and nature is pervasive and may be found in most national and international instruments and policies. This human-nature dualism fosters the illusion that humanity could exist apart from or in control of the rest of nature. Considering humanity to be part of nature (i.e., one member or citizen of nature among many others) would lay the foundation for a more respectful and sustainable relationship, as shown by indigenous peoples' and local communities' traditional practices and uses.

1.1 INTRODUCTION

Rapid declines in biodiversity and degradation of ecosystem functions and global environmental commons, such as climate and water resources, heavily affect human well-being (IPBES, 2019a; Millenium Ecosystem Assessment, 2005). The nature and extent of this decline is well documented from an ecological/conservation perspective (IPBES, 2018a, 2018b, 2018c, 2018d, 2019a; IUCN, 2021b; WWF, 2018) due to strong and long-lasting efforts from several international bodies, the academic research community and environmental non-governmental organizations. This decline is substantial as, for instance, indicated by the International Union for Conservation of Nature Red List of Threatened Species, which classifies 28% of the species assessed to date as being threatened with extinction (IUCN, 2021b), or by the IPBES Global Assessment of Biodiversity and Ecosystem Services (IPBES, 2019a), which documented an unprecedented rate of species extinction and its effect on human well-being over the past decades. These effects can be attributed to direct drivers, such as habitat destruction, biological invasions, climate change and overexploitation (IPBES, 2018e, 2019a; Román-Palacios & Wiens, 2020) or indirect drivers, that can alter ecosystem functioning and productivity (Casini *et al.*, 2012; Daskalov *et al.*, 2007; Palkovacs *et al.*, 2018). The adverse consequences of species decline on food security and nutrition (Golden *et al.*, 2016), human health (Sandifer *et* *al.*, 2015), conservation and the rights of indigenous peoples and local communities (Sasaoka & Laumonier, 2012; Turner *et al.*, 2013) and other requirements for human well-being are receiving increasing global attention.

There is consistent and substantial evidence that use of wild species has in many cases occurred at unsustainable levels, exceeding the populations' capacities to recover (IPBES, 2019a; Vignieri, 2014). Declines in a wide range of taxa (both plants and animals), due to non-sustainable use of wild species, have been recorded across marine (FAO, 2020b; Lam & Sadovy de Mitcheson, 2011; Pacoureau *et al.*, 2021; Worm *et al.*, 2009), inland waters (Allan *et al.*, 2005; FAO, 2020b; Fluet-Chouinard *et al.*, 2018) and terrestrial ecosystems (Coad *et al.*, 2019; Fa *et al.*, 2006; FAO, 2018b). Direct exploitation by humans has been identified as the most serious driver of biodiversity loss in marine ecosystems and as the second most important driver in terrestrial and freshwater ecosystems (Coad *et al.*, 2019; IPBES, 2019, 2018a, 2018b; FAO, 2018a, 2018b; Vignieri, 2014; Fa *et al.*, 2006; Allan *et al.*, 2005; Fluet-Chouinard *et al.*, 2018). The extent of decline has clearly shown that many current policies are inadequate and/or their implementation is ineffective. This has increased the urgency to identify ongoing policies that work and scale them up, or find alternative approaches when ongoing policies have been unsuccessful (IPBES, 2019a).

The decline in biodiversity also affects human communities who directly or indirectly depend on the use of wild species. Regular use of wild foods is an important component of global food and nutrition security. Although more data are needed to establish a complete picture of the contributions of wild foods to people around the world, some countries report that between one third and 100% of their national or subnational populations may use wild foods at certain times (FAO, 2019). Wild marine and freshwater species (mostly fish, crustaceans and mollusks) provide 54% of the world's seafood production which accounted, in 2017, for 17% of the global population's intake of animal proteins and 7% of all proteins consumed (FAO, 2020b). Wild meat from terrestrial animals is also a major source of protein for rural and urban populations (Coad *et al.*, 2019). A wide range of wild-harvested plants, fungi and lichens are used and traded, including 30,000 plant species for medicinal or aromatic uses, an estimated 60-90% of which are gathered in the wild (Jenkins *et al.*, 2018). Wild forests (often referred to as natural forests) provide a significant proportion of wood for material and construction, energy (fuelwood or charcoal) and food to people, particularly in developing countries (FAO, 2018b). An estimated 5% to 8% of current global crop production depends on wild animal pollination, which corresponds to an annual market value of US$235 billion to US$577 billion (IPBES, 2016). People in vulnerable situations are often most reliant on wild species and are most likely to benefit from more sustainable forms of use of wild species to secure their livelihoods (FAO, 2018b). Biodiversity decline nevertheless also affects the economies of developed countries, especially those depending on the use of wild species, such as fisheries, the logging industry, the medicinal plant industry or tourism (see Chapters 3 and 4). Further, the use of wild species provides non-material contributions by enriching people's physical and psychological experiences, including their religious and ceremonial lives (Anthony & Bellinger, 2007; Russell *et al.*, 2013). Determining and enhancing the sustainability of uses of wild species is thus a critical issue for conserving biodiversity and contributing to human well-being.

Although overexploitation of wild species is well documented, there are many examples of success in maintaining or restoring populations for long-term use (Cromsigt *et al.*, 2018; Lichtenstein & Vilá, 2003; Mahoney, 2019). Finding ways to prevent the ongoing loss of species and mitigate the concomitant impacts on human well-being remains a major challenge. Human societies have grappled for millennia with profound questions relating to the harvest of wild species to meet their needs, the balance required for those same species to thrive, and the distribution of benefits derived from wild species. The knowledge, customary institutions and practices of many indigenous peoples and local communities ensure sustainable use of the species and environments on which they rely (Berkes, 2018; Comberti *et al.*, 2015; Minnis & Elisens, 2000). However, local and global changes in the environment, consumption patterns and the rapid growth in human population have greatly altered the context in which wild species are used and managed. Complex social-ecological dynamics operating from local to global scales underlie the use of wild species (Brashares & Gaynor, 2017; Ostrom, 2009) and influence the likely outcomes of policies and practices aimed to maintain and restore them.

There have been numerous national, bilateral and multilateral initiatives to find policy and management solutions favoring the sustainable use of wild species. National policies and regulations relating to the use of wild species date back more than 2000 years in China (Schäfer *et al.*, 2018; Yi-Ming *et al.*, 2000) and at least to the 13th century in Europe (Bazeley, 1921; R. C. Hoffmann, 2005). Over the past century, many agreements for the use of wild species have been developed and refined (Gulbrandsen & Humphreys, 2006; McDermott *et al.*, 2007; Rice, 2014, see Chapter 2). These include specific agreements on whales, fishing, logging, and hunting that have been set at national levels or through specific international management bodies, such as the International Whaling Commission, regional fisheries management organisations, and the International Tropical Timber Organization, which all aim to ensure more sustainable harvest of wild species. They also include more general instruments, such as the Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity adopted under the Convention on Biological Diversity (see:

https://www.cbd.int/doc/decisions/cop-07/cop-07-dec-12-en.pdf). Various global targets for sustainable use have been developed, such as the Global Strategy for Plant Conservation, the Aichi Biodiversity Targets of the Strategic Plan for Biodiversity 2011–2020 and the Sustainable Development Goals adopted by the United Nations. However, these are non-binding policy instruments and the Global Strategy for Plant Conservation and Aichi Biodiversity Targets failed to achieve sustainable use (IPBES, 2019a). It will remain a challenge to achieve the targets under the Sustainable Development Goals by 2030 and it is therefore important to understand how sustainable use of wild species contributes to the Sustainable Development Goals and what can be done to achieve sustainable outcomes.

Sustainable use of wild species features prominently in several international assessments, such as those done by the Food and Agriculture Organization of the United Nations (FAO) on fisheries and forestry (FAO, 2018b, 2018c, 2020b, 2020a), the Center for International Forestry Research on terrestrial wildlife (Coad *et al.*, 2019) and IPBES on biodiversity at global (IPBES, 2019a) and regional levels (IPBES, 2018d, 2018a, 2018b, 2018c). These assessments provide a strong background on the status and trends of wild species and problems relating to use of wild species (see section 1.5). Nevertheless, the status of many species remains unassessed because of a lack of monitoring, technical limitations, unreported illegal practices and trade, lack of appropriate experts or simply lack of recognition of existing practices and sources of knowledge (e.g., indigenous and local knowledge, see Chapters 3 and 4). Governance systems in place are also often undocumented, particularly those of indigenous peoples and local communities. Further, the nature and extent of human uses, harvesting rates and traditional management practices remain poorly documented, especially for uses that are not subject to trade. Despite general approaches, such as those identified by the precautionary approach (Garcia, 1996), uncertainty and lack of consensus regarding scientific advice (e.g., about the way to model population dynamics under use) have resulted in often divergent views on which policies to support and sometimes led to heated controversies, such as on whaling, fisheries or trophy hunting (e.g., Fromentin *et al.*, 2014; Mkono, 2019; Peace, 2010). This can lead to policy inertia or policies being maintained that are ineffective or, worse, that provide perverse incentives resulting in further loss of biodiversity and human well-being. It is also crucial to clearly understand and define people's needs (Singh *et al.*, 2021) and to assess with them potential solutions to optimize the social acceptability of various policy instruments put in place to regulate the use of wild species (see also Chapters 4 and 6).

The IPBES thematic assessment of the sustainable use of wild species (hereafter "the sustainable use assessment") is a comprehensive and ambitious intergovernmental effort that aims to build on previous assessments and address the challenges faced by policymakers. According to the scoping report set out in annex IV to decision IPBES-5/1, the objective of this thematic assessment is: "to consider various approaches to the enhancement of the sustainability of the use of wild species and to strengthen related practices, measures, capacities and tools for their conservation through such use". In other words, the aim of this assessment is not to evaluate the status of wild species worldwide, nor to exhaustively document the impacts of human uses on wild populations or the various biotic and abiotic components of the ecosystems that they inhabit, as this has already been done by the IPBES Global Assessment of Biodiversity and Ecosystem Services (IPBES, 2019a) or by the International Union for Conservation of Nature (2020). Instead, the core of this assessment is to evaluate sustainability through the lens of different practices and uses by:

- Reflecting on how sustainable use is conceptualized by different groups (stakeholders, scientists, indigenous people, local communities);
- Assessing the status and trends in the use of wild species and consequences for nature and nature's contributions to people;
- Understanding and assessing the main drivers of change;
- Examining scenarios for the future;
- Assessing the effectiveness of policies, governance systems and institutions for managing the sustainable use of wild species;
- Identifying the main gaps in knowledge and data as well as the main challenges and opportunities associated with the sustainable use of wild species;
- Addressing uncertainties regarding the outcomes of policies and actions; and
- Providing an objective assessment of disputed facts and statistics.

1.1.1 Diverse uses of wild species by people and practices associated with them

All uses of wild species are embedded in social-ecological systems, defined as complex adaptive systems that include social (human) and ecological (biophysical) subsystems in a two-way feedback relationship (Berkes, 2011; Chapin *et al.*, 2009). Because the social and ecological subsystems function as a coupled, interdependent and co-evolutionary system (Berkes & Folke, 1998), social-ecological systems constitute natural units of analysis of the sustainability of wild species use. An analytical framework proposed by Ostrom (2009) distinguishes four interacting subsystems which comprise the resource units (e.g., fish), the resource systems (e.g., coastal fishery), the users (fishers) and the governance systems (organizations and rules that govern fishing on that coast). These components interact to produce outcomes at the system level, which are also influenced by external drivers (see **Figure 1.1**). For the purpose of this assessment, drivers are recognized as all the factors that directly or indirectly influence the use of wild species, such as environmental, economic or cultural drivers (see Chapter 4).

A first step for undertaking an assessment of the sustainable use of wild species is to recognize the diverse ways in which people use wild species. This diversity results from the intersection of several dimensions **(Figure 1.1)**, primarily: (i) the wild species used by people, which encompass all main species groups, including algae, animals, fungi and plants, from freshwater, marine and terrestrial habitats; (ii) the goods and services derived from those species, referred to in this assessment as "uses", including food, energy, materials, medicine or recreation (see section 1.3.4); (iii) the means or practices used to obtain benefits from wild species, including extractive and non-extractive practices; (iv) the destination and distribution of benefits derived from wild species, ranging from personal/family use or consumption to products sold in local informal markets, to those traded as global commodities in the international market; and (v) the statutory, customary and informal institutions, access regimes and rules that regulate uses and practices. The intensity of use of wild species and the scale of the operations involved vary enormously and are the main factors in evaluating sustainability and suitable forms of regulation. Furthermore, the components are affected by various drivers and the way they are managed can determine whether the outcomes of such complex social-ecological systems are consistent with sustainable use.

The use of wild species involves various practices associated with their harvest and/or other kinds of interactions with them. For the purpose of the assessment, these practices have been classified into five categories, which are generally associated with the species in use, i.e., fishing, gathering, terrestrial animal harvesting, logging and non-extractive practices. While most practices used to obtain benefits from wild species clearly fit within one of these five categories, there are some that are not so obviously classified. To avoid ambiguity, a working definition of the five practices for use across all chapters is developed in Section 1.3.4. Within each practice, uses may be characterized by the users, the wild species and

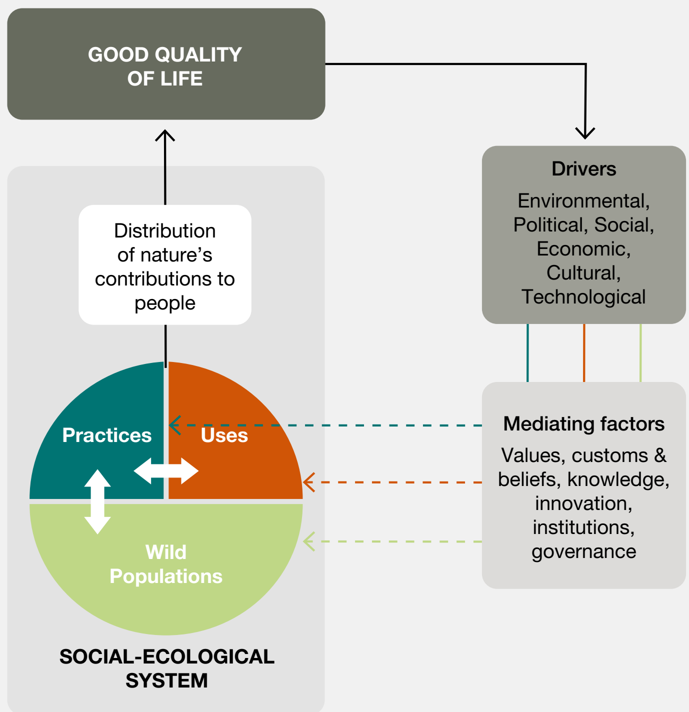

Figure 1 1 **A diagrammatic representation of the interactions between the end use of wild species, the practices associated with use, and the populations under use within the context of the drivers and responses that may influence sustainability.**

ecosystems used, their interactions and the context within which uses occur.

The wide diversity of uses within each practice needs to be considered in order to provide a balanced and representative assessment of the sustainable use of wild species, as well as a suitable analysis of possible pathways to further sustainability. For example, a discussion of policy measures that may be effective at achieving sustainable fishing needs to consider the full spectrum of tools and institutions, but also the different types of fishing categories and operations, as well as the local context. What may work for large, industrial fisheries from regions with strong management capacity and resources tends not to be suitable for the management of small-scale artisanal fisheries, especially in resource and capacity-limited situations (FAO, 2020b; Hilborn *et al.*, 2020). This lack of singular solutions and the dependency of most suitable forms of governance and tools on the attributes of the social-ecological system involved and the operational scale and intensity of wild species use is common to all the practices.

The operational scales of extractive practices cover the full spectrum, ranging from manual gathering of a few grams of biomass to highly technological and capital-intensive harvesting methods that remove tons. While the total quantity extracted relative to the total population biomass or abundance (i.e., the harvest rate) has direct implications for the impact and sustainability of extraction, the operational scale of an extractive activity also has implications for the types of regulations and regulatory schemes that may be most effective to achieve sustainability (Kurien & Willmann, 2009; Parma *et al.*, 2006). For example, depending on the intensity of use, the population impact of a small-scale artisanal extraction is not necessarily lower than that of an industrial operation; however, the suitable means for keeping harvest rates within sustainable levels will likely be very different (see Table 6.5 in Chapter 6, section 6.4.4.5). Similarly, non-extractive uses include a wide range of operational scales which have different regulatory implications, from individual experiences of watching wild species for recreation and inspiration to the high-end tourist industry built around whale watching, diving or game watching. Especially at the large-scale end of the spectrum, non-extractive recreational uses supporting the tourist industry can have negative impacts on wild species and the ecosystems they inhabit if not properly conducted; hence the need for guidelines and regulations (e.g., Parsons & Brown, 2017; Tapper, 2006, see also Chapter 4).

When the complex social-ecological systems of wild species uses are managed to maintain and/or enhance nature's contributions to people while ensuring the productivity of the species (or population) used and the integrity and functioning of the ecosystems in which they occur are preserved to meet current and future human needs, sustainable use is one possible outcome. However, outcomes may be highly heterogeneous across the different dimensions of the social-ecological system, and specific management interventions may be focused on strengthening sustainability of the resource system (e.g., reduce harvest rate to improve population status), the users (e.g., build users capacity) or the governance system (improve institutional arrangements) (Leslie *et al.*, 2015). Furthermore, these complex interactive systems can be managed to produce wider ecosystem outcomes linked to sustainable use, beyond sustaining the wild species used and the direct benefits derived from them, such as to incentivise habitat and biodiversity conservation (Abensperg-Traun, 2009; Allen & Edwards, 1995) or to improve human well-being and achieve sustainable development goals (Mahapatra & Mitchell, 1997; Pullanikkatil & Shackleton, 2019).

1.1.2 Placing the assessment within the IPBES conceptual framework and nature's contributions to people

The IPBES conceptual framework provides a simplified model of the interactions between people and the natural world (Díaz, *et al.*, 2015a; Díaz *et al.*, 2018), which serves as a tool for assessing issues relevant to nature's contributions to people and good quality of life. Since its approval by the IPBES Plenary in 2013, the conceptual framework underpins all IPBES deliberations and provides a consistent structure and terminology to IPBES products across spatial scales, themes, and regions. The conceptual framework includes six primary interlinked elements that operate across different spatial and temporal scales:

- Nature;
- Nature's contributions to people;
- Anthropogenic assets;
- Institutions and governance systems and other indirect drivers of change;
- Direct drivers of change; and
- Good quality of life.

These elements have been conceived as broad, inclusive categories intended to be meaningful to a wide range of stakeholders while being flexible and amenable to interpretation as the conceptual framework is applied to particular topics of interest to the members and stakeholders. Sustainable use of wild species is a case in point. Previous IPBES assessments have quite reasonably treated "use" as one driver of change in natural systems, among many. In contrast, use of wild species is the central focus of this assessment. The flexibility of the IPBES conceptual framework enables its application to the assessment of the sustainable use of wild species. In the section that follows, this assessment shows how sustainable use can be mapped onto the conceptual framework **(Figure 1.2)**, highlighting some concepts that are particularly germane to this assessment.

For the core concepts in the framework, definitions here draw on those from Díaz *et al.*, 2015a. Elements of special importance to sustainable use of wild species are put forward, with the benefit of insights that emerged from a participatory process intended, among other things, to ensure that understandings of the conceptual framework elements would be meaningful and relevant to all stakeholders.

The current assessment engaged indigenous peoples and local communities following the IPBES approach to recognizing and working with indigenous and local knowledge systems and seeks to include their perspective and insights for the sustainable use of wild species (see section 1.4). Through this process, participants suggested the phrase "people's contributions to nature" would better capture the multiple ways humans engage with, maintain, and, to varying degrees, produce nature (IPBES, 2019b, 2019c). In proposing the language of people's contributions to nature, participants in indigenous and local knowledge dialogues explicitly insisted on the importance of conceptual symmetry between nature's contributions to people and an expanded understanding of what is taken into account as direct and indirect anthropogenic drivers. In particular, their worldviews and experience suggested a need to re-examine the notion of human impacts as acting upon a separate pre-existing nature (see 2.2.4). Workshop participants were concerned that a language of "drivers" alone could not easily include concepts, such as caring for, nurturing, or stewarding nature, as well as broader concepts such as responsibility and reciprocity relative to the complex interactions between the natural

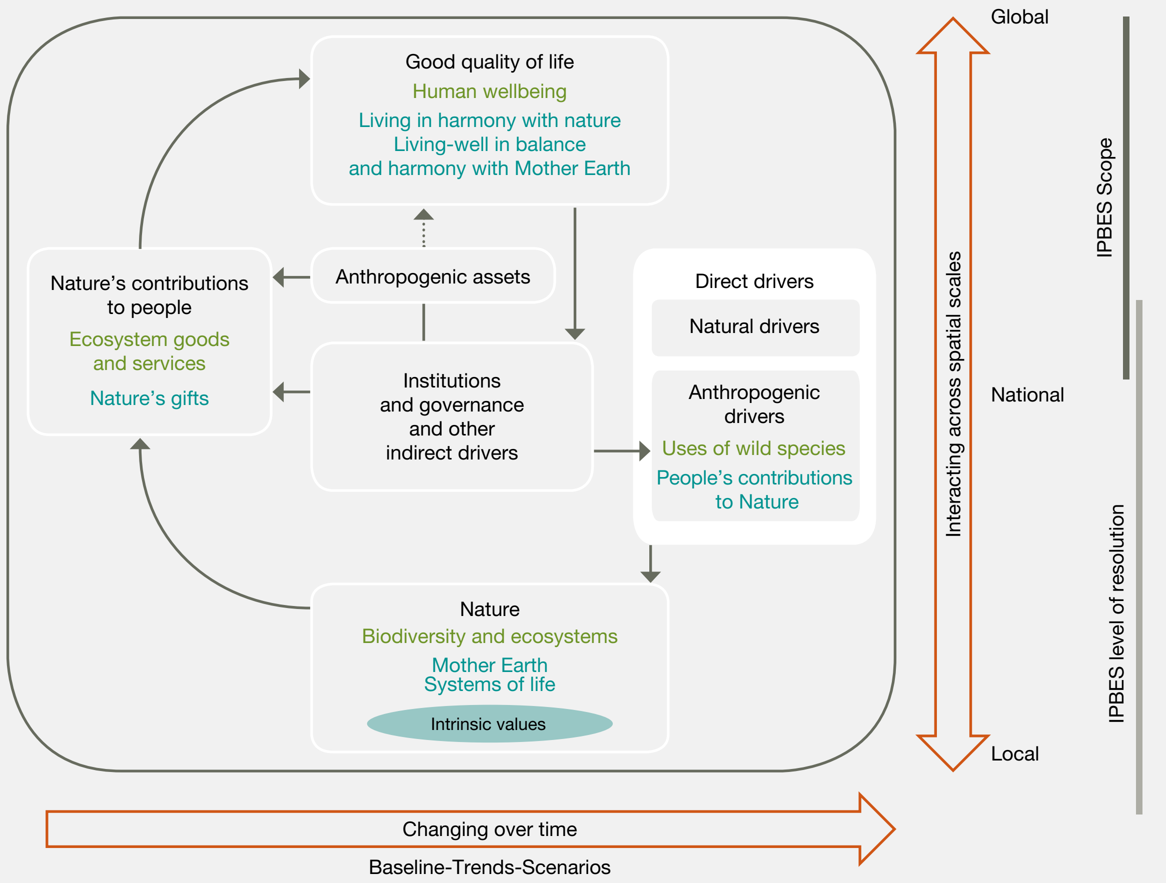

Figure 1 2 **The sustainable use of wild species in the IPBES conceptual framework.**

The boxes and arrows of the central panel, delimited in grey, denote the elements of nature and society that are at the main focus of IPBES. In each box, the headlines in black are inclusive categories for stakeholders involved in IPBES and embrace the categories of science (in green) and equivalent categories according to other knowledge systems (in blue) (IPBES, 2019a). This assessment foregrounds wild species uses as anthropogenic drivers and notes that many indigenous and local knowledge systems view such uses through a lens of people's contributions to nature. Modified from Díaz *et al.*, 2015b under license CC-BY 4.0.

world and human societies. The definitions below, as well as inclusive text added to the direct drivers box in **Figure 1.2** endeavor to honor this input while following the definitions, approved by the IPBES Plenary, for the main elements of the IPBES conceptual framework (IPBES, 2019a). The following text reproduces partially or in full these definitions and provides additional insights compatible with the IPBES commitment to understand elements of the framework in an inclusive manner in the context of the current assessment.

- **Nature** encompasses the nonhuman world, with particular emphasis on living organisms, their diversity, their interactions among themselves but also with their abiotic environment. The current assessment is particularly attentive to the abundance, distribution, and traits of wild species that are used by people as well as the entanglements of nature and society that those uses imply. The inclusivity of this element is manifest in the multiple ways nature can be understood and engaged. Within the framing of the natural sciences, for example, nature includes all dimensions of biodiversity, from the genes to the ecosystems, including species and communities and their associated ecological, evolutionary and biogeochemical processes. Within the framework of ecological economics, it includes disciplinarily specific categories such as biotic natural resources, natural capital and natural assets. In the context of other social sciences and humanities disciplines, as well as interdisciplinary environmental sciences, nature is referred to with categories such as natural heritage, living environment, or the nonhuman. Finally, within the framing of a wide range of knowledge systems grounded outside science, nature includes categories such as Mother Earth (shared by many indigenous peoples and local communities around the world), Pachamama (South American Andes), sēnluó-wànxiàng and tien-ti (East Asia), Country (Australia), fonua/vanua/whenua/ples (South Pacific Islands), Iwigara (northern Mexico), Ixofijmogen (southern Argentina and Chile), among many others (see Díaz *et al.*, 2015b for references). Across different knowledge systems, both scientific and non-scientific, the degree to which humans are considered part of nature varies considerably.

- **Nature's contributions to people** are all the contributions of nature to the quality of life of humans, as individuals, societies or humanity as a whole that emerge from the interactions of nature with anthropogenic assets, institutions, and governance. In particular, the use of wild species makes possible a wide range of direct and tangible contributions to people that include food, energy, medicine, materials, physical and psychological experiences, learning and inspiration, and identity. In some knowledge systems such contributions may be understood as, for example, "ecosystem goods and services," while in others they may better be seen as "nature's gifts." Furthermore, nature's *contributions* to people have replaced nature's *benefits* to people (found in earlier versions of the conceptual framework) to not only accommodate the multiple ways nature's contributions to people are understood and enacted, but also to better reflect the fact that contributions may have detrimental or beneficial consequences for people's quality of life.

- **Good quality of life** is the achievement of a fulfilled human life. Visions, concepts and indicators of good quality of life are highly diverse, both in cultural roots and in geographical application. Approaches applied internationally can be based solely on the economic aspects of social systems (e.g., gross domestic product per capita), be more inclusive in the social factors considered (e.g., human development index, inclusive wealth) or holistic framings (e.g., living in harmony, gross national happiness index). Other more culturally specific and place-based approaches include Sumak Kawsay/Buen vivir (Central Andes), teko porã (Paraguay), vida plena (Amazonian basin), or shizen kyosei shakai (Japan) (Díaz *et al.*, 2015b). Within the context of a wide range of good quality of life conceptualizations, wild species are vitally important as sources of food, energy, medicine and other materials; a current and potential source of livelihoods; and a key contributor to rich and meaningful cultural and spiritual lives. A society's quality of life and the vision of what constitutes a good quality of life strongly influence all other elements in the conceptual framework. For the purposes of this assessment, people's quality of life is regarded not just as an outcome of nature's contributions to people, but also as influencing direct anthropogenic drivers that impact and shape nature.

- **Direct drivers** refer to natural and anthropogenic factors that act directly on nature. Natural drivers are abiotic forces that have generally been regarded as beyond human control, such as disturbances caused by earthquakes or extreme climate events, although the concept of the anthropocene calls attention to the increasing degree to which human actions may influence these systems (see, for example, Steffen *et al.*, 2011, 2018). In contrast, direct anthropogenic drivers comprise factors that are under human control. This assessment focuses on the practices related to the use of wild species (i.e., fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices) as direct drivers (see Chapter 3). In scientific knowledge systems, direct anthropogenic drivers often are conceived as external factors that change or transform a pre-existing nature. In other knowledge systems, including much indigenous and local knowledge, humans are considered part of nature. Indeed, nature itself is co-produced through interactions between humans and nonhumans, with both playing an active role. Ideally, but far from always, this process of co-production is characterized by mutual caring and responsibility. However, just as nature's contributions to people may be beneficial or adverse, people's contributions to nature can include positive and negative outcomes. For example, the age and sex classes targeted by some hunters may disrupt breeding success or increase population productivity. This perspective explicitly contains conceptual room for a range of actual and potential human "contributions" to nature and can facilitate identification of and support for existing sustainable uses of wild species.

- **Institutions and governance systems and other indirect drivers** include human actions and decisions that indirectly affect nature by altering and influencing human practices relating to the use of wild species. Along with good quality of life, they influence and mediate direct anthropogenic drivers that affect nature both positively and negatively. Indirect drivers include economic, demographic, institutional, technological and cultural processes (see Chapters 2, 4 and 5). Special attention is given, among indirect drivers, to the role of institutions and governance systems, including formal and customary systems of access to land and property rights as well as those emerging from indigenous and local knowledge systems (see Chapter 6). Indirect drivers include, for example, socially shared rules, legislative arrangements, international regimes such as agreements for the protection of endangered species, and economic policies. It is important to note that this assessment does not deal separately with direct and indirect drivers, which are dealt with collectively in Chapter 4. The reason for this approach is that sustainable use is an outcome of a system that includes nature, and the drivers acting on it, as well as the institutions and governance systems that act as drivers of uses and practices (as depicted in **Figure 1.1**). Sustainable use is therefore affected by multiple interacting drivers comprising both direct and indirect drivers.

- **Anthropogenic assets** refer to knowledge (including indigenous and local knowledge and technical or scientific knowledge), technology (both physical objects and procedures), labor, financial assets, and built infrastructure. These are closely tied to institutions, governance and other indirect drivers as indicated by the line linking them in the conceptual framework figure **(Figure 1.2)**, which suggests that accumulated assets and systems of decision-making work together to influence and shape interactions between nature and human society. While such interactions clearly emerge as nature's contributions to people, they also are integral to those practices and uses that directly produce nature. Thus, anthropogenic assets may contribute as much to people's contribution to nature as they do to nature's contributions to people.

1.2 ASSESSING SUSTAINABLE USE OF WILD SPECIES: A ROADMAP TO THE CHAPTERS

The sustainable use assessment is a critical evaluation of the state of knowledge carried out under the principles of relevance, legitimacy and credibility. The sustainable use assessment has not undertaken new primary research, but analyzed, synthesized and critically evaluated available information and data previously published or otherwise made available in the public domain in a traceable way.

1.2.1 Overarching questions

The sustainable use assessment is structured according to ten overarching questions defined in the scoping report (annex IV to decision IPBES-5/1). They provide a framework for evaluating and integrating evidence from local to global levels, spanning past and future:

1. How can the sustainable use of wild species be appropriately conceptualized and operationalized? (Chapter 1 and Chapter 2)

2. What methods and tools exist for assessing, measuring and managing the sustainable use of wild species? (Chapter 2)

3. What are the positive and negative impacts of various uses of wild species and other direct drivers on nature and nature's contributions to people? (Chapter 3)

4. Who are likely to be the main beneficiaries of the sustainable use of wild species? (Chapter 3)

5. What are the drivers that affect the sustainability of the use of wild species, including systemic obstacles and perverse incentives preventing sustainable use? (Chapter 4)

6. What are the different scenarios related to the sustainable use of wild species? (Chapter 5)

7. What policy options and governance pathways relating to various scenarios of the use of wild species, including socioeconomic and ecological considerations, can lead to the achievement of sustainability of the use of wild species in the ecosystems they inhabit? (Chapter 5)

8. What policy responses and methods and tools for assessing, measuring and managing sustainable use of wild species have proved to be appropriate and effective, in which contexts and over what time

frames? To what extent can they be replicated in other contexts? (Chapter 6)

9. What gaps in data and knowledge regarding status, drivers, impacts, policy responses and policy support tools and methods need to be addressed in order to better understand and implement the variety of options and opportunities for enhancing conservation through the sustainable use of wild species? (All chapters)

10. What opportunities does the sustainable use of wild species offer with regard to alternative land uses (for example, replacing less sustainable land use activities)? (All chapters)

1.2.2 Outline of chapters

The assessment is organized into six chapters, comprising this introduction followed by five chapters that form the core of the assessment. The broad areas covered by the chapters are summarized below.

Chapter 1 provides the conceptual framework, organizing structure, terminology and definitions that apply to all chapters. It emphasizes the relationship to the IPBES conceptual framework and shows how this assessment both builds on and differs from other recent assessments of biodiversity and nature's contributions to people.

Chapter 2 focuses on the question of conceptualizing and operationalizing sustainable use. It provides a history and lays out the main features of diverse conceptualizations of sustainable use. It also identifies considerations that influence the ability to achieve sustainability, as well as methods and tools needed to assess and measure sustainable use of wild species.

Chapter 3 assesses the status and trends in the use of wild species and effects on their conservation. It examines what levels of use could be sustainable and when management is required in order for species to recover in relation to international instruments (Sustainable Development Goals, Convention on Biological Diversity, Convention on International Trade in Endangered Species of Wild Fauna and Flora, etc.). The implications of use with regard to nature's contributions to people and good quality of life are also investigated in this chapter.

Chapter 4 provides an assessment of the drivers affecting sustainable use. It identifies the main drivers (environmental, political, social, economic, cultural, scientific and technological) that positively or negatively impact the sustainable use of wild species, including the effects of international agreements and commitments (e.g., Convention on Biological Diversity, Convention on International Trade in Endangered Species of Wild Fauna and Flora).

Chapter 5 assesses scenarios and how future trajectories may be affected by different policies and approaches. It examines plausible futures for the use of wild species, using a range of scenarios. This chapter also addresses pathways to transformative change in sustainable use of wild species to achieve targets under the Sustainable Development Goals and the Convention on Biological Diversity.

Chapter 6 assesses the effectiveness of policy responses with regard to the sustainable use of wild species, including regulatory, economic, social and rights-based instruments, and best practices. It explores the enabling conditions for effective policy options, summarizes the lessons learned and suggests solutions for ensuring success of sustainable use of wild species.

1.3 SCOPE AND ORGANIZING STRUCTURE FOR ASSESSING THE SUSTAINABLE USE OF WILD SPECIES

The scoping document for the assessment of the sustainable use of wild species, as accepted by the IPBES Plenary, provides the broad framework for the work presented here. The main components outlined in the scoping report (annex IV to decision IPBES-5/1) have been interpreted and defined in the following ways for the purposes of this assessment.

- **Wild species** refers to populations of any species that have not been domesticated through multigenerational selection for particular traits, and which can survive independently of human intervention that may occur in any environment. This does not imply a complete absence of human management and recognizes various intermediate states between wild and domesticated (see section 1.3.2). For the sustainable use assessment, the scope mostly excludes feral and introduced populations although these may satisfy the general definition of wild and they may be included in some aspects of the assessment. The rationale for this definition and the scope of the assessment is provided in section 1.3.2.

- **Sustainable use** is an outcome of social-ecological systems that aim to maintain biodiversity and ecosystem functions in the long-term, while contributing to human well-being. It is a dynamic process as wild species, the ecosystems that support them, and the social systems within which uses occur, change over time and space.

- **Use of wild species** is interpreted in a narrow sense as applying only to the direct use of species through the practices of fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices. These practices are explained in greater detail in section 1.3.4. The rationale for this narrow focus is: (i) that it is consistent with the policy issues raised in the scoping report; (ii) past global, regional and thematic IPBES assessments have already assessed other ecosystem services and nature's contributions to people; and (iii) the concepts, principles and evidence relating to the direct use of wild species represent a significant issue that needs to be assessed in its own right.

This means that the interpretation of this assessment is aligned with the concept of nature's material contributions. The scope does not include the contribution of wild species to nature's regulating contributions (e.g., pollination, carbon sequestration) nor to contributions to people through indirect uses such as grazing for livestock. In the case of non-extractive practices, it is often difficult to separate practices that are directly related to wild species (e.g., wildlife watching) from those that relate more generally to nature or wild spaces (e.g., sacred groves). The intention of the assessment of the sustainable use of wild species is to focus primarily on those practices that involve interactions with wild species. There are also emerging initiatives that explore financing mechanisms for conservation based on the existence values of iconic species. These are largely regarded as beyond the scope of the assessment but this assessment acknowledges that initiatives based on existence values may interact with other practices involving direct use. This is noted in later chapters although there is currently very little evidence available to assess their impact on other uses of wild species.

- **Extractive and non-extractive practices.** The scoping report outlined the need to consider consumptive and non-consumptive uses. The preferred terminology used in the sustainable use assessment is extractive and non-extractive practices. Extractive practices result in the temporary or permanent extraction of individuals or harvest of biomass, which may or may not result in the death of the individual organism (e.g., hunting of big horn sheep *versus* shearing and releasing of vicuña). Non-extractive practices do not involve extraction or removal of biomass (e.g., wildlife watching).

This section further refines the focus of the assessment and provides a consistent structure and terminology that is used throughout the assessment. The structure is intended to:

- Clarify what is included in the assessment;
- Achieve consistency and coherence among categories, terms and definitions throughout the assessment;
- Ensure adequate coverage across uses, species, biomes, and geopolitical regions;
- Maintain focus on sustainable uses, and;
- Present the document in a way that enables distillation of policy relevant findings and messages from the detailed analyses.

1.3.1 Defining sustainable use

The conceptualization of sustainable use of wild species in international policy can be traced at least back to the Declaration of the United Nations Conference on the Human Environment in 1972. Principles 2, 3 and 4 arising from this conference are particularly relevant:

Principle 2: The natural resources of the earth, including the air, water, land, flora and fauna and especially representative samples of natural ecosystems, must be safeguarded for the benefit of present and future generations through careful planning or management, as appropriate.

Principle 3: The capacity of the earth to produce vital renewable resources must be maintained and, wherever practicable, restored or improved.

Principle 4: Man has a special responsibility to safeguard and wisely manage the heritage of wildlife and its habitat, which are now gravely imperilled by a combination of adverse factors. Nature conservation, including wildlife, must therefore receive importance in planning for economic development.

Likewise, the World Charter for Nature adopted by the United Nations in 1982 reaffirms that "man must acquire the knowledge necessary to maintain and enhance his ability to use natural resources in a manner which ensures the preservation of the species and ecosystems for the benefit of present and future generations."

Sustainable use is a concept that is now widely applied in various sectors, including natural living resources (e.g., wild animals or wild plants), natural non-living resources (e.g., water, air and soil), and human products (e.g., agricultural products, pesticides, other goods) (Cooney, 2007). Using the term "sustainable use" in such different contexts leads to different meanings. The sustainable use assessment's definition is restricted to the context of wild species (or wild living resources).

For the Convention on Biological Diversity since 1992, sustainable use is mostly defined according to the target resource (see **Figure 1.3**): "the use of the components of biodiversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations". As such, sustainable use is defined using primarily ecological criteria, but within a framework of human needs. Some other international organizations have adopted the CBD definition, but included further considerations in policy positions, e.g., the International Union for Conservation of Nature states that it is 'committed to ensure that any use of wild species is equitable and ecologically sustainable' (IUCN Resolution 2.29, 2000). Other formulations, e.g., the White Oak principles, include a clearly articulated social dimension as well: "a dynamic process toward which one strives in order to maintain biodiversity and enhance ecological and socio-economic services, recognizing that the greater the equity and degree of participation in governance, the greater the likelihood of achieving these objectives for present and future generations". The sustainable use assessment's definition of sustainable use considers both the ecological and social dimensions and should be understood as applying to multiple aspects of human-ecological interactions around use (see below and **Figure 1.3**).

Indigenous and local knowledge offer additional perspectives on sustainable use. Many indigenous peoples regard humans and wild species as relatives, existing in relationships like those of the members of a family, in which each has an essential role to play (IPBES, 2019a, 2019b; Muir *et al.*, 2020). In this worldview, the social and ecological dimensions of the use of wild species are inseparable (Nadasdy, 2007; Polfus *et al.*, 2016; Robinson & Raven, 2019). To be sustainable, the use of wild species should ensure the well-being of both humans and other species (Sangha *et al.*, 2015). Seen through this lens, to choose between human well-being and that of wild species is both unethical and untenable.

In defining sustainable use, the following aspects, which are discussed thoroughly in Chapter 2, are critical to this assessment:

- Sustainable use is an outcome of social-ecological systems, in which nature's contributions to people derived from extractive or non-extractive uses of wild species are managed to meet current human needs while maintaining or co-creating natural systems that promote the continued survival of the species being used and the ongoing provision of nature's contributions to people. It is not, and cannot be, a static endpoint because the target species, the ecosystems that support them, and the social systems within which uses occur are dynamic and change over time and space. Consequently, the sustainability of use is an ongoing adaptive process, which may be depicted as follows: (i) assess status and trends in wild species under use, (ii) identify drivers of (un) sustainability, (iii) adapt uses and management (which may include, if necessary, stopping use for a period of time), (iv) re-assess after a given time interval and re-adapt use and management if needed.

- Sustainable use has a narrower and more specific meaning than sustainable development or sustainable management and these should not be used as synonyms. Sustainable development has a clear economic basis and can be seen as a quest to reconcile economic growth with social and ecological challenges and problems (often conceptualized through the three-pillars, social-economic-environmental, diagram, see Purvis *et al.* (2019)). Sustainable management also encompasses a broader array of actions related to the reduction of environmental, and social (including economic) impacts associated with any activity, not only use (Cooney, 2007).

- Sustainable use emerges from social-ecological systems that meet human needs without compromising ecosystem health. Sustainable use is thus not limited to anthropocentric considerations (i.e., the sustainability of the use for the benefit of people) or to ecological/environmental considerations (i.e., the conservation of the target resource from an ecosystem perspective). Rather, it encompasses both social and ecological considerations as well as the multiple aspects of their interactions.

- Human views on sustainable use are diverse, resulting from local, indigenous and scientific knowledge that should each be appreciated as relevant experiments in sustainable use from which people can learn.

- For practical purposes, especially for an assessment of this nature, the definition of sustainable use or what is assessed as being sustainable, needs to be precise enough that assessors can determine whether or not use is sustainable.

- Sustainability should therefore be clearly defined through a set of specific targets or indicators in the social and ecological domains. Ideally, this set of indicators should be developed jointly by all the actors of the social-ecological system.

- Animal welfare and animal protection are important considerations receiving increasing social, ethical and legal consideration worldwide (see the Global

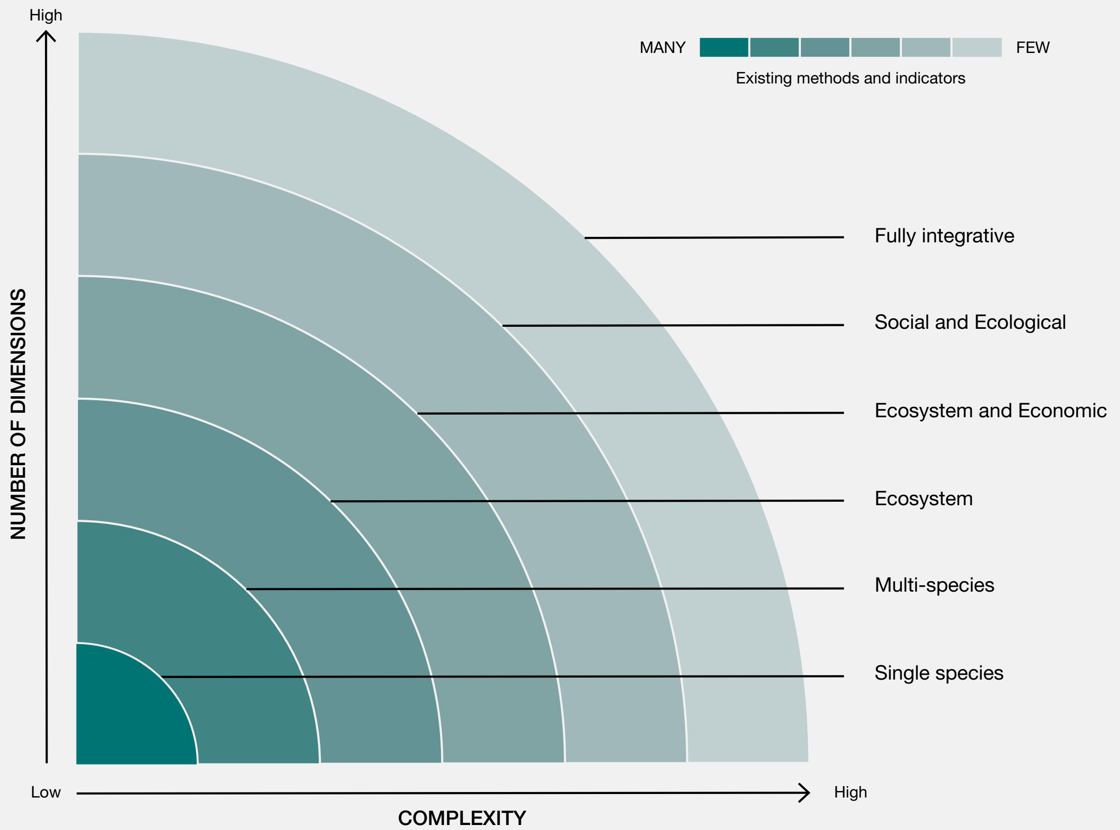

Figure 1 3 **Different conceptions of the sustainable use of wild species, illustrating the increasing degree of complexity associated with them as well as the availability of methods and indicators to evaluate sustainable use.**

Most international organizations consider only the "single species" dimension when evaluating sustainable use and managing human uses of wild species, others have introduced the "multi-species" dimension, while some seek to use an ecosystem approach (for example, taking into account the impacts on the functioning of ecosystems and habitats). Economic and social dimensions are more rarely taken into account by international organizations. The indigenous and local knowledge approach is often more integrative and considers the socio-economic and ecological dimensions as inseparable. The availability of indicators and methods by dimensions is approximated by the color level and is inversely proportional to the complexity or the number of dimensions, illustrating the more comprehensive development of indicators at the species level and the general lack of indicators for higher level ecological dimensions or social dimensions.

Sustainable Development Report 2019 by the Independent Group of Scientists appointed by the Secretary-General). Animal welfare is increasingly incorporated into the concepts of sustainable use of wild species, but it was not identified in the scoping report for the IPBES assessment of the sustainable use of wild species (annex IV to decision IPBES-5/1). Therefore, animal welfare was not addressed in this assessment.

1.3.2 Unpacking the definition of wild species

The scoping report for the sustainable use assessment (annex IV to decision IPBES-5/1) identified the need for a general definition of wild species that could be applied in different assessments and across conventions. Despite the widespread reference to specimens from the the wild, or wild species, in both the academic literature and policy documents (see Chapter 2), there is no universally accepted definition and the majority of papers do not refer to a clear definition for wild species.

The definition of wild species adopted for the sustainable use assessment (1.3) clarifies two aspects that are relevant to this assessment. First, the definition focuses attention on wild populations and not on the species as an entirety. This is because populations of the same species can span a continuum from those that do not experience any human intervention to being fully domesticated. The naming of domesticated taxa in relation to their wild progenitors, linked to debates about whether domesticated forms should be recognized as distinct species, has been extensively discussed in terms of both the International Code of Zoological Nomenclature (Gentry *et al.*, 2004) and the International Code of Nomenclature for Algae, Fungi and Plants (Spooner *et al.*, 2003). As noted by Gentry *et al.* (2004) for animals, some domesticated forms have scientific names which are distinct from those applied to their wild ancestors, but the majority of wild progenitor species and their domestic derivatives are considered to be the same species and this is also true for plants, algae and fungi. Some examples include *Coffea arabica* for wild and domesticated coffee (Wiersum *et al.*, 2008), *Salmo salar* for wild and cultured Atlantic Salmon (Teletchea & Fontaine, 2014), *Agaricus bisporus* (button mushrooms) and *Struthio camelus* for wild and domesticated forms of ostrich (Spinu *et al.*, 1999). For precision, the assessment should refer consistently to wild populations of particular species but this is often not practical and any reference to wild species should be read as an abbreviation for wild populations of a species.

The second clarification relates to the term 'wild' which, although commonly used, is open to different interpretations and needs to be more precisely defined in this assessment. A common starting point is to distinguish wild forms from domesticated ones. For example, the International Union for Conservation of Nature Red List defines wildlife as living things that are neither human nor domesticated (IUCN, 2021a). The Convention on Biological Diversity does not define wild but, instead, defines domesticated to mean species in which the evolutionary process has been influenced to meet human needs. By implication, wild populations are those that do not fit the definition of domesticated.

It is *well established* in both scientific and indigenous and local knowledge systems that a binary separation between 'wild' and 'domesticated' populations does not exist. Scientific analyses of use systems for plants (Muir *et al.*, 2020), terrestrial animals (Child *et al.*, 2019) and aquatic organisms (Bell *et al.*, 2006; Hilborn & Hilborn, 2019) recognize intermediate stages between wild and domesticated. At one extreme, wild populations are identified as those that retain the capacity to evolve autonomously under conditions where genetic diversity enables natural selection to produce adaptation (Redford *et al.*, 2011; Mallon and Stanley Price, 2013). Along the continuum towards domestication, populations may be managed by people, to a greater or lesser extent, to increase accessibility and productivity or to promote the forms with traits most sought after by the people concerned. In this transition, the population may increasingly depend on human intervention to survive one or more life history stage, till finally at the other extreme the population is selectively bred over multiple generations to serve human needs (Vigne, 2011). Typically, the path to domestication is characterized by intensification of the relationship between forms derived from wild progenitors and human societies (Vigne, 2011), is accompanied by changes in phenotype and has been defined as a distinctive coevolutionary, mutualistic relationship between domesticator and domesticate (Zeder, 2015).

A commonly accepted definition for wild animals, accepted by the Collaborative Partnership on Sustainable Wildlife Management (IUFRO, 2018), applies to animals that have a phenotype unaffected by human selection and can live independently of direct human supervision or control. There may be a continuum from truly wild, where animal populations are self-sustaining and exist without human intervention, through various levels of confinement and intervention (such as feeding), to domestication. Similarly, wild products from plants have been described as those derived from untended wild resources (Muir *et al.*, 2020). Domestication is not just a state of being, but a process that results in genetic adaptation to the extent that animals will breed readily in captivity, their owner has some control over reproduction, and it results in detectable differences between the domestic populations and their wild progenitors.

The scientific literature and indigenous and local knowledge literature are also quite clear that there is no single dimensional point that can be used to distinguish wild from not wild (Child *et al.*, 2019; Cruz-Garcia, 2017; Redford *et al.*, 2011). Biologists have proposed various ways to categorise wild populations which may vary depending on the purpose of the categorization. These include a five-node system for evaluating self-sustaining sub-populations (Redford *et al.*, 2011) focusing on reintroducing captive animals into the wild; a timebound system, also focusing on reintroductions, where populations that can survive longer than ten years in the absence of human intervention would be wild (Hayward *et al.*, 2015; IUCN Standards and Petitions Committee, 2019); a composite score based on the existence of certain management interventions (Child *et al.*, 2019); and a five-stages process from wild to domesticated for fish (Teletchea & Fontaine, 2014). Indigenous peoples and local communities have developed their own classification systems based on different criteria to define wildness. For example, some communities in the Amazon categorize 'wild' plants into six different groups based on how they are used and managed (Cruz-Garcia, 2017) and indigenous peoples and local communities in Peru distinguish between domesticated and two types of wild animals on the basis of their interactions with humans and domesticated animals.

The relationship between wild, introduced, feral, domesticated and captive can be mapped using three axes linked to human interventions (**Figure 1.4)**. These are (i) the extent of human intervention in reproduction and survival; (ii) multigenerational selection for traits by people to suit human needs; and (iii) the extent to which populations are dispersed through human intervention. In interpreting the scope of this assessment, the emphasis is on those populations that are situated on the lower end of these three axes, i.e., those that still occur in their natural range, have not undergone multigenerational selection for traits and can survive without human intervention. Nevertheless, some of the intermediate conditions along the continuum from wild to domesticated can be important for any assessment of sustainable use and are included in the assessment when appropriate (see **Box 1.1**). The terminology for the intermediate states between wild and domesticated varies between taxa (e.g., animals and plants), practices (e.g., fishing or gathering) and purpose (e.g., conservation versus use) (Bell *et al.*, 2006; Child *et al.*, 2019; Lorenzen *et al.*, 2000; Muir *et al.*, 2020). For the purposes of this assessment, the typology of wild, wild managed, farmed and domesticated provides a sufficient framework for analysis (see **Table 1.1**).

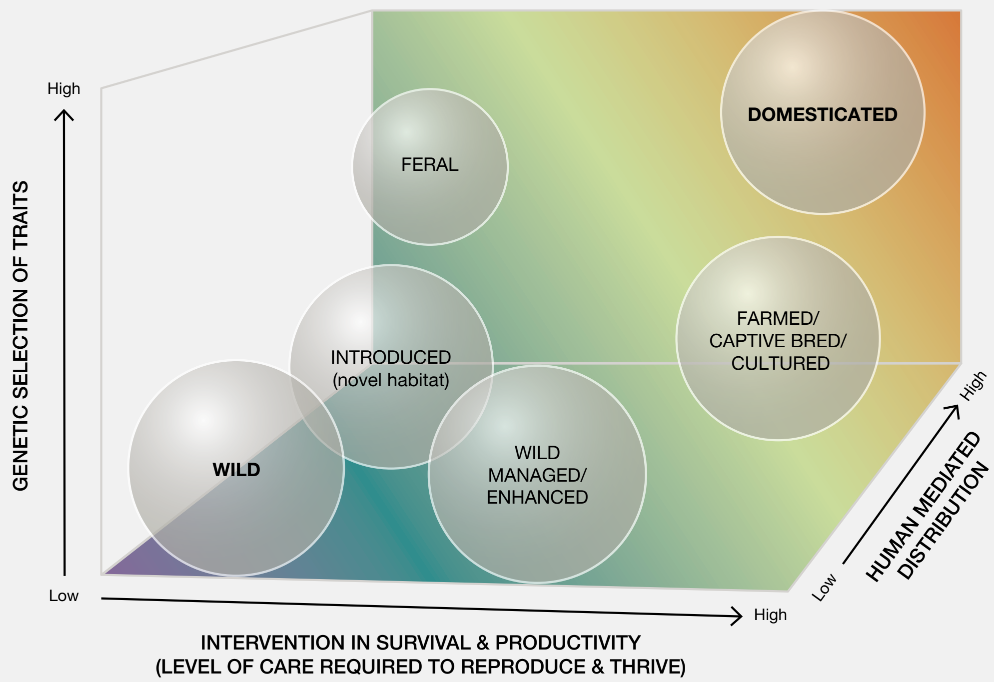

Figure 1 4 **A diagramatic presentation of the multiple dimensions that may be used to define the continuum between 'wild' and and domesticated.**

The bubbles represent various examples of states that can exist between the extremes of wild populations occurring freely within their original habitat and those that are fully domesticated. This is not a complete list of possible states.

Table 1 1 **Categorisation of intermediate states between wild and domesticated, comprising wild, wild-managed, farmed and domesticated populations and showing how these intermediate states correspond to similar typologies used in other contexts.**

Wild	Wild managed	Farmed	Domesticated	Application & references
Wild capture fisheries	Enhanced capture fisheries (limited technological interventions in the life cycle of aquatic resources)	Aquaculture	Domesticated	Fishing (Bell *et al.*, 2006; Lorenzen *et al.*, 2000)
Wild (untended wild plant populations)	Semi-wild algae, fungi and plants (biological resources that are subject to some form of human intervention to increase productivity)	Cultivated, Artificially propagated, farmed	Domesticated	Mostly for algae, fungi and plants (Muir *et al.*, 2020)
Wild	Wild managed (animal populations where some level of supplementary feeding, watering or veterinary care is provided to increase productivity)	Captive bred, ranched (animal populations where space, supplementary feeding, watering, breeding and veterinary care are managed to increase productivity)	Domesticated	Terrestrial animal populations (Child *et al.*, 2019)

Scope of the sustainable use assessment in relation to wild species

The scope of the sustainable use assessment is guided by the requirements of the scoping report (annex IV to decision IPBES-5/1). A primary concern for the public and policy makers is that unsustainable use of wild populations is leading to their decline and collapse (1.1). To address this aspect of the assessment, the focus should be consistent with populations that are included in the indicators used to measure decline and collapse. The International Union for Conservation of Nature Red List of Threatened Species and other similar metrics use criteria to evaluate the ability of species to survive as self-sustaining entities, mostly within their original distribution range (e.g., Traill *et al.*, 2007). This would include their capacity to evolve autonomously under conditions where genetic diversity enables natural selection to produce adaptation (Redford *et al.*, 2011; Mallon and Stanley Price, 2013). Hence the emphasis on populations that meet these criteria.

A second factor for policymakers is the link between the use of wild species and the achievement of the Sustainable Development Goals adopted by the United Nations (see also section 1.6). In this context, the use of wild species may present different opportunities and risks for development when compared to the use of completely domesticated species. As a result, the definition applied in this assessment should differentiate between species that have been selected for traits that suit human needs, and where production is under human control, versus wild species that are self-sustaining and express traits that have evolved in response to environmental pressures. Some indigenous peoples and local communities' terminology refers to wild species as 'gifts' and this reflects the essence of what is meant perhaps more effectively than scientific definitions.

The sustainable use assessment does not focus specifically on feral populations, or populations that have been introduced by humans to outside their native range **(Figure 1.4)**. These species may be included in aspects of the assessment, for example where invasive species offer alternative resources for use, but they are not the primary focus of this assessment. Many non-domesticated species have been introduced to outside their original distribution range through human-mediated dispersal. Their release into novel habitats can result in significant changes to these habitats and such biological invasions have been identified as one of the main drivers of decline in biodiversity in certain ecosystems (IPBES, 2019a). Depending on societal values, scientific interpretation and the perceived utility of alien and invasive species, they have been considered as a natural part of emerging novel ecosystems (wild) (e.g., Hoffmann & Courchamp, 2016), they may be considered as part of the wild population under special circumstances (e.g., IUCN Standards and Petitions Committee, 2019) or they can be regarded as an unintended negative consequence of human activities and therefore need to be managed and controlled (IPBES 2019). There are numerous instances of the use of introduced species, including by indigenous peoples and local communities (Bhattacharyya & Larson, 2014; Tebboth *et al.*, 2020) but this is not a primary focus of this assessment since the main policy concern relates to the status of species within their original distribution range.

Similarly, populations that were introduced as domesticates, but then escaped and established in the wild as feral populations also fulfil some of the criteria relating to wild populations **(Figure 1.4)**. These, too, are frequently used by people either to replace or complement use of other species, but they are not a main focus for this assessment.

In adopting this approach, the sustainable use assessment acknowledges the rich body of work dealing with the biological, social and philosophical complexities of defining the meaning of wild (Haraway, 2003; Latour, 1993, 2004; Maris, 2018; Palmer, 2011). The IPBES conceptual framework (Díaz *et al.*, 2015a) emphasizes the unity of nature and humanity, which recognizes the ongoing interaction between environmental and social processes. This is consistent with a conceptualization of wild which is not in opposition to that belonging to the human or cultural sphere. The concept of wild has received much scrutiny in the humanities and social sciences during the past decades, notably in relation to the issues of wilderness and the social construction of nature (Comberti *et al.*, 2015; Nelson & Callicott, 2008; Neumann, 1998). Although 'wild' and 'wilderness' should not be confused, they are related in the way that nature is conceptualized. Early criticisms of the separation of people and nature in the conceptual and regulatory framework of areas designated as wilderness came from indigenous peoples and local communities and the issue has been problematized and debated since at least the 1960s. One of the key issues in this debate is the consequences of the western notion of wilderness as a pristine, idealized and distant nature devoid of human activity that, by extension, discounts the value of the environment in which people live and fails to provide an environmental ethic that will tell as much about using nature as not using it (Cronon, 1996; Fletcher *et al.*, 2021; Glacken, 1976; Leopold, 1949).

The concept of the Anthropocene has further problematized the idea of nature as a pure and timeless place characterized by the absence of humans (Lorimer, 2015). There is growing recognition that in the current era, few environments are unaffected by human activity (Cookson, 2011), and even conservation efforts might transform the characteristics, composition and distribution of biodiversity (Stokland, 2020). However, co-production of nature by humans and non-humans did not commence with the Anthropocene. Humans have played active roles in shaping life on land for millennia (Ellis *et al.*, 2021). Scholars of biocultural diversity have noted strong correlations between cultural diversity and biological diversity globally (Gorenflo *et al.*, 2012; IPBES, 2018e; Maffi, 2005; Pretty *et al.*, 2009; Sterling *et al.*, 2017). Their work indicates that many ecosystems that are regarded as natural or wild and evincing little human influence are, in fact, the result of long-term interactions between indigenous peoples and local communities and their biophysical environments (Levis *et al.*, 2017). Likewise, the species composition in these areas reflects varying intensities of management by indigenous peoples and local communities. For example, Peacock and Turner (2000) and Anderson (2013) note that indigenous peoples of northwestern North America managed the land on which they lived at scales from the individual plant (e.g., through practices such as pruning and weeding) to the landscape (see also, Deur & Turner, 2005; N. J. Turner, 2014). The area managed by indigenous peoples coincides with approximately 40% of terrestrial conserved areas, including those with high biodiversity (Garnett *et al.*, 2018). In many cases, loss of indigenous and local knowledge and practices results in reduced species population size and distribution (see, for example, the case of camas bulbs *Camassia* spp., (N. J. Turner & Turner, 2008). This perspective suggests that the defining characteristics of 'wild' cannot be represented as a simple dichotomy between management and no management by humans and that excluding all human management from the concept of wild species is problematic (Lepofsky & Caldwell, 2013; Mathews & Turner, 2017; McGregor *et al.*, 2003; Mueller-Dombois, 2007; Mueller-Dombois & Wirawan, 2005; N. Turner *et al.*, 2013; Posey, 1985; Zeder, 2015). Rather, wild is located on a continuum somewhere between instances in which humans have no current or remembered historical contact with a location and the species in it and intensive interventions with landscapes and the species in them (Ford, 1985).

Indigenous peoples and local communities' world views and concepts of nature offer an additional perspective on definitions of wild in relationship to animals, fungi and plants. Indigenous peoples and local communities' definitions of wild species arise from worldviews that emphasize material and spiritual relationships between humans and other beings (IPBES, 2019c). While the defining characteristics of wild vary between cultures (where the concept exists), commonalities and differences between them offer insights into how indigenous peoples and local communities' definitions of wild species are intertwined with notions of sustainable use (see section 1.4.1). Some cultures do not identify a sharp boundary between wild and domesticated species. However, many indigenous peoples and local communities recognize distinct types of animals and plants based on the level of care they need from humans to reproduce and thrive. This distinction may be further expressed in terms of the realm or power with which a species is associated or the degree of freedom it can exercise. For example, the Mixtec peoples of Mexico conceptualize wild as something that grows by itself, without need for external help. In Russia and other eastern European countries, wild species often are described as gifts of the forest while Native Hawaiian, many Andean, and other cultures regard wild species as belonging to or associated with gods. Thus, relationships between humans and these species also entail relationships with these other

Box 1 1 **Case study on challenges with operationalizing the concept of wild species.**

In South Africa, a dramatic surge in the conversion of land use from livestock to wild species ranches resulted in an increase of wild species numbers from 0.5 million head of game in the 1960s to 16-20 million in 2014 (Carruthers, 2008; Taylor *et al.*, 2015). As a result, Southern Africa is the only region on the African continent where mammal populations, on aggregate, are not in decline (Craigie *et al.*, 2010), and private landowners have played a major role in reversing the trend. This rewilding has been viewed as a successful model for sustainable use of wild species (Cromsigt *et al.*, 2018), but the process has also highlighted the need to avoid a shifting baseline for what is meant by "wildness" (Child *et al.*, 2016).

Management interventions on wild species ranches may include artificially increasing the abundance of a population through supplementary resources, veterinary care or controlling which individuals breed with each other to enhance an economically valuable trait. This negates natural selection and may hinder adaptation to changing environments. Thus, population abundance does not necessarily equate to an ecologically functioning population if those animals are disconnected from the surrounding landscape and cut off from evolutionary trajectories. Metrics based on numbers alone may mask a gradual shifting baseline in what it means to successfully conserve wild species (Redford *et al.*, 2011).

Child *et al.* (2019) produced a framework to quantify the wildness of a managed population by mapping management thresholds between wildness 'nodes', using attributes such as available space, food and water provision, breeding freedom, and disease resistance, which have been demonstrated to influence the ecological and evolutionary attributes of a species. They found that population abundance did not correlate with wildness but that the area available to a population was a strong predictor of wildness whereas the frequency of supplementary feeding, density of artificial water-points and the degree of veterinary care provided were predictors of shifts away from wildness.

One of the key policy challenges is how to unlock economic opportunities associated with wild species without creating perverse incentives that may affect the wildness of managed populations (Turpie & Letley, 2018; Wanger *et al.*, 2017).

entities, with all the significance and consequences that this may imply (IPBES, 2019c, 2019b). These concepts are examined in greater detail in section 2.2.4.

Philosophers have identified three constituents of wildness (or wild), namely locational, dispositional and constitutional (Palmer, 2011). These constituents provide a qualitative framework for assessing wildness. Locational wildness refers to existence in an area free of human management; dispositional wildness relates to the state and behaviour of the organism; whereas constitutional wildness refers to an organism that has not been domesticated.

1.3.3 Impacts of nature conceptualizations on the uses of wild species

The traditional "western" view of human-nature relationship tends to separate nature (what exists by itself) from culture (what has been produced by humans). This human-nature dualism is deeply rooted in people's perception of the functioning of the biosphere as well as in their common language. It is pervasive and may be found in most national and international agreements and policies related to the conservation of biodiversity or the regulation of use of wild species. IPBES is not an exception in this regard. The IPBES conceptual framework presented above (see section 1.2) indeed defines nature as the entity that "encompasses the nonhuman world, with particular emphasis on living organisms, their diversity, their interactions among themselves but also with their abiotic environment". This influence can be subtle, such as in the definition of natural environment given by the Convention for Biological Diversity: "the natural environment comprises all living and non-living things that occur naturally on Earth. In its purest sense, it is thus an environment that is not the result of human activity or intervention" (CBD, 2008).

Traces of this human-nature dualism can already be found in Antiquity, notably among the Greek philosophers of the 7th and 6th centuries BC (Bouchard, 2020) and in the Bible as well, especially Genesis (chapter 1, 27-30):

> (27) "God created mankind in his own image; in the image of God he created them; male and female he created them."
>
> (28) "God blessed them and said to them, "Be fruitful and increase in number; fill the Earth and subdue it. Rule over the fish in the sea and the birds in the sky and over every living creature that moves on the ground."
>
> (29) "I give you every seed-bearing plant on the face of the whole Earth and every tree that has fruit with seed in it. They will be yours for food."
>
> (30) "And to all the beasts of the Earth and all the birds in the sky and all the creatures that move along the ground, everything that has the breath of life in it, I give every green plant for food." And it was so.

In Europe and the Mediterranean area, this human-nature dualism continued to develop during the Middle Ages with Christianity, according to which all creation proceeds from God, including humans who are the center of this creation and have the divine mission to control it (see Genesis citations above). God has thus bestowed strong power on humans and it is God's intention that humanity multiplies itself, spreads out over the Earth, exerting dominion over all of creation (Glacken, 1976). If humanity is clearly distinct from and positioned over the other living organisms in a hierarchy of creation, various passages from the old and new testaments also attest to the love and pleasure of humans for nature as a manifestation of God's work (Glacken, 1976).

This dichotomy between humankind and nature has permeated western thought over two millennia and is evidenced in the arts, philosophy and science. In 1637, Descartes in the *Discours de la Méthode* went a step further in this conceptualization of human-nature relationship through his famous quote: "to know the laws which govern nature to become masters and owners of nature". For Descartes, this expressed a dream of liberating humanity from the grip of magical explanations of nature through technique. Descartes wanted to demystify nature and understand its laws, so that humans can have control over their environment and no longer simply endure it. In this conceptualization, nature is, however, seen as an object that humans can or must take advantage of. Descartes' philosophy was later seen as the manifesto of human excess, of an anthropocentric conceptualization based on the sciences and techniques, which will be disputed by several philosophers of the 20th century, among which Plumwood (2002).

This mechanistic view of nature, in which the role of humans is to discover the underlying laws of nature, has pervaded the development of modern science since the 17th century and greatly contributed to its extraordinary success in e.g., astronomy, biology, chemistry, medicine or physics. Following a series of epistemological debates in Germany and North America at the end of the 19th century, this human-nature dualism finally led to the distinction of two broad scientific categories: the natural sciences and the cultural sciences, or simply the humanities, which still strongly structures the scientific fields of today (Bouchard, 2020).

Darwin's ground-breaking publication on the origins of species (1859) was the first scientific study (with Wallace's study published in 1855) challenging the divine creation of humans and so, the foundation of this separation between humankind and nature. This publication is considered to be the founding text of the scientific theory of evolution, according to which all current living species, including humans, have evolved from extinct ancestral species, by means of natural selection. The theory of evolution has been refined considerably since Darwin. It has in particular been enhanced by the contributions of genetics and it is today the unifying paradigm in life sciences (see e.g., Richerson *et al.*, 2021; Scheiner & Mindell, 2020 for a recent review on the scientific theory of evolution).

The theory of evolution challenged the Judeo-Christian view of the human-nature relationship in western culture, as, from an evolutionary perspective, humankind belongs to the long chain of living organisms on Earth and is thus part of it. This new paradigm has also fed other scientific fields, such as ecology, which defines the ecosystem as the largest functional unit that includes both living organisms and the abiotic environment, with each influencing the properties of the other, and the two being necessary to maintain life as it exists on Earth (Odum, 1953). There is a general consensus within the scientific community that humans are a part of ecosystems, as reflected in the World Charter for Nature adopted by the United Nations (1982), which declares that "mankind is part of nature and life depends on the uninterrupted functioning of natural systems which ensure the supply of energy and nutrients" and that "civilization is rooted in nature, which has shaped human culture and influenced all artistic and scientific achievement".

As demonstrated in this assessment and other works (e.g., through the "One Health" approach, see IPBES, 2020b), humans are indeed intimately connected to their environment and to the other living micro- and macro-organisms on which they rely for their food, their health, their shelter and the energy necessary for their activities. Humans are also strongly impacted by various processes linked to the functioning of ecosystems, and more generally of the whole planet, such as droughts, floods, storms, fires, desertification and zoonotic diseases. While most of these phenomena are intrinsic to the functioning of ecosystems, they have become more intense as a result of the degradation of the integrity and functioning of most terrestrial and aquatic ecosystems due to human activities (Crutzen & Stoermer, 2000; IPBES, 2019a).

This conceptualization which assumes that humanity is part of nature, however still remains marginal in western culture, even while it echoes the much older concept of "Mother Nature" or "Mother Earth" for which nature and humankind are indivisible, such as in many indigenous cultures (see section 1.4) and Taoism (Ma *et al.*, 2021). It also echoes American philosophers from the 19th and early 20th centuries, such as Emerson, Thoreau and, especially, Leopold. In his famous book *A Sand County Almanac* (1949), Leopold presents the basis of an ecological ethics, which can be summed up as an ethics of the earth which should not prohibit the use of its resources, but affirms the right of the living organisms of the earth to continue to exist in a natural state. The human thus passes from the role of conqueror of nature, inherited from Judeo-Christian theology, to that of member and citizen of the earth community. This conception leads to respect for other members and the community as a whole and reduces anthropocentrism, without sanctifying a static nature, which is, in fact, constantly evolving. The human-nature relationship therefore implies a continuous coordination of the interests of the different members of the earth community.

In contrast, human-nature dualism has fostered the illusion that humanity could exist apart from the rest of nature, to such an extent that humans' use of nature *ad libitum* ultimately led to major environmental crises (Ma *et al.*, 2021; Plumwood, 2002). An observation that is shared by the scientific community, which has pointed out the direct responsibility of human activity in climate change (IPCC, 2019b, 2019a), biodiversity decline (IPBES, 2019a) and the modification of the main planetary natural processes, ushering in a new geological era known as the Anthropocene (Zalasiewicz *et al.*, 2018).

Human-nature dualism also engendered the notion of wilderness (or pristine nature). This notion is mostly a western cultural construction, notably arising from Europeans and North Americans during the 18th and 19th centuries. "Wilderness" idealizes nature as a sublime, primitive and virginal natural space where the human has no place, except as a contemplative traveller (see section 1.3.2, Cronon, 1996). Such cultural construction of wilderness is problematic in general and particularly for the purpose of this assessment because (i) it ignores past and current scientific evidence according to which nearly three quarters of terrestrial nature (including landscapes and biodiversity) have been shaped over several millennia by diverse histories of human habitation and use by indigenous peoples and local communities (Ellis *et al.*, 2021), (ii) it tends to sanctify the notion of pristine landscapes in conservation practices and policies, which in turn denies the agency, access rights and knowledge of indigenous peoples and local communities in the maintenance of their territories and traditional uses of wild species (Fletcher *et al.*, 2021), and (iii) it does not allow the possibility for humanity to find an ethical and sustainable place in nature (Cronon, 1996).

Considering humans as part of nature (as in the earth community of Leopold) reframes the relationship of humans with other living organisms and the abiotic environment and could make this relationship more respectful and more sustainable, as demonstrated by indigenous peoples and local communities' traditional practices and uses (Barthel *et al.*, 2013). Indigenous peoples and local communities indeed offer a diversity of alternative worldviews, human-nature relationships, cosmologies and philosophies, which, in general, include a lack of division between nature and culture and respectful relations of kinship and reciprocity between humans and non-humans (Brondízio *et al.*, 2021). Such considerations have large implications for this assessment, as sustainable use of wild species would imply a transformative change in people's conceptualization of nature, shifting from still deeply rooted western human-nature dualism to a more systemic view, in which humanity is a member and one among many citizens of nature.

1.3.4 Organizing structure

As set out in Section 1.1.2, the core factors to consider in the IPBES assessment of the sustainable use of wild species are the components of nature that are affected (wild species), the practices associated with the use of wild species, and their end uses, i.e., nature's contributions to people. These take place within particular cultures, economies, governance systems, and technological developments. To ensure consistency across the assessment, and to facilitate the distillation of key findings, a common organizing structure has been used throughout and is summarized in **Figure 1.5**. Categories within each system for the use of wild species are presented in diagram form below with narrative explanations in the subsequent paragraphs. They are not presented as a hierarchy but rather as interacting elements of the social-ecological systems of the use of wild species.

It is worth noting that many categories are not mutually exclusive, a point essential to understanding wild species, their uses, and benefits to people. For example, many species occur in multiple ecosystems over the course of their lifecycle. Wild anadromous fish, such as salmonids are a case in point, as their lifecycle includes time spent in both freshwater and marine environments. Similarly, a single species may support multiple uses. For example, wild rice (*Zizania palustris* L.) is both a food and a ceremonial resource (see **Box 1.2**), while the white gum tree or gum Arabic *(Acacia senegal)* is widely used as a food additive and in the pharmaceutical industry for medical puposes (Catarino *et al.*, 2019). Also, a single species may be the focus of more than one practice, sometimes in the same location. In several African countries, large terrestrial animals are subject to non-extractive practices (wildlife watching) and trophy hunting (terrestrial animal harvesting).

The wild species panel

Species Groups. The sustainable use assessment used the following higher level categories of four species groups: (i) aquatic animals, (ii) plants (excluding trees), fungi and algae, (iii) trees and (iv) terrestrial animals because there are differences in the status of use and practices of these groups as well as in the policy options for managing their uses **(Figure 1.6)**.

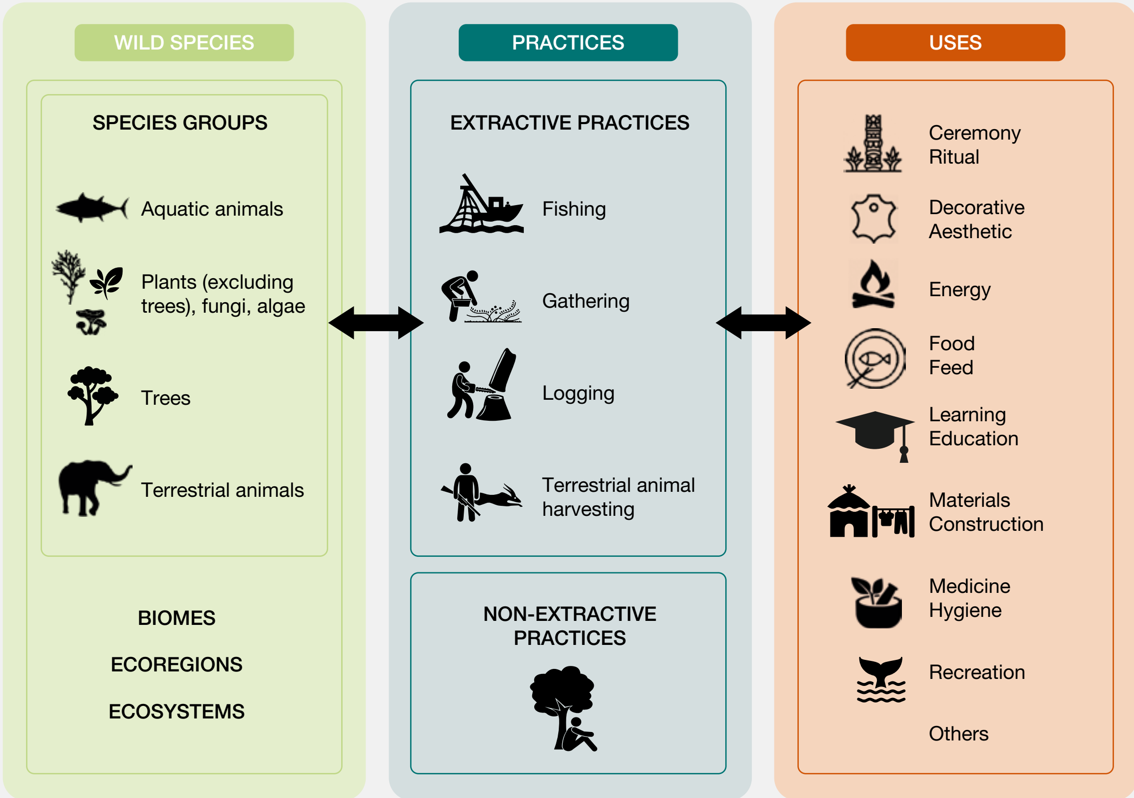

Figure 1 5 **Common organizing structure of the sustainable use assessment.**

Biomes, ecoregions and ecosystems. Each population of a given group of species lives in a given ecosystem or ecoregion of a given biome. To avoid a level of detail that will obscure identification of key points for policy makers, some information may be analysed according to ecological biomes (terrestrial, marine and freshwater). These have been defined at a fairly high level using the typology adopted by the IPBES Global Assessment of Biodiversity and Ecosystem Services, which is more aggregated than most biological typologies. Elements that are relevant to this assessment are:

- Freshwater biomes are classified as: (i) wetlands and (ii) inland waters.
- Marine biomes are classified as: (i) coastal systems, (ii) shelf systems and (iii) open and deep seas.
- Terrestrial biomes are classified as: (i) grasslands-steppes-savannas, (ii) forests (iii) deserts and (iv) mountains. Where appropriate, 'anthropogenic biomes' are also included, namely urban areas and cultivated areas.

The practices panel

For the purposes of this assessment, use of wild species involves both the practices associated with harvest or other direct interactions with wild species, as well as the end purpose for which the species is used (e.g., for food or medicine). Although the sustainable use of wild species has been discussed in academic and policy documents for more than 40 years, there is no single or accepted set of definitions for the practices associated with the use of wild species. Here the practices are defined to show how they have been applied in the assessment.

The scoping report directs the assessment to consider consumptive and non-consumptive activities, or practices (Annex IV to decision IPBES-5/1, 2018). These terms have been in use for a long time, referring mostly to the use of wild animals (FAO, 1995). However, they can be confusing due to various possible interpretations of consumption, particularly when one is looking for a term that can be used for both plants and animals. Following the FAO, this assessment uses the alternative terms of extractive (consumptive) versus non-extractive (non-consumptive) practices. Extractive practices involve temporary or permanent removal of organisms, part of them or materials derived from them from their habitat, and may result in mortality of the individual to be used (e.g., hunting or whole plant harvest), but does not necessarily do so (e.g., limited collection of plant propagules or wild honey, or shearing and releasing of vicuña). Non-extractive use does not directly entail removal of materials from wild populations (e.g., wildlife photography) but may result in inadvertent mortality as a result of, for example, disease transmission at artificial feeders.

For clarity, the sustainable use assessment then mapped different types and modalities of practices against the main taxonomic groups **(Figure 1.6)**. It started first by categorising the nature of different practices based on whether they were extractive or not, then on additional characteristics of the practices, such as whether it involved the entire organism or only a part or product of the organism. This mapping exercise showed that certain terms in common use were typically associated with a set of practices mostly aimed at one higher taxonomic group, e.g., fishing incorporates several practices relating to the extractive use of aquatic animals. In order to align with common understandings, the sustainable use assessment employed the terms fishing, gathering, and logging to cover the practices set out in **Figure 1.6**. The one deviation from this approach was for hunting. Whereas fishing is understood as almost any practice relating to the harvest of aquatic animals, and can even be applied to harvest of animals in captivity, hunting generally applies only to activities that result in the death of the target animals and is not commonly applied when there is no direct, intentional mortality, again, as in the example of vicuña shearing and release. As a result, terrestrial animal harvesting has been adopted as the generic term for the extractive practice focused on terrestrial animals (see below for a full definition).

Extractive practices. Extractive practices are broken down into the five following categories.

	PRACTICE	ALGAE, FUNGI AND PLANTS	TREES	TERRESTRIAL ANIMALS	AQUATIC ANIMALS
EXTRACTIVE PRACTICES	Harvest entire organism with mortality	GATHERING *(e.g., whole plant harvest)*	LOGGING *(e.g., sawn wood)*	HUNTING *(e.g., subsistence hunting)*	FISHING *(e.g., commercial fisheries)*
	Harvest part of organism with mortality	GATHERING *(e.g., excessive root harvest)*	LOGGING *(e.g., excessive branch removal)*	HUNTING *(e.g., amphibian's secretions)*	FISHING *(e.g., shark finning, fish roe)*
	Harvest entire organism with without intended mortality	GATHERING *(e.g., landscaping materials)*	LOGGING *(e.g., landscaping materials)*	"NON-LETHAL" TERRESTRIAL ANIMAL HARVESTING *(e.g., pet trade, green hunting)*	"NON-LETHAL" FISHING *(e.g., aquarium fish, catch and release)*
	Harvest parts or products of organism without mortality	GATHERING *(e.g., leaves, nectar, resin, latex, berries)*	LOGGING *(e.g., coppicing)* GATHERING *(e.g., leaves, fruits, bark)*	"NON-LETHAL" TERRESTRIAL ANIMAL HARVESTING *(e.g., wild honey, vicuña fiber, bird eggs)*	"NON-LETHAL" FISHING *(e.g., horseshoe crab's blood)*
NON-EXTRACTIVE PRACTICES	Direct interaction with organism	OBSERVING *(e.g., touching, smelling plants)*	OBSERVING *(e.g., touching trees)*	OBSERVING *(e.g., bird feeding)*	OBSERVING *(e.g., shark feeding)*
	No direct interaction with organism	OBSERVING *(e.g., photography, wild species watching)*	OBSERVING *(e.g., photography, wild species watching)*	OBSERVING *(e.g., photography, wild species watching)*	OBSERVING *(e.g., diving and scuba without contact)*

Figure 1 6 **Wild species *versus* different types of practices.**

Note: The definitions of practices are not intended to reflect on their impact. That is the role of the assessments that follow in Chapters 2-6. As a result, the definitions of non-lethal fishing and terrestrial animal harvesting should not be read as implying that these practices necessarily have less impact than lethal practices.

- **Fishing.** Fishing is defined as the removal from their habitats of aquatic animals (vertebrates and invertebrates) that spend their full life cycle in water (e.g., fish, some marine mammals, shellfish, shrimps, squids, corals). Fishing most often results in the death of the aquatic animal, but it may not in some cases. To reflect both situations, fishing has been sub-divided into a lethal and "non-lethal" category. Lethal fishing is defined as the general and more usual meaning of fishing that leads to the killing of the animal, such as in traditional commercial fisheries **(Figure 1.6)**. "Non-lethal" fishing is defined as the temporary or permanent capture of live animals from their habitat without intended mortality, such as in the aquarium fish trade or catch and release **(Figure 1.6)**. However, unintended mortality may occur in "non-lethal" fishing and the term "non-lethal" is therefore put in quotes. The killing of species that spend part of their life cycle in terrestrial environments (e.g., walrus, sea turtles) is encompassed by the definition of hunting.

- **Gathering.** Gathering is defined as the removal of terrestrial and aquatic algae, fungi, and plants (other than trees) or parts thereof from their habitats **(Figure 1.6)**. Gathering may, but often does not, result in the death of the organism. Gathering includes whole plant harvest and removal of above and below ground plant parts, as well as the fruiting bodies of macrofungi. It also includes removal of non-woody portions of trees (e.g., leaves, propagules, and bark). Where removal of propagules or death of an individual plant occurs (e.g., whole plant and root removal) effects on population sustainability are contingent upon factors including timing, frequency, and intensity of harvest **(Figure 1.6)**. The harvest of wood and woody parts of trees is encompassed by the definition of logging.

- **Logging.** Logging is defined as the removal of whole trees or woody parts of trees from their habitat **(Figure 1.6)**. Logging generally results in the death of the tree, but also includes cases in which it may not, such as coppicing. Logging occurs in forests that may be classified as primary, naturally regenerating, planted, and plantation (see below "other definitions"). This assessment does not address logging from plantation forests (except as it has bearing on the practice in the other forest types). Harvest of non-woody parts of trees (e.g., leaves, propagules and bark) are here defined as gathering.

- **Terrestrial animal harvesting.** Terrestrial animal harvesting is defined as the removal from their habitat of animals (vertebrates and invertebrates) that spend some or all of their life cycle in terrestrial environments. As with fishing, terrestrial animal harvesting often results in the death of the animal, but it may not in some cases. To reflect both situations, terrestrial animal harvesting has been sub-divided into a lethal and "non-lethal" category. Hunting is defined as terrestrial animal harvesting that leads to the killing of the animal, such as in trophy hunting or subsistence hunting **(Figure 1.6)**. "Non-lethal" terrestrial animal harvesting is defined as the temporary or permanent capture of live animals from their habitat without intended mortality, such as for the pet trade, falconry, or green hunting **(Figure 1.6)**. Non-lethal harvest of animals also includes removal of parts or products of animals that do not lead to the mortality of the host, such as vicuña fibre or wild honey. Unintended mortality may however occur in this category and the term "non-lethal" is therefore put in quotes.

- **Non-extractive practices.** Non-extractive practices are defined as practices based on the observation of wild species in a way that does not involve the harvest or removal of any part of the organism **(Figure 1.6)**. Observation can include some interaction with the wild species, such as the activities of wildlife and whale watching or no interaction with the wild species, such as remote photography.

Each of these practices and uses take place at multiple spatial and temporal scales, from the very large (hundreds to thousands of hectares) to the very small (single organisms) and from the long-term (over centuries) to the very short-term (days or weeks). They may involve technologies ranging from heavy machinery to manual tools or no tools. Likewise, they take place in economic contexts from supplying global commodity markets to satisfying household subsistence needs (see below).

The uses panel

For the purposes of this assessment, the uses of wild species have been divided into eight categories, which are not mutually exclusive:

- **Ceremony and ritual expression** are defined as the uses of wild species in collective or individual spiritual observances, including those that may be valued for their role in maintaining cultural identity.

- **Decorative and aesthetic** are defined as the uses of wild species in order to produce handicrafts and objects of adornment, beauty, and/or entertainment.

- **Energy** is defined as the use of wild species to provide energy for heat, cooking, water sterilization, etc.
- **Food and feed** are defined as the uses of wild species to provide food for humans and domestic animals.
- **Learning and education** are defined as uses of wild species in which the production of knowledge is a primary value.
- **Materials and construction** are defined as the uses of wild species to create shelter for humans or animals and to produce objects such as cordage.
- **Medicine and hygiene** are defined as the uses of wild species to heal illnesses or promote health and well-being of humans and domestic animals.
- **Recreation** is defined as the uses of wild species in which enjoyment is considered a primary value.
- **Other** is defined as the uses of wild species that are not encompassed by the categories above, such as companionship (i.e., pets).

Other definitions related to scale in fishing and logging

While the main components outlined in the scoping document have been defined in the previous sub-sections, it is also important to define key components of some practices (e.g., small-scale fisheries) as they are used in this assessment.

Small-scale versus industrial fisheries. Following the definition from the FAO (2001), the assessment considers that a fishery is a unit determined by an authority or other entity that is engaged in raising and/or harvesting fish. This unit is defined in terms of the people involved, species or type of fish, area of water or seabed, method of fishing, class of boats and purpose of the activities (see Glossary). International bodies often refer to specific fisheries categories, especially to small-scale fisheries. However, this category remains an unresolved (often fuzzy) category, which still generates a large debate within the scientific community, as well as within international bodies.

In its report of the Second Session of the Working Party on Small-scale Fisheries (2004), the Advisory Committee on Fisheries Research of the FAO concluded that there

Table 1 2 **Matrix table used for the characterization of fisheries based on multiple attributes along gradients between small-scale (lower scores) to large-scale (higher scores).**

(from Basurto *et al.*, 2017) m= meters, km = kilometers, GT = Gigaton, hp = horse power

Score	0	1	2	3
Size of fishing vessel (or equivalent range for fixed gears)	No vessel	< 12 m, < 10 GT	< 24 m, <50 GT	> 24 m, > 50 GT
Motorization	No engine	Outboard engine	Inboard engine < 400hp	Inboard > 400hp
Mechanization	No mechanization	Small power winch/ hauler powered off engine	Independently powered gear deployment/ hauling	Fully mechanized gear deployment and hauling
Refrigeration/ storage on board	No storage	Ice box	Ice hold	Refrigerated hold
Labor/crew	Individual and/ or family members	Cooperative group	< 2 paid crew	> 2 paid crew
Fishing unit/ ownership	Owner/ operator	Leased arrangement	Owner	Corporate business
Time commitment	Part-time/ occasional	Full-time, but seasonal	Part-time all year	Full-time
Day trip/ multiday	< 6 hours	Day trip	< 4 days	> 4 days
Fishing grounds/ zone/ distance from shore	< 100 m from shoreline	< 3 km from shoreline	< 20 km	> 20 km from shoreline
Disposal of catch	Houselhold consumption/ barter	Local direct sale	Sale to traders	Onboard processing and/ or delivery to processors
Utilization of cacth, value added/ preservation	For direct human consumption	Chilled	Frozen	Frozen/ chilled for factory processing (for human consumption or fishmeal)
Integration into economy and/ or management system	Informal, not integrated (no fees)	Integrated (registered, untaxed)	Formal, integrated (licensed, landing fees)	Formal, integrated (licensed, taxed)

was no globally agreed definition of small-scale fisheries and its Small Scale Fisheries Guidelines did not prescribe a standard definition of small-scale fisheries, but underlined the need to ascertain which activities and operators are considered small-scale.

The report of the FAO on "Improving our knowledge on small-scale fisheries: data needs and methodologies" (Basurto *et al.*, 2017) proposed a matrix approach for the characterization of diverse small-scale fisheries. This matrix (see **Table 1.2**) allows a value to be assigned to each characteristic which can then be aggregated into an overall score, allowing for clearer disaggregation between large-scale fisheries and small-scale fisheries, which is based on the following characteristics:

The World Ocean Assessment (see Ferreira *et al.*, 2016) gives the following definition: "Capture fisheries and aquaculture operate at many geographical scales, and vary in how they use marine resources for food production. Here, "small-scale" refers to operations that are generally low capital investment but high labour activities, relatively low production, and often family or community-based with a part of the catch being consumed by the producers (Béné *et al.*, 2007; Garcia *et al.*, 2008). Large-scale operations require significantly more capital equipment and expenditure, are more highly mechanized and their businesses are more vertically integrated, with generally global market access rather than focused on local consumption. These descriptions are at the ends of a spectrum continuum of scales with enormous variation in between."

The IPBES Global Assessment provides a definition for small scale fisheries only, based on the portal of the FAO (2018a), as follows: "Small-scale or non-industrial fisheries: Traditional fishing performed by family units rather than commercial units, using a relatively small amount of capital and energy, and carrying out short fishing trips close to coasts and mainly for local consumption".

According to the above reports and the fact that the IPBES assessment of the sustainable use of wild species needs common guidelines on the different types of fisheries to ensure consistency across chapters, it is acknowledged that capture fisheries operate at many geographical scales and vary in how they use marine resources for food production. The main fisheries categories are further distinguished as:

- **Small-scale fisheries** generally present (some of) the following characterics: (i) low capital investment, (ii) high labour activities often family or community-based, (iii) no vessel or small size vessel (< 12m and < 10 GT), (iv) relatively low production, which is household consumed or locally and directly sold and (v) operating close to the shoreline on a single day basis.
- **Industrial fisheries** generally present (some of) the following characteristics: (i) high capital equipment and expenditure, (ii) high level of mechanization, motorization and onboard processing, (iii) large vessel size (> 24 m and > 50 GT), (iv) based on a more vertically integrated business, with generally global market access, (v) operating offshore on a multi-day basis.

Organization and scale of logging. The organization of logging can be understood through the intersection of forest types, forest management objectives and forest ownership, including governance structures and institutions. Logging occurs in forests that may be characterized along a continuum of intensities of human intervention anchored at the one end by primary forests and at the other by plantation forests. Following the terms and definitions laid out in the Global Forest Resource Assessment 2020 by the FAO, the sustainable use assessment understands primary forests to be "naturally regenerated forest of native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed" (FAO, 2020a), while plantation forests consist of areas in which the trees are deliberately planted (whether native or introduced species) often with the intent to produce wood, fiber or energy on a short rotation interval and do not resemble naturally regenerating forests at maturity (FAO, 2020a). Although boundaries between them can be fuzzy, intermediate levels of human manipulation of forests include naturally regenerating forests (i.e., composed in their majority, but not necessarily exclusively, of native and/or introduced tree species) and planted forests, which are dominated by trees that have been deliberately planted as saplings and/or seeds (FAO, 2020a). Broadly speaking, levels of labor and/or capital investment required to establish these forest types correspond with the intensity of human intervention. That is, such investments are lowest for primary forests and greatest for plantation forests.

Logging occurs in forests that are managed for one primary objective or for multiple uses, with the volume of biomass removal ranging from coppice forestry, in which living trees remain on the landscape (Fabbio, 2016; Unrau *et al.*, 2018), to even-aged management systems (i.e., clear cutting), with all trees removed from an area (Savilaakso *et al.*, 2021). Timber is most obviously harvested to obtain wood and fiber for use as energy and construction materials (FAO & UNEP, 2020), but also is used in the production of decorative, aesthetic and ceremonial or ritual objects (Diamond & Emery, 2011; Frey *et al.*, 2019; Johnson *et al.*, 2021). Some logging also may occur on forest lands for which the primary management objective is protection of soil and water, conservation of biodiversity or provision of social benefits such as education and recreation (FAO, 2020a).

Forest ownership is the right to "use, control, transfer, or otherwise benefit from…the trees growing on land classified as forest" (FAO, 2020a) and may be separate from ownership of the land on which those trees are growing. Forest ownership types include: (i) local, tribal and indigenous communities, (ii) private and (iii) public entities (FAO, 2020a). Group ownership and management for group benefit are a shared characteristics of local, tribal and indigenous community forests. However, there is great variation in the governance structures and institutions through which they are established and managed. Private forest ownerships include individuals, businesses, and institutions with profit or non-profit aims. Approximately 22% of global forest area is in private forest ownership (FAO, 2020a), which may range in size from a few hectares to 2,000 or more hectares. An estimated 73% of global forest area is owned by public entities (e.g., the State, administrative arms of the State and parastatal entities) (FAO, 2020a) but logging on these lands may be carried out by local, tribal and indigenous communities or private entities through forest concessions (see, for example, FAO & EFI, 2018).

As with fishing, there is no easy crosswalk between forest type, management objective and ownership in which logging occurs. This assessment examines them as distinct and interacting aspects that influence the sustainability of this practice.

1.3.5 Use of indicators

Indicators that measure various elements of sustainable use are widely employed by a range of organizations and agencies from the local to the international level. As such, indicators illustrate and account for particular criteria of sustainable use that may be relevant to individual sectors (e.g., forestry or fisheries), habitats (e.g., particular marine or boreal ecosystems), or socio-environmental contexts (e.g., indigenous peoples and local communities' uses of wild species). Indicators may be quantitative, semi quantitative or qualitative. They are fundamental to monitoring the status of a wild species use at a particular place and time and they may be relevant to and allow comparison across a range of temporal and spatial scales. As such, indicators are key components to the operationalization of sustainable use concepts as well as of broader principles of sustainable use, inclusive of concerns for equity and social justice (see section 1.3.2). Finally, insofar as the enactment of sustainable use is closely related to the implementation and institutionalization of indicators, indicators also have the potential to powerfully format environmental as well as equity and justice outcomes.

Chapter 2 traces the development of the sustainable use concept relative to wild species and how it came to be flexible and context-specific in its application. It also reviews the operationalization of sustainable use in various wild species cases and the role of methods and metrics in implementation. In these cases, assessment and measurement rely on the use of indicators that align with case- and context-specific criteria which, themselves, are meant to reflect broader sustainable use concepts and principles. While the chain of translation from sustainable use principle to case-specific indicator will vary from one practice and context to the next, the use of often standardized and replicable indicators opens the door to meaningful comparisons over time within and across contexts (e.g., change in wild species population or habitat area), and it has the potential to foreground key drivers of change relevant across cases (e.g., demand or substitutable products). Finally, because indicators work well to capture change over time in sustainable use elements, they effectively support this assessment's contention that sustainable use be understood more as a process and direction than a particular stage or state.

The detailed review of the relationship between indicators, criteria, and key elements of sustainable use undertaken in Chapter 2 points to how indicators are useful not only to gauge the status or trajectory of sustainable use but also to make clear what elements of sustainable use are most valued (or not) in any particular context or sector assessment. Conversely, indicator choice has the potential to shape sustainable use concepts themselves as they become institutionalized through investments in particular survey protocols, standardized data streams, and hegemonic analytical methods. In addition to influencing sustainable use concepts, indicators have the potential to affect policy development. For example, the review in Chapter 2 makes clear that more weight is given to environmental factors than socio-economic factors in the development of indicator methodologies, thereby creating the conditions for policy development that does not (and cannot) effectively incorporate socio-economic concerns relative to the sustainable use of wild species.

1.3.6 Confidence framework

A qualitative method of communicating the level of uncertainty and confidence in a key finding or statement using accessible and agreed upon terms and language has been essential to communicate assessment findings to decision-makers. The evaluation of confidence of assessment findings in the sustainable use assessment is based on the experience of previous IPBES assessments, which in turn benefited from other international and intergovernmental assessment processes, such as the Millennium Ecosystem Assessment and those of the Intergovernmental Panel on Climate Change (IPCC).

The sustainable use assessment followed the schematics and criteria presented in **Figure 1.7** to guide authors in the process of assessing and communicating the degree of uncertainty, or confidence, related to key findings. This four-box confidence framework developed for IPBES assessments and their key findings are based on level of agreement of experts using their judgment (y-axis) in combination with the quantity and quality of evidence assessed (x-axis). The evidence includes publications, data, theory, models and information. Further details of the approach are documented in Section 2.2.6 of the IPBES guide on the production of assessments. The core version of the guide is available at: https://ipbes.net/sites/default/files/180719_ipbes_assessment_guide_report_hi-res.pdf.

The synthetic terms used to describe the evidence are:

- ***Well established:*** comprehensive meta-analysis or other synthesis or multiple independent studies that agree;
- ***Established but incomplete:*** general agreement although only a limited number of studies exist; no comprehensive synthesis and/or the studies that exist address the question imprecisely;
- ***Unresolved:*** multiple independent studies exist but conclusions do not agree;
- ***Inconclusive:*** limited evidence, recognizing major knowledge gaps.

Following other IPBES assessments, the sustainable use assessment does not use a likelihood scale or probabilistic certainty scale.

The synthesis of this large volume of evidence is challenging and complex and relies strongly on authors' expertise and joint deliberations, including authors from multiple disciplinary backgrounds and knowledgeable of issues related to other knowledge systems, particularly indigenous peoples and local communities. These confidence terms inform and communicate to decision-makers what the assessment author teams have high confidence in as well as what requires further investigation to allow decision makers to make informed decisions.

One of this assessment's findings is that sustainable use is highly complex to measure (see discussion in Section 1.3.1 above) and that it can only be defined with clarity *ex post*, as suggested in Cooney (2007). The findings of Chapters 3 to 6 highlight which patterns could lead to sustainable use of wild species in all the known cases that were documented and assessed as part of this work, and under which conditions sustainable use as an outcome could vary. Any *well established* or *established but incomplete* finding would need to be thought through when it leads to action on the ground. This assessment provides tools to do such measures, and model possible outcomes in terms of environmental and social benefits and provides a wide range of criteria to take into account, depending on the biome, species or type of practice or of use to be evaluated at the local or national level. Any conclusion of the sustainability of a specific use (see Chapter 3) would need to be regularly reassessed in light of the changing conditions affecting each driver (see Chapters 4 and 5), including how well policy and management are responsive to those changes (see Chapter 6).

Figure 1 7 **The four-box model for the qualitative communication of confidence.**

Confidence increases towards the top-right corner as suggested by the increasing strength of grey shading.

1.4 INCORPORATING MULTIPLE KNOWLEDGE SYSTEMS: A SYSTEMATIC AND MULTI-FACETED APPROACH

Incorporating multiple knowledge systems provides a more complete picture of the characteristics of sustainable uses of wild species than would be achieved through any single source. In particular, this assessment takes a systematic and multifaceted approach to integrate knowledge grounded in science and indigenous and local knowledge systems. Science is produced and interpreted through the preferred lenses and methods of diverse biophysical and social science disciplines. Among the strengths of a multidisciplinary approach such as that employed here is that it provides policy-relevant information at scales from the genetic to the landscape, the individual and household to the national and multilateral. Science, however, is not exhaustive: many of the thousands of wild species in use have yet to be the subject of detailed scientific inquiry. The same is true for the multifarious contexts of those uses (see Chapter 3).

The term "western science" is in wide use in scholarly work on diverse knowledge systems (Díaz *et al.*, 2015a), especially those that focus on indigenous and local knowledge. In this context, this assessment understands "western science" as defined in Díaz *et al.* (2015a, p.14); "as a broad term to refer to knowledge typically generated in universities, research institutions and private firms following paradigms and methods typically associated with the 'scientific method' consolidated in Post-Renaissance Europe on the basis of wider and more ancient roots. It is typically transmitted through scientific journals and scholarly books. Some of its central tenets are observer independence, replicable findings, systematic skepticism, and transparent research methodologies with standard units and categories." While recognizing and embracing the importance of understanding the context within which all knowledge is produced, the assessment of the sustainable use of wild species refers to scientific knowledge without qualifying it.

The use of wild species is central to the livelihoods and identities of many indigenous peoples and local communities. Many indigenous peoples and local communities have extensive knowledge of the wild species they use, as well as the ecosystems in which these occur. Often referred to as indigenous and local knowledge, it both results from and informs a long experience in managing the social and ecological aspects of the use of wild species for long-term sustainability. Indeed, a strong case can be made that much of the biodiversity people value, including the abundance and distribution of many species regarded as wild, are the result of indigenous peoples and local communities' practices interacting with other-than-human nature over time periods extending from millennia to centuries (Ellis *et al.*, 2021; Garnett *et al.*, 2018; Levis *et al.*, 2017). There are, however, examples in which indigenous peoples and local communities' uses of wild species have proven unsustainable over time and increasing pressures on indigenous peoples and local communities' lands, livelihoods, and cultures place indigenous and local knowledge and associated practices at risk (IPBES, 2019a, 2019b and sections 4.2.1, 4.2.3, 4.2.5 in Chapter 4). Thus, incorporation of indigenous and local knowledge and indigenous peoples and local communities' perspectives and experience is essential to achieving both the social and ecological goals of sustainable use of wild species. In the context of the implementation of the IPBES approach to recognizing and working with indigenous and local knowledge, those perspectives are integrated throughout the assessment in support of national and international laws and principles, as well as important sources of knowledge and approaches to sustainable uses of wild species for all peoples, while endeavoring to respect the principle of free, prior and informed consent (FAO, 2016).

The sustainable use assessment has taken a multi-faceted approach to integrate indigenous and local knowledge throughout, following methodological guidance for recognizing and working with indigenous and local knowledge in IPBES (IPBES, 2020a). It included work with indigenous peoples and local communities' organizations and international bodies representing or working closely with indigenous peoples and local communities. Direct input to the assessment by indigenous and local knowledge holders and experts was invited through a call for contributions distributed to indigenous peoples and local communities' organizations throughout the world, as well as three dialogue workshops held at key moments in the assessment process. The call for contributions (distributed in June 2020) invited indigenous peoples and local communities and academics who work with indigenous peoples and local communities to submit community reports, academic papers, case studies, videos, songs and artworks related to the use of wild species by indigenous peoples and local communities, as well as recommendations of individuals, communities, organizations and networks that could collaborate in the development of the assessment. Workshops brought together indigenous peoples and local communities and experts of the IPBES assessment of the sustainable use of wild species for two days of engagement with assessment content, with results captured in publicly available reports (IPBES, 2019b, 2019a, 2021b). The first two workshops were conducted in person in the second and fourth quarters of 2019. As a result of the coronavirus (COVID-19) pandemic, the final workshop was realized through a series of online sessions in May 2021.

The remainder of this section develops core definitions and conceptualizations of indigenous and local knowledge and indigenous peoples and local communities in relationship to the use of wild species. While recognizing their rich global diversity, indigenous peoples and local communities' uses of wild species and the indigenous and local knowledge that arises from and supports them share many characteristics. This assessment emphasizes approaches to safeguard continued capacity of indigenous peoples and local communities to engage in sustainable use of wild species and how active, respectful engagement with indigenous and local knowledge and indigenous peoples and local communities will enhance national and international policy on sustainable use of wild species at large. Supporting sustainable use and management of wild species by indigenous peoples and local communities and applying lessons from them more broadly are complementary goals. Realizing them will require understanding the common characteristics of indigenous and local knowledge and indigenous peoples and local communities' sustainable uses of wild species across the globe, as well as the nature and significance of their expression in particular places, times, and cultures.

1.4.1 Defining and conceptualizing indigenous peoples and local communities and indigenous and local knowledge in relationship to use of wild species

Methodological guidance for recognizing and working with indigenous and local knowledge in IPBES (IPBES, 2021a) provides foundational definitions for inclusion of indigenous and local knowledge and indigenous peoples and local communities' perspectives and experiences in the assessment.

Indigenous and local knowledge

The term "indigenous and local knowledge" is understood to connote:

> "dynamic bodies of integrated, holistic, social and ecological knowledge, practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments" (IPBES, 2020a).

Indigenous and local knowledge systems are grounded in specific places, worldviews, beliefs, daily practices, and social relations that arise from and inform formal and informal indigenous and local governance, spiritual, and educational institutions. As a consequence, there is no singular body of indigenous and local knowledge. Rather, multiple knowledge have grown out of diverse global ancestries, territories, and cultures. This is not unlike the diverse knowledge bases of scientific disciplines. Likewise, knowledge is not homogenously distributed across members of a given culture and may be differentiated based on social characteristics such as specialization, kinship, gender, and age.

Importantly for this assessment, indigenous and local knowledge is dynamic. It "continuously evolves through the interaction between experiences, innovations, languages, and non-local knowledge" and, in many cases, is "empirically tested, applied, contested and validated" (IPBES, 2020a). Depth of understanding and adaptation to specific locations is a central strength of indigenous and local knowledge. This highlights both opportunities and challenges for a global assessment such as the present assessment by providing examples of how knowledge and management systems can be adapted to support sustainable use of wild species in particular places, while underscoring the need for careful attention to both the contexts within which knowledge is developed and how it translates into other locations (see section 1.4.3).

Indigenous peoples and local communities

The term "indigenous peoples and local communities" is widely used by international organizations and conventions to refer to individuals and groups who self-identify as indigenous or as members of distinct local communities. The IPBES assessment of the sustainable use of wild species adopts this terminology, with particular emphasis on those who "maintain an inter-generational historical connection to place and nature through livelihoods, cultural identity, languages, worldviews, institutions, and ecological knowledge" (IPBES, 2020a). It notes that "recognition of an individual or group as indigenous is not necessarily synonymous with the group or individual holding indigenous knowledge about the environment" (IPBES, 2020a). That is, indigenous identity does not necessarily confer indigenous and local knowledge. Indeed, factors such as loss of indigenous and local language speakers imperils indigenous and local knowledge. Efforts to revitalize language and culture, including aspects related to sustainable use of wild species, have been initiated by indigenous peoples and local communities worldwide (McCarty *et al.*, 2019).

This assessment uses the term "local communities" to refer to non-indigenous communities with historical linkages to places and "livelihoods characterized by long-term relationships with the natural environment, often over generations" (IPBES, 2020). Such communities are characterized by distinctive approaches to management of the wild species they use. This management is grounded in place-based and hybrid environmental knowledge, often governed by both customary and formal institutions. Many local communities also have perceptions of the relationships between humans, wild species, and the environment that are grounded in traditional values and beliefs that differ from those of the dominant culture. As is evident from this definition, local communities frequently have characteristics similar to those of indigenous peoples and some groups may self-identify as indigenous but are not formally recognized as such by their national governments. Further, such local communities often rely on informal tenure arrangements to access the lands, waters, and species on which they rely. Lack of formal rights and recognition mean that their continued ability to engage in customary use of wild species can be precarious and that their local knowledge is often discounted or ignored in policy processes (IPBES, 2019b; Mattalia *et al.*, 2018, 2020).

Indigenous peoples and local communities' definitions of wild species

As noted in section 1.3.2, definitions of wild tend to be 'purpose built'. Among the purposes of definitions of wild encoded in indigenous and local knowledge and indigenous peoples and local communities' practices are the current and long-term viability of tightly interwoven cultures, identities, and livelihoods. Indeed, some wild species are so central to the well-being of indigenous peoples and local communities that they have been termed "cultural keystone species" (Garibaldi & Turner, 2004, see **Box 1.2**). Definitions of wild may also be said to reflect fundamental understandings of the differences and relationships between humans and other entities that inhabit the world (see section 2.2.4).

There are remarkable commonalities, as well as divergences, in understandings of wild species by indigenous peoples

Box 1 2 **Cultural keystone species: wild rice.**

Wild rice *(Zizania palustris)* is a cultural keystone species, providing physical, spiritual and cultural sustenance for many indigenous peoples in the Great Lakes region of North America (Matson *et al.*, 2021). Remarkable for its high protein and micronutrient profile, when processed correctly this aquatic grain can be stored for long periods of time (GLIFWC, n.d.), especially important properties in a region characterized by severe winters and short growing seasons. The significance of wild rice to the identities of indigenous peoples in the region can be seen in nomenclatures and traditions. The name of the Menominee Indian Tribe of Wisconsin (United States) means "wild rice people" (Whyte *et al.*, 2018). When the Anishinaabe peoples migrated from the Atlantic Coast and northeast of North America, oral tradition instructed that they should move westward until they arrived at "the place where food grows on water". Wild rice remains a healthy staple in the diets of indigenous peoples in the Great Lakes region and is an important part of many feasts and ceremonies (GLIFWC, n.d.).

Harvesting wild rice, a cultural keystone species for indigenous peoples in the Great Lakes region of North America.

Photo credit: CO Rasmussen/GLIFWC

and local communities around the world (see section 2.2.4; IPBES, 2019a, 2019b). Among some indigenous peoples and local communities, to differentiate between wild animals, fungi, and plants and domesticates would be to imply a separation between humans and the natural world; an understanding; that carries with it potentially problematic implications such as failure to recognize human beings' responsibilities and capacity to be good stewards and citizens of the natural world. Other indigenous peoples and local communities do recognize a distinction between wild and domesticated species. Although the way this difference is described differs from group to group, common aspects include notions that wild species do not need human help, do not belong to people, are gifts, and/or come directly from or belong to deities or other entities, specific to each cosmology.

Identification, rather than separation, between humans and wild species is a focal point of nearly all indigenous peoples and local communities' understandings. Wild species and humans are relatives in many indigenous belief systems. This relationship is literal, not figurative, with all the responsibilities and possibilities for mutual care and support this entails (IPBES, 2019c). Further, far from being antithetical to the definition of wild, a responsibility to steward or care for species and places is regarded by many, if not most, indigenous peoples and local communities as fundamental to the existence and well-being of humans and other-than-humans (see **Box 1.3**).

Indigenous and local knowledge, indigenous peoples and local communities and sustainable use of wild species

As the definition of indigenous and local knowledge above suggests, indigenous peoples and local communities' ways of knowing wild species include careful observation over time, often including intergenerational transmission of these observations, material practices (i.e., fishing, gathering, hunting, and logging), and spiritual practices, including ceremony and ritual (Emery *et al.*, 2014; Kimmerer, 2000). Much of indigenous peoples and local communities' knowledge of species and how to use them respectfully and sustainably are recorded in myths, stories, songs, and rituals (see section 2.2.4; IPBES, 2019a). Languages also encode information about the characteristics of wild species and human relationships with them (Terralingua, 2014). The knowledge systems indigenous peoples and local communities draw on to guide their uses of wild species may incorporate both scientific data and indigenous and local knowledge as complementary sources of information (see **Box 1.4**). As with scientific knowledge, indigenous and local knowledge and hybrid knowledge are dynamic, incorporating and adapting to new information as it becomes available. Indigenous and local knowledge often includes strategies for monitoring the status of wild species and their habitats as a means to adapt practices to changing conditions and ensure ongoing sustainable use (see Chapters 2 and 4).

Box 1.4 Communities around Mafungautsi State Forest embarked on a joint resource monitoring exercise with the Forest Commission of Zimbabwe, an arm of government responsible for managing all forest resources in the country. The communities took the lead in monitoring aspects of the forests that were of interest to them such as broom grass, honey and timber. Subsequent to the monitoring initiative, there was more sustainable use of the resources under observation, more equitable sharing of the resources and improved incomes and revenue to the resource harvesters and the state respectively (Mutimukuru *et al.*, 2007).

For indigenous peoples and local communities, a key measure of the sustainability of the use of wild species is whether it contributes to the long-term health and good quality of life of people, the species being used, and, in many cases, creation (or nature) as a whole. Often, this is expressed in terms of maintaining good relationships or living in balance and harmony with nature. Sustainable use and relationships between people and nature are often mediated by customary rules and norms, which have some broad similarities across many communities (IPBES, 2019b). Respect is often a guiding principle. For example, hunters should try not to cause non-lethal injuries to animals in order to minimize suffering and avoid waste of the life being taken (Reo & Whyte, 2012). Destroying mushrooms or plants 'just for fun' is unacceptable. Some form of reciprocity is

Box 1 3 **Conceptualization of the sustainable use of wild species by Andean cultures.**

Andean culture emphasizes the unity of nature, including humans, deities, wild and domesticated animals and plants, and land. The appropriate relationship between all these elements of nature is one of mutual love, respect, and responsibility. What could be translated as wild *(salqa)* are strongly associated with spiritual beings, which protect and control them, as well as higher, colder places where agriculture is not practiced. However, humans and deities, wild and domesticated species all exist in relationships of mutual care, nurturing, and communication. Humans tend wild species and land when these are understood to request or need it, following the appropriate rituals and petitions to deities. This is understood to be necessary to the well-being of all elements of nature.

Box 1 4 Communities around Mafungautsi State Forest.

Communities around Mafungautsi State Forest embarked on a joint resource monitoring exercise with the Forest Commission of Zimbabwe, an arm of government responsible for managing all forest resources in the country. The communities took the lead in monitoring aspects of the forests that were of interest to them such as broom grass, honey and timber. Subsequent to the monitoring initiative, there was more sustainable use of the resources under observation, more equitable sharing of the resources and improved incomes and revenue to the resource harvesters and the state respectively (Mutimukuru *et al.*, 2007).

frequently prescribed. Specifically, when people take a wild animal, mushroom, or plant they should acknowledge it as a gift. Some indigenous peoples and local communities' norms require that something be offered in return, such as a bit of a special plant, song, and/or prayer. Common norms prescribing when and how much of a wild species may be taken include limiting amounts to what is needed for immediate use by family or community, without any waste. Sharing is regarded as essential, assuring that enough is left for other people, as well as other species. Active tending or care for individual organisms, populations, and landscapes is also a strong norm for many indigenous peoples and local communities globally (Anderson, 2013; Peacock & Turner, 2000).

A suite of strategies is commonly employed to teach, regulate, and enforce these norms (see **Box 1.5**).

Challenges and opportunities for indigenous and local knowledge and indigenous peoples and local communities' sustainable use practices

Indigenous peoples and local communities face many challenges to retaining indigenous and local knowledge and maintaining the practices that have provided for sustainable use of wild species over time. These include both social and environmental forces (see Chapter 4; **Figure 1.8**). At the same time, a global surge of interest in cultural revival, emphasis on rights-based approaches to conservation, including community-based natural resources management (see section 6.4.4), and emerging national and international efforts to maintain and revitalize indigenous and local cultures offer hope for the continuity of indigenous and local knowledge and ongoing sustainability of the use of wild species by indigenous peoples and local communities.

The COVID-19 pandemic illustrates the forces that can threaten indigenous peoples and local communities' capacity to engage in sustainable use of wild species. At the same time, it demonstrates the value of those practices and the knowledge on which it is based for survival in the face of crisis, as well as the potential value of dialogue between indigenous and local knowledge and other sources of knowledge for imagining a better way forward for all. Specifically, emerging evidence on the effects of the COVID-19 pandemic on indigenous peoples and local communities and the role of the use of wild species in their responses to it indicate that those communities with robust indigenous and local knowledge have been remarkably resilient in the face of the crisis, especially where customary

Box 1 5 Common indigenous peoples and local communities' strategies for teaching, regulating, and enforcing local norms of sustainable use.

(This list is not exhaustive and not all indigenous peoples and local communities make use these approaches). Source: (IPBES, 2019b)

- **Calendars:** Calendars or schedules may indicate times to take and not take wild species, as well as where these activities may take place. Calendars may be based on religious rules, moon cycles, or patterns and indicators in the environment.
- **Monitoring:** Ongoing observation and monitoring of habitats, land and seascapes, and wild species populations and health.
- **Spiritual practices:** Ceremonies, including songs and dances, help teach and reinforce the actions necessary to maintain sustainable use and good relations with nature. They may be done, for example, before cutting a tree, picking medicines, hunting, fishing, or consuming animals.
- **Prohibitions and rest periods:** Permanent prohibitions against the use of a species (i.e., taboos) and temporary rest periods frequently are important aspects of customary rules and norms governing the use of wild species. Prohibitions may apply to individual species, groups of species, ecosystem types, or specific places.
- **Sanctions or punishments:** Sanctions for violating customary norms and rules may be enforced by the human community or be considered to come from the spiritual realm in the form of bad fortune for the individual who has transgressed and/or their family.

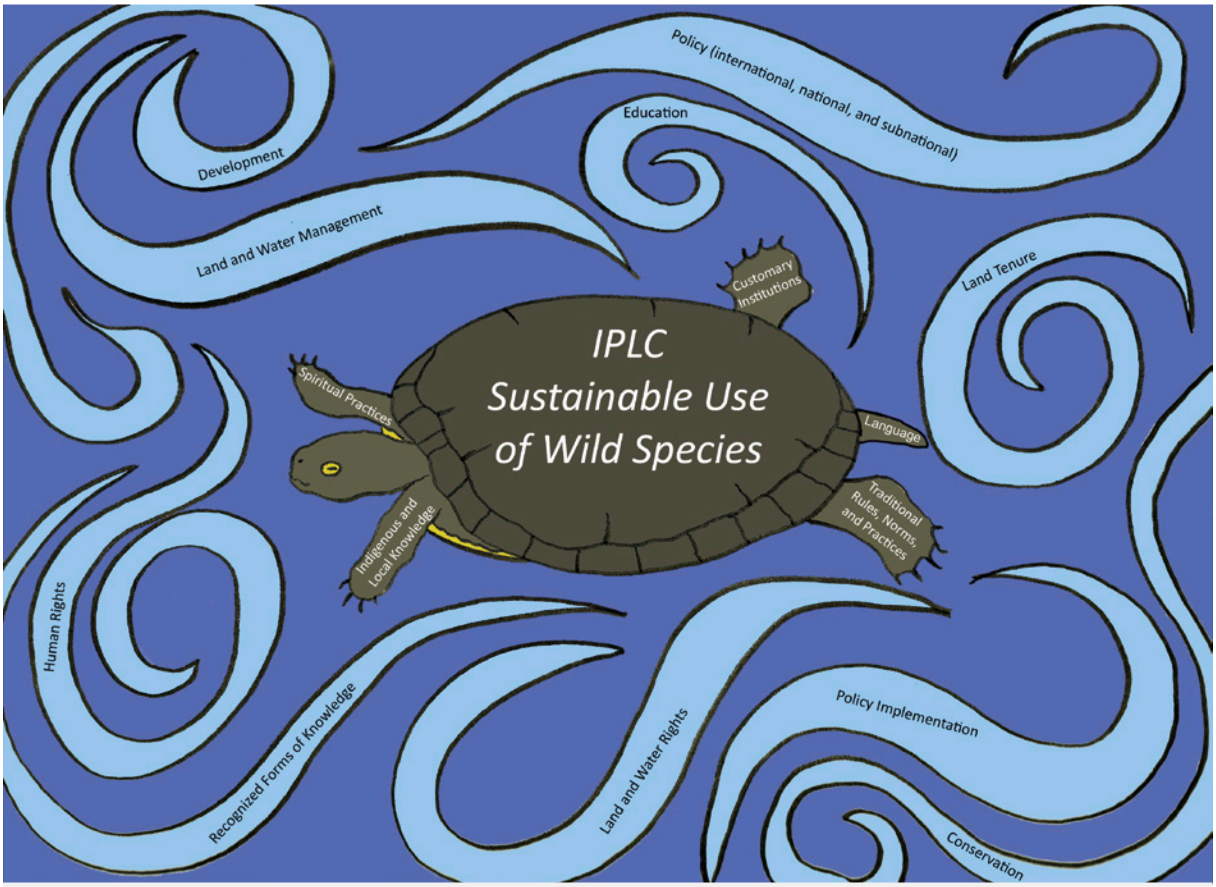

Figure 1 8 **Indigenous peoples and local communities' (IPLC's) sustainable use of wild species: enabling and inhibiting forces.**

Labels on the turtle's legs and tail represent aspects of culture and practice that participants in the second indigenous and local knowledge dialogue workshop identified as central to sustainable use of wild species by indigenous peoples and local communities (IPBES, 2019b). The currents in the water around the turtle represent external forces or conditions identified as supporting or impeding sustainable use of wild species by indigenous peoples and local communities.

norms and institutions remain vigorous. Often located far from national centers of power, many communities have been largely on their own to manage the impacts of the pandemic, which include disruptions to government services, supply chains and markets, as well as the return of community members who had migrated to urban centers. For indigenous peoples and local communities who have retained access to healthy lands, waters, and wild species populations, fishing, hunting, and gathering have provided essential food and allowed them to care for vulnerable individuals (i.e., elders, children, and those with disabilities) (Forest Peoples Program, 2021a, 2021b; UN General Assembly, 2020; Walters *et al.*, 2021). Traditional medicinal systems make extensive use of wild animals, fungi and plants (see Chapter 3). These have been widely used for immune system support and treatment of symptoms of COVID-19. However, many other communities have seen their capacity to turn to the use of wild species erode as illegal expansion of agricultural frontiers, encroachment by criminal actors, and land grabs and displacement of indigenous peoples and local communities from their lands by extractive industries have increased. Enforcement of indigenous peoples and local communities' territorial rights and measure to assure the safety of their leaders could help to redress these trends and the loss of food and health security that attend them (Forest Peoples Program, 2021a, 2021b; UN General Assembly, 2020; Walters *et al.*, 2021). These examples of resilience and loss provide models for understanding and governing sustainable uses of wild species that can inform discussions of a 'green recovery' from the pandemic.

1.4.2 Scaling up the analysis of indigenous peoples and local communities' contributions to sustainable use of wild species

The actual strategies developed by indigenous peoples and local communities to enhance sustainable use of wild species have been developed through context-dependent learning, adaptation to changing environments and, often, sustained negotiations to resolve conflicts among individual users, sectors or communities. As a result, the ontological foundations and epistemological modes of indigenous peoples and local communities often diverge from those of research-based science and the management systems it informs. Indeed, the specific rules and approaches to sustainable use that have been developed by indigenous peoples and local communities are embedded in complex knowledge systems and socio-cultural milieux that differ not only from hegemonic institutions but also from one local context to the next. The identification of effective sustainable use strategies for the purpose of transposing such strategies benefits significantly from being attentive to the contexts from which they emerge, to the local knowledge and existing practices and rules that make such strategies effective. Nevertheless, the essential elements of successful strategies and the processes involved, as well as the concepts and principles with which they align, may find purchase beyond the local context and come to inform practices of sustainable use in other locations and at other scales.

Successful strategies developed within specific indigenous peoples and local communities' contexts to be useful in other locations and across larger scales will require some degree of assessment and translation by institutions intent on transposition. While institutions and organizations (e.g., state sponsored agencies, international regulatory bodies, non-governmental organizations) charged with developing approaches for sustainable use often document and amplify successful indigenous peoples and local communities' strategies for sustainable use, they could also engage in the explication of specific strategies (as well as concepts and principles) that are potentially translatable and transposable. To do so, such institutions and organizations may modify and recalibrate their own systems of sustainable use observation, measurement, and analysis in order to "see" and learn from indigenous peoples and local communities' sustainable use systems built upon other ontological and epistemological foundations. In this case, those translated and transposable strategies that emerge from engagements with indigenous peoples and local communities can best be understood as co-productions (by indigenous peoples and local communities and "larger" institutions) with capacities that are more likely to resonate beyond the local context from which they were derived.

While a range of indigenous peoples and local communities' strategies, concepts, and principles suitable for regulating specific types of resource uses may be identified, translated, and proposed as relevant elsewhere, their effective transposition will depend on how they are implemented. It is essential to have institutions and processes in place to facilitate discussion among stakeholders and indigenous and local rights holders on implementation details adapted to each particular context (Carter & Currie-Alder, 2006). There is also a need to uncover and understand customary rules and institutions that may be operating effectively but could be easily destabilized when formal rules are introduced. Two examples in Chile illustrate ways that formal rules can clash with traditional fisheries systems: (i) regulatory requirements of the Chilean system of territorial use rights in fisheries disrupt the traditional system of rotating kelp harvesting practices (Gelcich *et al.*, 2006); (ii) recommendations for closing areas disrupt a tightly woven system of tenure of lobster fishing spots evolved over decades in the Chilean Juan Fernández archipelago (Ernst *et al.*, 2013).

Just as context matters in terms of learning about successful strategies from indigenous peoples and local communities, so too will context matter when proposing that such strategies be adopted elsewhere. The re-location and/or re-scaling of successful indigenous peoples and local communities' practices benefits significantly from recognizing their dynamic, experimental, and outcomes-based nature. In this case, it is recommended that institutions and formal management systems incorporate such practices into explicitly adaptive management approaches with the flexibility to include a range of concerns (e.g., socio-cultural) and avoid the inflexible institutionalization of particular regulations or rights (e.g., permanent property rights, see Cinner & Aswani, 2007). The success of indigenous peoples and local communities' systems of sustainable use is, in part, due to their ability to allow for and adapt to changing natural and social conditions (e.g., Berkes *et al.*, 2000). Successful practices and mistakes-to-avoid need to be documented to leverage local learning and scale-up successes. There is a strong potential to create, encourage and support communities of practice (Wenger, 1998) to share knowledge and learn from past mistakes and achievements.

1.5 THE IPBES ASSESSMENT OF THE SUSTAINABLE USE OF WILD SPECIES IN THE CONTEXT OF OTHER ASSESSMENTS

There have been very few international assessments targeting the sustainable use of wild species and those past reports focused only on a few species and/or case studies (see e.g., Prescott-Allen & Prescott-Allen, 1996). Nonetheless, previous biodiversity and sectoral assessments offer valuable insights into uses of wild species, their contributions to human well-being, and factors contributing to long-term prospects for their sustainable use. The sustainable use assessment builds on global assessments produced by IPBES, organizations of the United Nations and other global organizations. It also considers one national assessment dedicated to non-timber forest products, since the practice of gathering (1.3.3) was not thoroughly reflected in the other global assessments. All these assessments address human uses of wild species and factors contributing to their sustainability (or lack thereof) as a primary or secondary focus.

Collectively, the assessments document widespread global dependence on wild species for food, medicine, and other purposes (FAO, 2018c, 2018b, 2019, 2020b, 2020a; HLPE, 2017; IPBES, 2018a; Vira, *et al.*, 2015; WHO & CBD, 2015). Contributions of use of wild species to good quality of life include direct provisioning, sources of income, and energy, the latter especially for cooking and sanitizing water (FAO, 2018c, 2018b, 2020b, 2020a; HLPE, 2017; IPBES, 2016, 2018a, 2018b; Vira, *et al.*, 2015). For many indigenous peoples and local communities, the use of wild species is also essential to identity and culture (Chamberlain *et al.*, 2018; IPBES, 2016). These contributions of use of wild species to human well-being are continuous and quotidian, as well as episodic and exceptional.

The International Union of Forest Research Organizations estimates that nearly 20% of the global population directly depend on forests, tree-based systems, and the wild species in them (Vira, *et al.*, 2015), while the FAO estimates that fisheries and aquaculture support the livelihoods of 12% of people around the world and provide 17% of the global population's intake of animal proteins (FAO, 2018c, 2020b). In addition to serving as primary sources of subsistence resources, income, and identity, uses of wild species also serve as safety nets enabling survival during seasonal shortfalls and crises provoked by anthropogenic (e.g., armed conflicts) and non-anthropogenic (e.g., slow and rapid onset natural disasters) forces (see Chapter 4; FAO, 2015, 2018b, 2019, 2020a; HLPE, 2017; Vira, *et al.*, 2015; WHO & CDB, 2015). The use of wild species also contributes to the global economy. In the European Union alone, international legal trade of wild species is estimated at 100 billion euros (TRAFFIC, 2020).

These various contexts mean there are intra- and interannual variations in the frequency and intensity of the use of wild species throughout and across years, and these variations may impact the sustainability of use. Whether quotidian or exceptional, nearly all assessments note that human uses of wild species are particularly important to individuals and groups in vulnerable situations, including women, marginalized peoples, indigenous peoples, and forest-dependent communities (note that these may be overlapping rather than mutually exclusive categories; FAO, 2015, 2018b, 2019, 2020a; HLPE, 2017; Vira, *et al.*, 2015; WHO & CDB, 2015).

Multiple assessments document the particularly important contributions of use of wild species to food security and nutrition (FAO, 2015, 2019; HLPE, 2017; Vira *et al.*, 2015; WHO & CBD, 2015). Consumption of wild animals, fungi, and plants contributes directly to human health and well-being through dietary quality and diversity, in rural and urban areas, in developed and developing countries (WHO & CBD, 2015). Reports to FAO from 91 countries included a total of over 2,800 distinct wild species used for human food across the world, the largest share of wild species used for food coming from aquatic and forest production systems, with capture fisheries likely the largest use of wild food by volume, for human consumption or feeding aquaculture species (FAO, 2019, 2020b). A majority of wild fungi, insects, plants and, to a lesser extent, mammals and birds are obtained from forested ecosystems (FAO, 2018b, 2019). Consumption of wild food also enables greater dietary choice (i.e., food sovereignty) and is often used as a complement to a limited set of cultivated crops (FAO, 2019; WHO & CBD, 2015). It has demonstrated benefits in terms of reducing metabolic diseases such as obesity and diabetes, which are epidemic in some parts of the world (Vira, *et al.*, 2015). In Madagascar, it was found that risk of aenemia in children from poor households was lowered by nearly 30% when the household consumed wild meat, even in small quantities (Golden *et al.* 2011 in WHO & CBD, 2015). Some assessments note that wild species are an important or primary source of protein (IPBES, 2018a) and provide important micronutrients. Examples show that, in many instances, wild species contain higher levels of micronutrients, vitamins and proteins than similar domesticated crops or livestock (FAO, 2019; WHO & CBD, 2015). Beyond addressing primary needs, wild species may also be preferred to domestic species even when the latter are available through markets. Preference for wild species comes from traditional food preferences (e.g., for people moving from rural to urban areas) or "from a revival of interest in wild foods", often associated with cultural, recreational or nutritional values (FAO, 2019). However, use of wild species may include risks to human health through the transmission of diseases. Hunting, butchering, transportation and storage of live wild animals or their meat in unsafe conditions particularly presents risk of zoonotic diseases (IPBES, 2020; WHO & CBD, 2015).

The reliance of biomedical processes and traditional medicine alike on wild species, and more specifically on wild plants is widely documented (WHO & CBD, 2015). Many biomedical innovations rely on wild species, but their development at an industrial production scale may threaten the preservation of the very resources underpinning traditional medicine. The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization aims, among other things, to acknowledge communities' traditional knowledge such as use of plants or animal parts for medicine, in order to protect their rights to those resources, which may include support for conservation and sustainable use on the ground or financial compensation for use of the resources by third parties. Wild species also contribute to mental health and wellbeing, including through extractive and non-extractive practices related to ceremonial and ritual, decorative and aesthetic, recreational and learning and educational uses (FAO, 2019; WHO & CBD, 2015).

Several assessments observe that in addition to land use/land cover change, unsustainable agriculture and forestry, pollution, and climate change, unsustainable uses of wild species are a primary driver of biodiversity loss (IPBES, 2018a, 2018d, 2018b, 2018c, 2018e).

Intensification of uses that had been sustainable in the past may lead them to become unsustainable if practices do not adapt to the new drivers (see Chapter 4, IPBES, 2019a). Such drivers may influence:

- Wild species populations (e.g., a disease affecting the wild species, or climate change leading to a shift in wild species range (Chamberlain et al., 2018; FAO, 2019, 2020b);
- The practices (e.g., technological change leading to more intensive or extensive harvesting, industrialization of a wild species use or commercial or demographic drivers leading to increased demand for a wild species, often entailing expansion from local to regional or global markets (FAO, 2019, 2020b);
- The uses (e.g., new applications found for wild species, or shifts from subsistence to commercial uses (Chamberlain et al., 2018; FAO, 2019).

For extractive practices, all those drivers may lead to an increased share of the biomass being removed from nature, disturbing the social-ecological system's equilibrium.

However, some assessments also note that much biodiversity is underpinned by the long-term results of indigenous and local knowledge and indigenous peoples' and local communities' customary practices associated with uses of wild species (Chamberlain *et al.*, 2018; FAO, 2018b, 2020a; Forest Peoples Program *et al.*, 2020; IPBES, 2016, 2019a). Further, erosion of indigenous and local knowledge, in concert with indigenous peoples and local communities' loss of access and tenure rights to traditional territories and resources appears to be a driver of unsustainable uses of wild species and biodiversity loss (Chamberlain *et al.*, 2018; FAO, 2018b, 2020a; HLPE, 2017; IPBES, 2016, 2019a). All assessments in this review identify governance as an important factor in support of sustainable uses of wild species. Several document positive ecological and social outcomes from decentralized, multi-sectoral approaches in which decision-making and management authoriiesy do not rest solely at the level of the nation state (Forest Peoples Program *et al.*, 2020; IPBES, 2016, 2018a, 2018b; Vira, *et al.*, 2015). Rather, they recommend approaches that bring together the public and private sectors, non-governmental organizations, and local communities and integrate multi-sectoral actors from resource management, health, education, and others (Vira, *et al.*, 2015). Acknowledgement of and support for indigenous and local knowledge, tenure, and access to resources, including genetic resources, are identified as a keys step toward the sustainable use of wild species (Forest Peoples Program *et al.*, 2020; HLPE, 2017; IPBES, 2016, 2018e; Vira, *et al.*, 2015). Likewise, the importance of a rights-based approach with particular importance given to complying with international human rights laws and standards in all governance instruments and processes is noted as fundamental to governing the use of wild species (Forest Peoples Program *et al.*, 2020; HLPE, 2017).

No assessment on non-extractive practices was identified, but some activities associated with nature-based tourism have been the focus of global reports (INTOSAI WGEA, 2013; Tapper, 2006). A study conducted in the early 2000s found that 20% to 40% of all international tourists included some form of wildlife watching in their trip. Tourism focusing on wild species sustains the whole tourism sector in some countries, and provides income and employment to people such as guides and drivers, as well as employees in the hotel and food services industries. Wildlife watching tourism "ranked as one of the top three export sectors for more than three-quarters of all developing countries in 2000, and was the principle export in a third of these countries" (Tapper, 2006). Globally, "wildlife tourism" was estimated to represent 9% of gross domestic product in 2011 (INTOSAI WGEA, 2013). Because protected areas are often wildlife watching destinations it also can support biodiversity conservation. It is therefore in the interest of national or local governments, but also of the tourism businesses, to support conservation of those areas (INTOSAI WGEA, 2013; Tapper, 2006).

In the early 2000s, Tapper (2006), noted that little was known about the actual income generated by wildlife watching or the impacts of tourism activities on the targeted species. Audits of the activities around wildlife watching, to assess their ecological and social impacts, were still scarce (INTOSAI WGEA, 2013). Another report by Tonazzini *et al.* (2019), focusing on coastal and marine tourism concluded that tourist density should be constrained to avoid negative impacts. When nature-based tourism is over developed, it can have negative impacts on wild species through increased disturbance, and on the local communities who risk being excluded from the benefits with the arrival of bigger, external players investing in tourism activities or through the commodification of people's cultures. The emphasis on economic returns may also contribute to an increase in local conflicts between people and wild species (INTOSAI WGEA, 2013). Further, if it becomes a main or single source of income, households and communities are vulnerable to variations in tourist flows within and across the years.

The picture of the relationship between human uses of wild species and biodiversity that emerges from this review of previous assessments is far from simple. Opportunities for and outcomes of human uses of wild species are mediated by complex, interacting factors including environmental, economic, social, and cultural contexts (HLPE, 2017). There are clearly documented instances in which the relationship between biodiversity and nature's contributions to people through the use of wild species is reciprocal; nature's contributions to people depend on biodiversity and much biodiversity is maintained through indigenous and local knowledge and practices related to the use of wild species. Equally, there are well-documented cases in which the use of wild species results in biodiversity losses. There are both rich sources of information on these processes and significant gaps in data and synthesis of existing knowledge from diverse sources. These gaps impede understanding of the processes and of the pathways to greater social and ecological sustainability of the use of wild species.

Contributions of the IPBES assessment of the sustainable use of wild species

The IPBES assessment of the sustainable use of wild species is the first international endeavor to be fully comprehensive of all practices and uses associated with the sustainable uses of wild species. While many previous assessments focus on drivers of unsustainable uses of wild species and their consequences for biodiversity, the mandate of the IPBES assessment of the sustainable use of wild species is to identify solutions that enhance their sustainable uses. To do so, this assessment uses a groundbreaking conceptualization that enables analysis of any type of use of any species (see the organizing structure in section 1.3.4) and supports analyses across scales and comparison of successes and failures of interventions across practices. The focus on sustainable use of wild species is also a novel aspect of this assessment. Building on assessments that have come before, the IPBES assessment of the sustainable use of wild species approaches the task through systematic review of the scientific literature and addressing and working with indigenous and local knowledge to fill gaps in knowledge and identify pathways to enhanced sustainability of the use of wild species that contribute to conservation and development.

Regarding fishing and logging, the sustainable use assessment draws from the work of the FAO and especially the State of the World's Forests and the State of World Fisheries and Aquaculture, which focus on resources (respectively, timber and non-timber forest products, and fish and shellfish), in order to present the various uses associated with these species and where, how and why those uses are sustainable. Regarding terrestrial animal harvesting, gathering and non-extractive uses, the IPBES assessment of the sustainable use of wild species similarly draws the bigger picture related to those practices, while also collating for the first time global data and evidence on those species' uses. This assessment also gives a clear picture of where gaps are in data and synthesis of existing knowledge around the sustainable use of wild species (see supplementary material S1.1). As those gaps are filled, understanding of pathways to greater social-ecological sustainability of the use of wild species will improve.

1.6 MAPPING SUSTAINABLE USE OF WILD SPECIES CONTRIBUTIONS TO THE SUSTAINABLE DEVELOPMENT GOALS

While this assessment focuses on sustainable use and not on sustainable development (1.3.2), it is important to stress the multiple contributions that sustainable use of wild species can make to the achievement of the Sustainable Development Goals. That contribution is overlooked for many Goals, with the phrasing of their targets or indicators making no link to the sustainable use of wild species. This section aims to highlight, in particular for policymakers, the role that sustainable use of wild species can play if taken into account in strategies for sustainable development. As noted below, the sustainable use of wild species can support better quality of life for people of the world in the most vulnerable situations, but is also an essential component of good quality of life for all. For many people, especially indigenous peoples and local communities, uses of wild species are understood as characteristic of abundance and wealth. As highlighted in **Table 1.3** and throughout this assessment, the sustainable use of wild species offers potential synergies to realize almost all Sustainable Development Goals, and could be incorporated as a central or complementary strategy for many of them. When the use of wild species is sustainable, there are few drawbacks. Such drawbacks may include potential adverse human health and climate implications of some uses of wild biomass for energy and misidentification or unsafe handling of wild foods (see section 1.5).

It should be acknowledged that since all Sustainable Development Goals are interdependent and indivisible, achieving them will also create favorable conditions for the sustainable use of wild species, through for example better recognition of access and tenure rights, implementation of the rule of law, better distribution of benefits or opening up of more options e.g., for food, income generation etc. The analysis for each Sustainable Development Goal is presentented in **Table 1.3** below and further discussed in the rest of the section. It covers only "outcome targets", leaving aside targets on the means of implementation which fall beyond the scope of this assessment.

Table 1 3 **Meeting Sustainable Development Goals (SDGs) via socially & ecologically – actual & potential – sustainable uses of wild species.**

SDGs	**Potential contributions of the use of wild species to achieve the Sustainable Development Goals** (Numbers in brackets refer to sections in the chapters that provide underlying evidence)
SDG1 **No poverty**	Sustainable uses of wild species reduce poverty (i.e., lack of the resources necessary for subsistence) by providing food, medicine, and materials for personal use, as well as sources of income. The role of fishing, gathering, terrestrial animal harvesting and logging in poverty reduction is particularly important for many of the world's poorest individuals and households. Globally, the proportion of household income from extractive and non-extractive uses of wild species ranges from 17% to 98%, depending on location, social identity, and types of products harvested **(3.2.4, 3.3.1, 3.3.3, 3.3.4, 4.2.3.4)**.
SDG 2 **Zero hunger**	Wild foods are central to food security and nutrition for millions of people residing in rural and urban settings worldwide, providing essential energy, as well as macro- and micro-nutrients. Thousands of species of wild animals, fungi, and plants are used as food on a regular basis or provide safety nets in times of shortage. For example, gathering provides food, income, and nutritional diversity for an estimated one in five people around the world, in particular women, children, landless farmers and others in vulnerable situations. Wild fish and wild meat are the primary or sole source of protein in some households' diets, where they can reduce the risk of anemia and provide important nutrients including calcium, zinc, and iron **(1.5, 3.3.1.5.1, 3.3.2.3.4, 3.3.3.2.3, 4.2.4.2.2)**. In addition to subsistence consumption, wild foods are traded in formal and informal markets at scales from the local to the global. In some cases, competition between commercial and subsistence harvesting may jeopardize the food security of local communities **(4.2.4.2.2)**. Indigenous and local knowledge can play a role in reducing global hunger through conservation of wild crop relatives and insights into uses of abundant but uncommonly used food sources such as insects **(3.3.2.3.4)**.
SDG 3 **Good health and well-being**	Harvest and use of wild species, especially plants, are central to the traditional health systems and primary healthcare of people throughout the world, including for COVID-19 treatments. Access to and uses of wild species have particular importance for the health and well-being of indigenous peoples and local communities **(1.4.1, 1.5, 3.3.2.3.5, 3.3.2.4, 4.2.3.5.1)**. In addition, wild food consumption has demonstrated benefits in reduced incidence of metabolic diseases such as obesity and diabetes, which are epidemic in much of the world **(1.5)**. Wild plant materials and genetic resources also are important components of industrially-produced medicines. An estimated 60-90% of the medicinal and aromatic plants traded globally are gathered in the wild **(1.1)**. Evidence suggests that connections to nature through non-extractive practices (e.g., forest bathing, bird watching) can benefit psychological health and improve well-being through effects such as reduced stress and increased mental abilities **(3.3.5.2.2)**. Evidence also exists for physiological and psychological welfare derived from fishing or hunting **(3.3.1.5.3, 3.3.3.2.1)**. However, unsanitary handling and consumption of wild animals can increase the risk of zoonotic diseases **(3.3.3.1)**.

Table 1 3

SDGs	**Potential contributions of the use of wild species to achieve the Sustainable Development Goals** (Numbers in brackets refer to sections in the chapters that provide underlying evidence)
SDG 4 Quality education	Income generated through harvest and trade of wild species can be an important source of cash to support children's educational costs **(3.3.2)**. Non-extractive practices (e.g., wildlife watching) may provide valuable educational experiences, enhancing understanding of nature and motivations to protect it **(3.3.5.2.4)**. Global trends toward standardization of education are resulting in decreasing attention to, and understanding of, local biodiversity and a decline in community resilience. Many local and indigenous groups are calling for systemic changes in educational systems to respect the traditions, knowledge, languages, values, history, and identities of their cultures. Formal recognition by national educational systems of cross-generational knowledge transmission and a wider range of approaches to learning (e.g., supporting and restoring indigenous and local knowledge, led by indigenous peoples and local communities) would support local stewardship and sustainable use of wild species **(4.2.6.4.2, 4.2.6.4.6)**.
SDG 5 Gender equality	Many uses of wild species are strongly gendered **(3.3.2.2.3, 3.3.4.4.2, 4.2.3.6)**. Sustainable uses of wild species empower women throughout the world. Women's uses of wild animals, fungi, and plants support their health, provide the means for women to support themselves and their families, confer financial independence, and give them recognition within their communities and beyond. For example, globally women occupy half the jobs in the seafood industry and small-scale fisheries activities. Despite this, women often lack clear rights of tenure and are excluded from meaningful participation in management discussions. Securing women's participation in decision-making can be seen as an outcome as well as a condition for sustainable use **(3.3.2.2.3, 4.2.2.6, 4.2.3.6)**.
SDG 6 Clean water and sanitation	Best management practices in logging can protect water quality, reduce soil erosion and maintain riparian habitat **(4.3.2.4)**.
SDG 7 Affordable and clean energy	2.8 billion people, or 38% of the global population, rely on biomass for energy. Logging for energy accounts for 50% of all wood consumed globally, and accounts for 90% of timber harvested in Africa **(3.3.4.4.2)**. While often affordable, in many cases wood energy is not clean because of the technologies used for cooking and/or heating. However, the demand for wood fuel is increasing due to renewable energy targets **(3.3.4.4.2)**.
SDG 8 Decent work and economic growth	Sustainable uses of wild species provide work for millions of people worldwide and contribute to economic growth and stability at local, national, and regional scales **(3.3)**. Mixed economies and diverse livelihood strategies that include subsistence uses of wild species and/or their trade in informal markets allow households and communities to respond to changes in the wage economy and variation in the availability of wild species **(4.2.4.2.1)**. A majority of jobs and income from sustainable uses of wild species likely involve local trade in the informal economy. Conversion from small-scale enterprises to more intensive commodification for a larger market often jeopardizes the social and ecological sustainability of subsistence activities and small-scale trade **(3.3.1, 3.3.2, 4.2.4.3, 4.2.4.4)**. Nevertheless, there is substantial global trade in wild species. For example, in 2009, TRAFFIC estimated legal international trade, including timber and fisheries products, at US$323 billion. Germany alone imported US$ 250 million of medicinal and aromatic plants in 2015. Nevertheless, caution is in order, as the direction of global trade in wild species typically flows from developing to developed nations **(4.2.4.3)** and often, the individuals and communities that harvest wild species for global commodity markets are not the primary economic beneficiaries of such trade **(4.2.4.3.1)**. When sustainably managed, naturally regenerating forests can provide diverse work and opportunities for economic return from each of the extractive and non-extractive practices considered in this assessment **(3.3.4.3.1, 3.3.5.2)**. Non-extractive practices (e.g., wildlife watching) can provide work for local communities and national economic growth. However, that income is vulnerable to shocks such as global recessions or pandemics and the distribution of benefits depends on factors including tax policy, infrastructure, and supply chains for goods and services **(3.3.5.3, 4.2.4.3.3)**.
SDG 9 Industry, innovation and infrastructure	Wild species are primary raw materials for numerous industrial sectors, *inter alia* apparel, construction, cosmetics, energy, food, and pharmaceuticals and traditional medicine formulations. These industries are national to global in extent, with annual values in the millions to billions of US dollars **(3.3.1.5, 3.3.2.3.2, 3.3.2.3, 3.3.3.2.3, 3.3.3.3.1, 3.3.4.4)**. Industries that initially use wild species as primary raw materials often shift to substitution of alternative materials, cultivation, or synthesis for reasons that include declines in commercially viable populations of the target wild species, interannual variability in the abundance of the wild species, and other efficiencies or cost cutting measures **(3.3.2.3.4, 3.3.4.2, 3.4.3, 4.2.1.5.3, 4.2.6.2.4)**. While indigenous peoples and local communities often derive important income from trade in wild species, conversion of subsistence and small-scale commerce to industrial scales can threaten the social and ecological sustainability of these practices **(3.2.4)**.
SDG 10 Reduced inequalities	Sustainable use of wild species can create new opportunities and upward social and economic mobility for some. Conversely, when species previously used for subsistence or small-scale trade enter larger-scale markets, supply chains often are taken over by more powerful individuals or organizations, reducing or eliminating benefits to people who do not enjoy institutional or political favor **(3.3.3.2.4, 3.3.5.2.3, 3.4.5.2)**. Indigenous and local people can make critical contributions to enhance the way people understand the natural world and the ways people conduct meaningful research and resource management **(2.2.4, 4.2.5, 6.6)**. For many rural families, the sale of wild species is the main source of cash income and provides access to modern services and basic necessities such as medicines, energy and education **(3.3.3.2.3)**. When well governed, nature-based tourism can support poverty alleviation and provide local employment. However, such benefits require that nature-based tourism enterprises provide direct employment for local people and source goods and services locally **(3.3.5.2.3)**.

SDGs	Potential contributions of the use of wild species to achieve the Sustainable Development Goals (Numbers in brackets refer to sections in the chapters that provide underlying evidence)
SDG 11 Sustainable cities and communities	Sustainable uses of wild species can and do occur in and around cities. Many urban residents consume wild meats, cook with wood fuels, and use medicinal plants. Some hunting, fishing, and gathering also occurs in urban and peri-urban environments. Urban residents' motivations for using wild species may include perceptions that consuming wild foods is more ecologically and ethically sound than conventional agricultural products, preference, tradition, status, and recreation. Demand for game meat or wood fuel in fast-growing cities can lead to unsustainable use of wild species in nearby areas. Approaches combining rural and urban planning, such as peri-urban agroforestry, can contribute to sustainable use. Time spent in urban greenspaces to engage in wild species-based activities such as wildlife watching and gathering has been shown to support physical and emotional well-being **(3.3.3.2.3, 3.3.3.2.6, 3.3.4.3.3, 3.3.5.2.2, 4.2.3, 4.2.5)**. SDG 11 also includes a target related to the protection of the world's cultural and natural heritage. In many instances, uses of wild species are directly or indirectly linked with cultural and natural heritage, and the erosion of one (either wild species or cultural and natural heritage) leads in many cases to the decline of the other. In some instances, urban greenspaces also support cultural and religious identity in a manner similar to that of rural sacred spaces **(3.2.1.5, 3.3.1.4, 3.3.2.3.2, 3.3.2.3.4, 3.3.5.2, 4.2.2.5, 4.2.5.2.2, 4.2.5.2.6, 4.2.5.2.7, 4.2.5.2.10)**.
SDG 12 Responsible consumption and production	Socially and ecologically sustainable use of wild species has a role to play in responsible production and consumption. A large proportion of wild species production and consumption is for personal use (i.e., subsistence) or trade that occurs in informal markets. For the use of wild species that take place through large-scale commercial trade, multilateral organizations, environmental nongovernmental organizations, and industry associations have developed programs to incentivize sustainable production and motivate consumers to make sustainable choices (e.g., the United Nations Conference on Trade and Development BioTrade program and certification schemes such as the Marine Stewardship Council and the Forest Stewardship Council). While there is some evidence of success in these endeavors, findings are mixed as to whether they have delivered hoped for outcomes including uptake of voluntary programs, equitable distribution of benefits from production systems, transparent supply chains, and changing consumer behavior. Factors contributing to responsible production and consumption of recreational benefits through non-extractive uses of wild species such as wildlife watching include respect for local community rights and customary practices, use of locally sourced material and labor, capacity building for providers, and environmental education programming for consumers **(3.2.4; 3.3.4.3.3, 3.3.5.2.3, 4.2.2, 4.2.3.5, 4.2.4)**.
SDG 13 Climate action	For millennia, the use of wild species has provided safety nets in times of abrupt and cyclical shortages due to meteorological events **(1.5, 4.2.1.2, 4.3.3)**. Education, awareness-raising and capacity building, including maintenance of indigenous and local knowledge and capacity building for indigenous peoples and local communities, can enable future contributions of use of wild species to climate change adaptation and impact reduction strategies **(6.5.2.1)**. Policies for climate action, such as those for the reduction of emissions from deforestation and forest degradation, can build on the sustainable use of wild species, e.g., through decreasing logging and improving gathering practices **(4.2.1.2.5, 6.4.1)**.
SDG 14 Life below water	The status of fish stocks in the temperate north, which provide half of the world's catch, show positive trends in good part due to monitoring of fish stocks and regulation of catches. The status of the other half of world's catch, largely from South-East Asia, is unknown. Industrial fishing now occurs in over 55% of the global oceans, and several countries have established arrangements to guarantee access to those resources by local communities. Granting user rights to communities has usually had positive impacts for the sustainability of fisheries. Although informal and largely unreported, small-scale fisheries sustain local based economies and provide for the food security of people living in conditions of poverty all over the world. Illegal, unreported and unregulated fisheries do not necessarily mean that those fisheries are unsustainable, but in most known cases they are or are very likely to become so. There is some evidence for unsustainable use in regulated fisheries although robust fisheries management generally leads to more sustainable use. Very successful management measures adopted by large-scale and small-scale fishing systems (e.g., in Europe) have been able to promote better fishing practices, including the recovery of many over exploited fishing stocks, the readoption of old technologies and gears, and even the recovery of lost jobs and economic viability. This can include, among other effective regulation measures, the creation of marine protected areas to regulate fishing, which are more successful when local fishers are engaged. It is *well established* that co-management practices are very effective in the adoption and promotion of good fishing practices, with very positive effects in almost all places it is implemented. Potential revenues from non-lethal or non-extractive practices (e.g., catch-and-release, diving) can be also substantial **(3.3.1, 3.3.5, 4.2.1, 4.2.2, 4.2.4.2, 4.2.4.3.3)**.
SDG 15 Life on land	Often local livelihoods are believed to be in conflict with conservation and are restricted by rules and regulation that impede local economic development and effectively criminalize customary activities. Where conservation actions are co-designed and co-managed with local communities, they can support recovery of species and further sustainable use. Nature-based tourism as a complementary activity that substitutes completely, or partially, unsustainable use of wild species requires a fundamental re-organization of a community's economic and social structure. Local communities who participate in nature-based tourism and receive tangible benefits from it tend to become cautious in their use of natural resources and more likely to support conservation **(3.2.1, 3.3.3.4.1, 3.3.4.3.2, 3.3.5.2.3)**. There is increasing recognition that cultural diversity plays a pivotal role in sustainable use of wild species. A growing body of work indicates that multi-use systems and de-centralized, small-scale community and household economies adapt more readily to variability and shocks in the availability of wild species. They also have benefits for social equity and community well-being. Tenure arrangements that secure local rights over land and resource use and trade, management systems co-designed with indigenous peoples and local communities, clear incentives and equitable sharing of benefits can lead to sustainable use, diversification of livelihoods, and biodiversity conservation. There is evidence that centralized management has failed to ensure sustainable use in several instances **(4.2.2, 4.2.4.2, 4.2.5.1)**. The Convention on International Trade in Endangered Species of Wild Fauna and Flora is an international treaty to prevent species from becoming endangered or extinct because of international trade. Trade bans were important in the recovery of many species but depending on the resource and the circumstances they may have unintended consequences. Indiscriminate/blanket trade bans create the risk of undermining the potential for sustainable use to provide critically-needed revenue and incentives for conservation. Mediating factors such as the scale of trade, species characteristics, governance, trade relationship, local incentives for conservation, supply chains and market demand are important in determining the sustainability outcomes of a particular trade. Empowering local people to capture legal benefits from trade in wild species can be an important step in reducing excessive illegal harvests, when efforts to provide alternative livelihoods are unsuccessful. It can further lead to species conservation efforts, by creating an incentive to mitigate other threats to biodiversity, such as habitat loss through land conversion **(4.2.4.3.1)**.

Table 1 3

SDGs	**Potential contributions of the use of wild species to achieve the Sustainable Development Goals** (Numbers in brackets refer to sections in the chapters that provide underlying evidence)
SDG 16 Peace, justice and strong institutions	Effective governance of wild species can contribute to peace, justice and strong institutions, especially where indigenous peoples and local communities are dependent on these resources for food, medicine, and other purposes. Investments in strong, transparent institutions, distribution of information through clear communication, and a focus on rights and equity support more sustainable, just outcomes. Illegal and unsustainable use of wild species is often linked to international criminal organizations **(3.3.1.4, 3.3.3.2.4, 3.3.4.2, 4.2.2, 4.2.4.3.2, 4.2.2.6)**.
SDG 17 Partnerships for the Goals	Many systems for sustainable use of wild species currently involve partnerships that contribute to achieving one or more sustainable development goals (see, especially, 14 and 15) and provide an arena in which cross sectoral and multi-lateral cooperation can be further strengthened. For example, scientific reports on fisheries and forests produced by the FAO are important mechanisms for developing and transferring scientific information, which could be enhanced by additional attention to how effective governance of practices such as gathering can strengthen progress toward goals 1, 2, 3, and 5. Likewise, the United Nations Permanent Forum on Indigenous Issues can raise awareness and disseminate information about indigenous rights, as well as strategies to support indigenous and local knowledge and build capacity among indigenous peoples and local communities. Global commercial trade in wild species is worth billions of US dollars, with goods flowing mostly from developing to developed countries. Many existing governance and institutional frameworks for the sustainable use of wild species include provisions to ensure equitable distribution of benefits. However, implementation is often flawed, with adverse consequences for social and ecological sustainability. Evidence shows that where benefits are equitably shared with the communities who are custodians or primary users of wild species, this can lead to overall progress towards all Sustainable Development Goals **(1.5, 3.2.4, 3.3.1.4.4, 3.3.2.3.2, 3.3.4.4.1, 3.3.4.4.3, 3.5, 4.2.2, 4.2.3.4, 4.2.4.2)**.

While this assessment and previous ones (1.5) highlight the critical role that sustainable use of wild species can play in eradicating poverty (Goal 1) and reducing inequalities (Goal 10), only one target (1.4) of Goal 1 explicitly mentions natural resources and implies that control of those can contribute to eradicating poverty. Evidence shows that sustainable use of wild species is central to the livelihoods and resilience of billions of people. While not captured in formal statistics, personal consumption of wild species and trade in informal markets are particularly important to the capacity of people in vulnerable situations to meet their basic needs (see Chapter 3). The sustainable use of wild species is also central to long term strategies for financial stability and employment, especially in rural communities, where personal consumption can free up monetary resources for other purposes, and trade in formal and informal markets can generate income in the same order of magnitude as some national employment sectors. In particular, sustainable use of wild species is critical for many women's financial independence and contributes to giving them a role in decision-making. At the State level, many sustainable uses of wild species occur in developing countries, including non-extractive practices, with many exported globally as a national asset. However, one cannot expect to fully eradicate global poverty or inequalities, solely on the basis of sustainable use of wild species. Indeed, evidence demonstrates that to remain sustainable, uses must respect ecological boundaries and social contexts, which can be exceeded or disrupted when subjected to intensification. Good governance frameworks are critical to ensure that use remains sustainable while benefiting people in the most vulnerable situations, who are in most cases the custodians and harvesters of the species (see Chapter 3 and Chapter 4). This is linked with the opportunities that sustainable use of wild species offer for providing decent work and economic growth, which are at the core of Goal 8 (see below).

Three out of the five outcome targets of Goal 2 relating to ending hunger focus on agriculture. This emphasis overlooks the critical contributions that wild foods make to the nutrition of many people, including those in the most vulnerable situations (see Chapter 3). Recognizing the contributions of wild species in food policies could enhance nutritional outcomes, provided long-term availability of these resources is prioritized. Doing so would also help to avoid undermining current contributions of use of wild species to ending hunger, noting the need for attention to both near-term and long-term outcomes. For example, agricultural expansion may produce short-term improvements in development status while reducing long-term access to wild species as safety nets in times of individual or collective crisis, with especially adverse consequences for the most vulnerable peoples. Sustainability of a use will depend on the relationship between commercial and subsistence harvesting, and whether local communities receive equitable sharing of the benefits from harvests (see Chapter 4).

Targets of Goal 3 on achieving good health and well-being do not provide much insight into the contributions that wild species can make to this goal. However, through use in many traditional medical systems and the pharmaceutical industry, as well as their contributions to sound and nutritious food (see above), sustainable use of wild species plays a role in reducing child mortality, healing vector-borne diseases and preventing non-communicable diseases. Extractive and non-extractive practices can play a central role to achieve Target 3.4 aiming at promoting mental health and well-being. The use of wild species also carries health risks, however, as when zoonotic diseases are transmitted to humans through unsanitary handling or consumption of wild meat (see Chapter 3).

Goal 4 relates to giving access to quality education to all people, from small children to adults. Sustainable use of wild species indirectly contributes through the generation of income that in many instances is used to pay for education, especially among the poorest (see Chapters 3 and 4). More directly, practices associated with sustainable use contribute to target 4.4 on providing people with technical and vocational skills to have decent jobs and develop entrepreuneurship (see details below related to Goals 5 and 12, among others). The knowledge necessary to support sustainable use of wild species can greatly contribute to target 4.7 on acquiring knowledge and skills for sustainable development. In particular, inclusion of indigenous and local knowledge about sustainable use of wild species in school curricula and other programs can support culturally appropriate education for indigenous peoples and local communities, as well as broader understanding of sustainable lifestyles and an appreciation of cultural diversity for all. This also contributes to the social inclusion of people who are often marginalized (see Chapter 4).

In many local cases, sustainable use of wild species contributes to gender equality (Goal 5). Women participate heavily in the practices examined in this assessment, either as the head of the household in charge of providing food for their family through subsistence uses (see Goal 1 above) or through commercial sales of the species (see Goal 8). Examples identified in this IPBES assessment of the sustainable use of wild species demonstrate particularly key roles for women in fishing and gathering. Nevertheless, the literature shows that conditions supporting the sustainable use of wild species by women often are precarious, with most lacking rights over the natural resources they use. Further, when commercial uses of wild species enter large-scale markets women's practices frequently are taken over by men. Targets on gender equality and sustainable use of wild species influence each other mutually: efforts to increase the contributions of use of wild species to eradicate poverty and provide jobs could include measures that reduce inequality, in general, and contribute to gender equality, in particular (Goals 10 and 5, respectively).

As a primary tool for forest management, sustainable logging can play an important role in ensuring availability and sustainable management of water (Goal 6). The role of forest functions in the health of surface and ground water is widely recognized. Where logging is sustainable and contributes to the maintenance or restoration of healthy forests, it also can play a role in addressing water scarcity and improving water quality.

Sustainable logging also is a potential contributor to Goal 7, although views on its potential in this regard are mixed. Wood fuel and charcoal provide affordable energy for millions of people worldwide (Goal 7). However, the technologies used to burn wood fuel and charcoal often are not clean or safe and can create health risks (thus undermining Goal 3). Biomass energy from timber is increasingly common in Europe and North America, as is the development of combustion technologies that are clean and efficient. There is lack of consensus, however, on the net effect of forest management for the production of woody biomass energy on carbon budgets (Schlesinger, 2018; Sterman *et al.*, 2018), which could undermine progress towards Goal 13 on climate change mitigation and adaptation.

Goal 8 is closely related to other Sustainable Development Goals, especially Goals 1 and 5 to which the contribution of the sustainable use of wild species is discussed above. Wildlife watching and other non-extractive practices can be important components of the service industry, contributing to economic growth at local and national scales. Likewise, observations of wild species have triggered innovations, to increase harvesting ease and efficiency. Such innovations may enhance the sustainability of a use (e.g., design of fishing gear to reduce bycatch) or they may decrease sustainability (e.g., through bigger fishing vessels and fleets with onboard processing that make it possible to increase catch volumes in waters farther from shore; see Chapter 4). More generally, resource efficiency is critical for the sustainability of many uses of wild species and is well reflected in this Goal. The sustainable use of wild species can thus bring much in terms of economic and social development, especially through high-added value uses, when all environmental and social safeguards are implemented. However, the sustainable use assessment also raises cautionary flags about the potential for efforts aimed only at economic growth, noting the need for attention to both near-term and long-term sustainability outcomes. For example, unregulated recreation and tourism development may produce short-term improvements in development status while reducing long-term access to wild species as safety nets in times of individual or collective crisis, with especially adverse consequences for peoples in the most vulnerable situations (see in 1.5 above: FAO, 2018b, 2020a; HLPE, 2017; IPBES, 2018b, 2018a; Vira, *et al.*, 2015).

The contribution of wild species to Goal 9 is a double-edged sword. The sustainable use of wild species inspires and is central to several big industries such as the construction, food, pharmaceutical, cosmetic and fashion industries. Many local users of wild species also rely on them as the basis for small-scale industries. The production scale will greatly impact the sustainability of the use. When the demand from industry for a species is too high to be sustained from the wild, the species can be cultivated or bred (e.g., plantation of forests for timber) (see **Box 1.1**), in the field or in laboratories. Such alternatives can jeopardize the sustainability of local uses of the species, whose sales to the industry provide income to the local communities. For example, small-scale fisheries are threatened by industrial fishing, in many cases placing the viability of small-scale fisheries communities at risk (see Chapter 3). They can also lead to other environmental concerns when it comes to the production of feedstock, such as land use conversion for cultivation or depletion of wild populations to supply raw materials for the synthesis of pharmaceuticals (see Chapter 4).

With regard to sustainable use of wild species, Goal 9 is closely linked with Goal 12, which focuses on sustainable production and consumption. The IPBES assessment of the sustainable use of wild species notes that private companies often do not divulge the origin of the products they process, and that the assessment of the social dimension of sustainability is often neglected in current sustainability assessments of supply chains. Improving those would contribute to target 12.6 under the Sustainable Development Goals and enable individuals to make more informed decisions about the sustainability of their consumption practices (target 12.8). This IPBES assessment also identifies key elements, enabling conditions and criteria for sustainable use of wild species to inform industries and companies that have wild species in their supply chains or work in areas that provide habitat for such species. Business schemes for the sustainable use of wild species (e.g., certifications and labels) can contribute to Goal 12, but need to be implemented with care. Indeed, research indicates that some of them create inequalities, and thus undermine progress towards other Sustainable Development Goals, such as Goal 5 or Goal 10.

As noted above, sustainable use of wild species can play an important role in reducing poverty, especially among people in vulnerable situations. As such, it can help reduce inequality within countries (Goal 10) by supporting food security, health and well-being, access to education, gender equality, and incomes (see Goal 1-5 and 8). These functions of sustainable use of wild species, as well as their contributions to maintaining cultural identity, can be especially important to indigenous peoples and local communities. Establishment of laws and policies that support indigenous peoples and local communities' rights of access to land, waters, and wild species for sustainable use will reduce inequality within and among countries.

Sustainable cities and communities are at the core of Goal 11 and impact the sustainable use of wild species in two different ways. While Goal 11 only mentions green spaces (target 11.7) that may be a relevant contribution of wild species, the other contributions that the sustainable use of wild species can make to increase the sustainability of cities need to be highlighted. City-dwellers gather fungi and wild plants in urban environment and benefit from non-extractive practices such as bird watching and forest bathing (see Chapter 3). In that sense, target 11.7 which aims to provide universal access to green spaces reflects well the potential contributions of wild species. City-dwellers also use wild species coming from peri-urban or rural areas, with attendant effects on the sustainable use of wild species outside. Awareness of such practices is increasing in Europe and North America, where the use of wild species may be seen as more sustainable than alternative resources (e.g., game meat instead of ranched cattle, wood fuel instead of fossil-fuel energy). Recent rural migrants to cities also bring knowledge and practices with them, which they may continue to draw on in urban and peri-urban environments. The IPBES assessment of the sustainable use of wild species notes (see e.g., Chapter 4) that high urban demand for wild species imported from rural areas may lead to their overexploitation, especially in the cases of wood for cooking and heating or game meat for food. Aiming for the sustainable use of wild species in urban contexts could contribute to several targets of Goal 11, especially target 11.6 about reducing the environmental impact of cities and target 11.A on the economic, social and environmental link between urban, peri-urban and rural areas. Another component of Goal 11 appearing in target 11.4 relates to the protection of the world's cultural and natural heritage, which are both closely interlinked as this assessment demonstrates: many cultures around the world are built around their relationship with nature, and their use of it. Likewise, many features of the world's natural heritage are influenced by people's use of nature (Brondízio *et al.*, 2021; Ellis *et al.*, 2021).

The sustainable use of wild species is at the very core of Goal 14 for marine resources and of Goal 15 for terrestrial and aquatic species. Sustainable use of wild species will contribute to and benefit from the sustainable management of ecosystems (see Chapter 2). More generally, it will contribute to biodiversity conservation efforts. Efforts towards conservation and sustainable use of wild species and against drivers of unsustainable use are directly mentioned in 13 out of the 16 targets assessed. Nine of those targets were to be met by 2020, as they reflected the Aichi Biodiversity Targets adopted as part of the Strategic Plan for Biodiversity 2011–2020. As highlighted by the IPBES global assessment and the 5th edition of the Global Biodiversity Outlook (CBD, 2020), those targets were not met. There is therefore a great need for reinforcing the sustainable use of wild species across the globe, so that it can deliver its potential for biodiversity conservation. All relevant targets for sustainable use in Goal 14 and 15 are addressed by the IPBES assessment of the sustainable use of wild species, including through its analysis of non-extractive uses. For example, target 14.7 includes sea-based tourism as a development pathway, especially for Small Islands Developing States. While sustainable use of wild species will necessarily contribute to the targets related to sustainable management, conservation of biodiversity and phasing out of subsidies leading to overexploitation (mentioned only in target 14.6 for fishing), it should be noted that illegal, unreported and unregulated uses targeted in 14.4 and 15.7 are not in all cases unsustainable (although they often reflect a lack of efficient governance which often leads to unsustainable use), just as legal uses are not in all cases sustainable (see Chapter 4). Progress towards Goals 14 and 15 could therefore take into account local practices, including which species are targeted, which ones are incidentally captured, how much is taken from the wild etc. to better inform regulations around uses. Species management will likely have to evolve under the influence of multiple drivers, such as climate change (see Chapter 5).

There is no target of Goal 16 on peace, justice and strong institutions that points to the sustainable use of wild species as a way forward. Impacts of armed conflicts on sustainable use are diverse and varied across contexts and through different direct and indirect pathways. Much evidence shows that illegal harvest of wild species has been used as a financial means by organized crime and armed conflict operations, while sustainable use practices offer more desirable alternatives to the populations. The end of armed conflicts and return of peace often provide opportunities for local and rural communities, however unregulated uses due to lack of governmental control in previously inaccessible regions pose significant risks to sustainable use. Inclusion of local communities in the management of natural resources in post-conflict areas improves governmental control and promotes the sustainable use of resources (see Chapter 4). As further evidenced by this assessment, sustainable use can also support better decision-making, by giving a voice and weight to communities that are otherwise missing from decision-making processes.

Target 17.14 of the Sustainable Development Goal on partnerships for the Goals is on enhancing policy coherence for sustainable development. As evidenced throughout this analysis of the actual and potential contributions of sustainable use of wild species to the Sustainable Development Goals, sustainable use of wild species can be an entry point for many policies related to sustainable development, both in developed and developing countries. Since it relates to so many Sustainable Development Goals, a successful policy for sustainable use of wild species would increase overall policy coherence. Indicators for the sustainable use of wild species are still lacking for many social dimensions (see Chapter 2). Working on those could contribute to target 17.19 on measuring progress toward sustainable development. Those two points are the main contributions that sustainable use of wild species can make to Goal 17, but other targets related to international cooperation on and access to science (17.6), the development and transfer of environmentally sound technologies (17.7), the increase of the contribution of developing countries to global trade (17.11) and the creation of public, public-private and civil society partnerships (17.17) would benefit from it as well.

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Chapter **2**

CONCEPTUALIZING THE SUSTAINABLE USE OF WILD SPECIES[1]

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Chapter 2

Chapter **2**

CONCEPTUALIZING THE SUSTAINABLE USE OF WILD SPECIES

EXECUTIVE SUMMARY

1 **The sustainable use of wild species is conceptualized in multiple shifting ways. It has changed considerably over time and differs strongly across cultures. Nonetheless, common attributes of different conceptualizations emphasize that sustainable use is dynamic and emerges from social-ecological systems that aim to maintain biodiversity and ecosystem functioning in the long term, while contributing to human wellbeing *(well established)* {2.2.2, 2.2.3, 2.2.4}.**

2 **In the academic literature, conceptualizations of sustainable use in the different practices have generally broadened along similar pathways but with different timings *(well established)* {2.2.3}.** Initial focus was on avoiding excessive harvests or stress on the specific populations being used. Interest in the economic performance of the practice generally followed, as did a growing accommodation of concern for more inclusive ecosystem properties that might be altered by each practice. Social concerns other than revenue and employment in large scale operations were usually a minor or neglected factor in how sustainability was conceptualized until the latter part of the 20th century. These generally appeared first in terms of supporting local employment and livelihoods, and then governance aspects also became part of the discussion, largely in the contexts of inclusiveness and equity in decision-making. Only quite late in the development do matters of culture, identity, community wellbeing and spiritual values appear as elements that are fundamentally interrelated and inseparable from ecological and socio-economic aspects, other than in conceptualizations by indigenous peoples and local communities, where they have long been central.

3 **In the 21st century broad ecological and social aspects of sustainable use dominate academic literature for all practices *(well established)* {2.2.3}.** The dominant ecological aspects focus on how commercial harvesting may damage habitats, cause incidental mortalities, and alter relationships in ecological communities. Small-scale livelihoods are a central consideration in sustainable use, with governance issues, including equity and social justice, increasingly prominent in conceptualizations. There is growing focus on a wider range of ecosystem services provided by sustainable use, acknowledgement of the need to co-produce information across diverse knowledge systems when evaluating sustainability or seeking more sustainable practices, and to exercise greater risk aversion in the face of growing awareness of the many sources of uncertainty. The 2015 Sustainable Development Goals are prompting debate among experts regarding appropriate benchmarks for sustainability. Overall, there is high agreement that ecological, socio-economic and socio-cultural factors are central to sustainability, but no census among experts regarding their most appropriate balance.

4 **Indigenous and local worldviews on sustainable use are highly diverse but often share a common focus on reciprocal connections and respect shared between human and non-human "relatives", community well-being, and social responsibilities to care for people and place *(well established)* {2.2.4}.** Indigenous and local worldviews, including their associated sustainable use and harvesting practices and knowledge are encoded in cosmologies, myths, stories, songs, rituals, and numerous other forms of cultural expression. Informed by place-based practices and lifeways that have been developed and refined over centuries and generations, the diversity of indigenous and local worldviews enhances understandings of the natural world.

5 **Customs and norms are critical components of indigenous peoples and local communities' conceptualizations of sustainable use and serve a key role in the stewardship, management, and care for wild species *(well established)* {2.2.4, 2.2.8}.** Cultural norms and practices surrounding the sustainable use of wild species are heterogeneous and dynamic across indigenous peoples and local communities but share important commonalities. Sustainable use practices are often guided or informed by intricate and nuanced combinations of spiritual customs and ceremonial practices, regulations, sanctions, and taboos, respect for wild species as kin, sharing across social networks, and maintaining and transmitting indigenous and local knowledge.

6 **International and regional standards, agreements and certification schemes for sustainable use have a common emphasis on not causing serious or irreversible harm to biodiversity and supporting the**

material and non-material contributions of biodiversity to human wellbeing *(well established)* {2.2.5}. A set of key elements that span themes in five broad categories were identified: ecological impacts, management and monitoring, socio-economic benefits, governance, and education *(well established)* {2.2.6}. These elements encompass ideas from the ecosystem approach and the precautionary approach. Most documents include elements of the first four of these categories, indicating that this arena is consistent with academic literature and indigenous and local knowledge and practices. Within those broad categories, the following concepts are present in sustainable use key elements:

- Respect for laws, policies and institutions;
- Respect for local community rights and access;
- Effective interlinkages among levels of governance;
- Empowerment of local communities;
- Respect for customary law;
- Minimization of ecological impacts;
- Restore and/or improve ecological context;
- Management and monitoring plans are in place;
- Adaptive management;
- Minimization of waste;
- Use of participatory approaches to monitoring and decision-making;
- Integrate science and indigenous and local knowledge;
- Provision of socio-economic benefits;
- Provision of local capacity building;
- Fair and equitable sharing of benefits;
- Support for workers' rights and health;
- Provision of socio-cultural/community wellbeing benefits;
- Raising of understanding and awareness.

Ideas missing or less explicitly represented in the list of key elements, but that represent core dimensions of many indigenous peoples and local communities' conceptualizations, include reciprocity between people and nature, respect for nature as kin, sharing networks, cultural continuity and community health and wellbeing as fundamental, interconnected aspects of sustainable use.

7 Global policy agreements and policy statements on sustainable use of wild species show substantial uptake of most key elements of sustainable use *(established but incomplete)* {2.2.6, 2.2.7}. There has been lesser uptake of elements related to minimizing waste and support for workers' rights and health. There was similar uptake of elements among organizations and agencies with business/corporate, environmental non-governmental and intergovernmental perspectives. At the regional scale, conventions, policies, and regulations of regional bodies with jurisdictional foci on fishing, hunting, and logging differ in completeness of coverage of the key elements of sustainable use, with much more complete coverage in forestry than the other practices. Binding agreements for fishing display the strongest integration of these seven key elements, although two social key elements (inclusive and participatory decision-making, acknowledgement of rights and equitable distribution of benefits) remain largely absent, as regional fisheries management organizations commonly only have jurisdiction outside national jurisdictions, such that policies on local communities, levels of governance, and customary law are devolved to their member States.

8 At the national scale, a review of national biodiversity strategies and action plans show that there is substantial consistency between how countries approach the uses of biodiversity within their country and the Addis Ababa Principles for Sustainable Use *(established but incomplete)* {2.2.9}. National uptake of Addis Ababa Principles for adaptive (Principle 4) and participatory (Principle 9) management, for addressing the threats to ecosystem services, structure and functions (Principle 5), and for education and knowledge-sharing (Principle 14) were very high. There has also been high uptake of Addis Ababa Principles relevant to inclusive and participatory governance models for development (Principles 1,3 6) and implementation (Principles 2,7,13) of national policy frameworks for sustainable use of wild species. However, aspects of the corresponding principles that directly focus on roles of indigenous peoples and local communities appear to have had less explicit uptake in the national biodiversity strategies and action plans {2.2.9.3}. Almost all of the national biodiversity strategies and action plans include provisions that policies should take into account current and potential values derived from the use of biodiversity in relation to market forces affecting the values and uses (Principle 10). However, commitments to reduce perverse incentives (Principle 3) and to minimize waste (Principle 11) are much less common. Similarly, it is uncommon to find information on accommodation and valuation methods for non-monetized values of the uses of biodiversity, including spiritual and/or relational values (Principle 10).

9 **The ecological and economic aspects of sustainable use are almost fully embraced in policy commitments at all levels, with almost comparable uptake of macro-economic, employment, and general quality of livelihoods *(established but incomplete)* {2.2.10}.** Uptake in policy does not ensure success at or even adequate resourcing for implementation, but it provides a strong foundation for unified and integrated efforts at achieving and maintaining sustainability. The foundations in national policies for efforts at the more socio-cultural aspects of sustainable use are weaker and less unified.

10 **The Sustainable Development Goals are highly relevant to dialogue on policy and progress for sustainable use of wild species. However, less than half of the associated indicator framework considers the use of wild species at all, and at most a third of the framework expresses sustainable use of wild species strongly *(well established)* {2.3.2}.** The relevant indicators in the Sustainable Development Goals Global Indicator Framework are consistently more sensitive than they are specific. The greater sensitivity means that when the sustainability of any or all of the practices in an area change, the changes are likely to be captured by relevant indicator values. However, the low specificity means that changes in the indicator values cannot be attributed to comparable changes of any specific practice, posing challenges to identify specific changes to policies, regulations or customary activities to respond to the indicator. Many of the ecological, economic and governance indicators in global and regional indicator sets have low sensitivity or specificity for the sustainability of individual practices, thus requiring substantial contextual information to be interpreted reliably *(established but incomplete)* {2.3.4}.

11 **As conceptualizations of sustainable use have changed over time, indicators for sustainability have also shifted. Ecological, economic, and social components of sustainable use are present in several global indicator sets. Yet there remain gaps around indicators that convey social-ecological linkages and socio-cultural benefits *(established but incomplete)* {2.3.2, 2.3.3, 2.3.4}.** Today, global indicator sets for sustainable use of wild species capture many ecological, economic and social components of sustainable use that are broadly agreed upon in the academic literature, and that are present in global standards and policy agreements for sustainable use, especially for fishing and logging. Global and regional indicator frameworks for gathering, non-extractive practices and terrestrial animal harvesting are largely lacking *(established but incomplete)* {2.3}. Those indicators overlap with some used in indigenous peoples and local communities. However, there are some widely agreed upon aspects of sustainable use of wild species that are poorly represented in global indicator sets. These include indicators that capture social-ecological linkages and those that relate to socio-cultural benefits. Indicators that relate to indigenous peoples and local communities' community rights and access are also poorly represented even though these ideas are well represented in the key elements of global standards for sustainable use of wild species. Little monitoring combines indigenous and local knowledge with scientific monitoring methods. Progress towards addressing these conceptual shortcomings will contribute to reduce inefficiencies and inequity in the management of the use of wild species *(well established)* {2.2.10, 2.3.4}. These targets and indicators will therefore require periodic revision, as knowledge and experience grow and public policy dialogue progresses *(well established)* {2.3.1, 2.3.4}.

12 **Increased and improved collaboration with indigenous peoples and local communities represents an important opportunity for better measuring and monitoring sustainable use across local to global scales *(well established)* {2.3.3, 2.3.4}.** Methods for tracking sustainable use have long been used by indigenous peoples and local communities to monitor linkages among ecological and social elements, including community wellbeing and cultural continuity. These approaches can inform development of appropriate global and regional indicators. Likewise, collaborations with indigenous peoples and local communities as well as other communities to co-create local metrics can help adapt global, regional or national indicators to local realities.

13 **Overall, this chapter shows that although there are many broad commonalities, conceptualizations of sustainable use of wild species are also highly dynamic and variable over time and across practices, cultural and social contexts *(well established)* {2.2.10}. Successful adaptation and negotiation require attention to the dynamics of both the social and ecological contexts of uses *(well established)* {2.2.3.7}.** The diversity of ways in which sustainability is conceptualized means that there is no "one size fits all" approach to appropriately and effectively characterize, measure and monitor sustainable use. The policy and practical implications of this legitimate diversity of conceptualizations of "sustainable use" will be explored in the rest of this assessment.

2.1 INTRODUCTION

This chapter provides context central for the assessment by examining how sustainable use is conceptualized and monitored. It is divided into two themes. The first theme explores how sustainable use of wild species is conceptualized in different contexts and scales – from global to national to local (including indigenous peoples and local communities), and across practices (fishing, gathering, terrestrial animal harvesting, logging and wildlife watching). It reviews broad conceptualization of sustainable use of wild species in the academic literature prior to the 1980s, followed by review of the literature in each practice from the 1980s to 2010, and a detailed review of new ideas and consensuses emerging in the most recent decade. This is followed by a review of conceptualizations of sustainable use by indigenous peoples and local communities. To identify how sustainable use of wild species is conceptualized in global and regional sustainable use agreements, standards and certification schemes, and if it is consistent with the academic literature and with indigenous peoples and local communities' conceptualizations, a review of the key elements in these documents is carried out. The subsequent section then examines if and how the key elements are reflected in policy commitments on sustainable use at the global, regional, and national scales.

The second theme reviews how sustainable use of wild species is measured and monitored. This is addressed by identifying, comparing and contrasting indicators used to measure and monitor sustainable use of wild species across scales, from global to indigenous peoples and local communities, and across practices. The chapter concludes with a crosswalk of the academic literature, global key elements and policies, and indigenous peoples and local communities' conceptualizations with indicators, to identify which ideas about sustainable use are captured in commonly used metrics of sustainable use and which are poorly represented.

2.2 HOW IS SUSTAINABLE USE CONCEPTUALIZED AND HOW HAS THE CONCEPT EVOLVED?

2.2.1 Overview of approach

"Sustainable use" can mean very different things to different people, agencies, and institutions (Cooney, 2007). Ideas about sustainable use have also varied greatly over time. The scientific (natural and social) and economic/policy literature on the concept of sustainability and sustainable use reviewed in sections 2.2.2 ad 2.2.3 is dominated by publications from the perspectives of countries from the Global North, particularly prior to the 21st century. With many of the foundational policy documents drafted and negotiated in the late 20th century these perspectives on sustainable use are prominent in the language of international agreements and other policy documents. However, concepts of sustainable relations of humans and nature are found in all cultures, and not solely cultures rooted in the western, largely Judeo-Christian world. By the United Nations Conference on Sustainable Development in 1992, the voices of indigenous peoples and local communities were increasingly prominent, with recognition that their cultural practices and traditional livelihoods have been tied closely to nature, often including values and approaches that are inherently oriented to sustainable uses of nature. This knowledge of indigenous peoples and local communities is recognized by IPBES and increasingly by the international policy world (Hill *et al.*, 2020; Thaman *et al.*, 2013). Section 2.2.4 introduces some of the diversity of conceptualizations and perspectives of indigenous peoples and local communities on the notion of "sustainable use", together these overviews of evolving perspectives provide a foundation to discuss what differing worldviews, values and resultant conceptualizations may mean for policies and practices on the sustainable use of wild species.

2.2.2 Historical development of the concept of "sustainable use" in the global conservation arena

Ideas and conceptualizations of sustainability have a long and complex history. In this section, the historical background of academic, largely western, conceptualizations of sustainability is presented, focusing mainly on aspects related to the sustainable use of wild species. Following this, the narrower and shorter history of the explicit use of the concept 'sustainable use of wild species' is narrated. The historical account presented in this section is based on a literature review of 179 sources. The data management report for this review is available at: https://doi.org/10.5281/zenodo.6472995.

2.2.2.1 Historical background of western conceptualizations of sustainability

The word ‘sustainability’ did not emerge in the English language until the early 1970s (J. A. Simpson *et al.*, 1989), but the German equivalent, *Nachhaltigkeit*, was coined in the mid-eighteenth century (Warde, 2011). However, the historical background of ideas and conceptualizations of sustainability extends beyond explicit use of the term. The survival and well-being of people has always depended on a sustained output of food and other material derived from natural resources. Considerations of sustained yield from the natural environment have existed at least since the agrarian revolution. However, the historical background of the conceptualization of sustainability reflects a societal issue and discourse that comprises more than local concerns over needs and benefits.

Sustainability in this context emerged in early modern Europe (Warde, 2018) and Japan (Caradonna, 2014). The conceptual development was to some degree global, as aspects of it related to the European exploration and colonialism of the period (Grove, 1995). The discourse on sustainability involved many factors related to the political, economic and environmental management of emerging nation-States and their increasingly proactive governance from the sixteenth century (Warde, 2018). As the state came to rely on revenue from the exploitation of natural resources to compete internationally in commerce, war and religion, the natural world increasingly became a political issue and object of the governance by nation states. The earliest discourses about state-governed sustained yield centered around the supply of grain and timber products (Grober & Cunningham, 2012; Scott, 1998; Warde, 2018).

The development of scientific, knowledge-producing networks in early modern Europe also played a central role in emerging discourse on sustainability (Warde, 2018). Many of the active network participants optimistically saw this knowledge generation as part of a larger project to improve states’ and privileged individuals’ wealth by increasing output of natural resources. By the end of the eighteenth century, development of methodologies for survey, measurement and control provided a quantifiable framework that enabled assessment of the degree to which natural resource output was sustained or not. This was particularly well developed within the emerging field of forestry. Technologies that made nature ‘legible’ to States in a quantified manner, were decisive in framing a particular conceptualization in the developing discourse on sustainability (Höhler and Ziegler 2010; Scott, 1998; Warde, 2018). During the industrial revolution, the limits of natural resources and degradation of environments became gradually clearer, due both to improved knowledge generation and highly visible environmental destruction. As a result, some of the optimism and beliefs in unlimited progress and growth diminished. The optimism was, replaced by a growing concern with sustainability and the realization that development and progress could potentially be unsustainable, and that individuals, the state and the environment might suffer from it (Dresner, 2008; Warde, 2018).

Timber was a valuable natural resource to the emerging nation states of Europe due to its military and industrial uses. As the industrial revolution and growing populations required increasing amounts of wood products, timber scarcity became a problem and issue for governance in many localities (Caradonna, 2014; Warde, 2018). Another factor that might have advanced discourses of sustainability related to timber was the long time horizon compared to other wild species in use; meeting timber demands required planning and governance that spanned human generations. It was in this context that Hans Carl von Carlowitz wrote *Sylvicultura oeconomica*, often viewed as the work that established forestry as a science and management field, and the first to explicitly address sustainable use of a wild species (von Carlowitz, 1713). Von Carlowitz saw the growing scarcity of wood as a threat to further progress of western civilization, and argued that if replanted and cultivated properly forests could produce a significantly higher timber yield that could be sustained over time (Hölzl, 2010; Warde, 2018; Wiersum, 1995; Worster, 1993). John Evelyn, Jean-Baptiste Colbert, Jean-Jacques Rousseau and Thomas Malthus also contributed to the further development of the discourse on sustainable forestry, and sustainability more generally (Caradonna, 2014; Dale, 2018, Du Pisani, 2007). Most western nations established forestry institutions to manage their forests in line with this ideology in the 18th and 19th century.

The pursuit of increased and sustained yield from natural resources that emerged with forestry in the 18th and 19th centuries had repercussions for the understanding and management of other wild species understood to be natural resources. Declining populations of wild terrestrial animals became a concern in the same period, both in Europe and, in particular, in areas under the influence of European colonization (Barrow, 2009; Worster, 1994). In North America, dramatic declines in once numerous species were clearly documented. During the 19th century, in particular, game animals came to be understood as natural resources in a utilitarian, resource conservation perspective inspired by agronomy and forestry (Dunlap, 1988; Scott, 1998). Correspondingly, game management institutions were established in many western nations and tasked with securing a maximized and sustained yield of game animals (Stokland, 2015; Worster, 1994). The eradication of game predators was widely thought to be a prerequisite for fulfilling this task, and became central to ‘sustainability’ of game management (Coleman, 2004; Robinson, 2005; Stokland, 2016).

In the late 19th century, a more ecologically-based and romanticist conservation ideology emerged with growing environmental movements. This ideology was more inclined towards preservation and ecological limitations, and developed in dialogue and tension with the utilitarian conservation ideology (Robinson, 2004; Worster, 1994). These ideological developments are exemplified by the conservation ethos and practices of Americans John Muir and Gifford Pinchot, respectively (E. W. Johnson & Greenberg, 2018), and the more utilitarian conservation ideology of Aldo Leopold (e.g., Leopold, 1933, 1949). Environmental movements became prominent in the "age of ecology" (1960s and 1970s) playing a central role in this formative phase of the sustainability concept (E. W. Johnson & Greenberg, 2018; Worster, 1994). The issues of pollution and pesticides, as well as ecological limits to growth, received increased attention after publications such as Rachel Carson's *Silent Spring* (Carson, 1962) and the Club of Rome's *Limits to Growth* (Meadows, 1972). Drawing public attention to environmental concerns, and emphasizing the science of ecology and a greater sensitivity to the ways in which human socio-economic and biophysical systems interact, the environmental movements prepared the ground for ecological issues to become prominent on governmental, business, and international institutions' agendas. A crucial step in this development was the linking of human well-being and economic development to ecological systems – familiar now as a central tenet of sustainability – in issues such as pesticides, water pollution, and smog (E. W. Johnson & Greenberg, 2018; Worster, 1994).

In the 1980s, sustainability became an identifiable and publicly discussed concept, growing out of the work of ecologists, economists, systems theorists, energy specialists, environmentalists, biologists and other scientists, and diplomats or appointees within the Organization of Economic Cooperation and Development and the United Nations (Caradonna, 2018). The political context of the 1980s, in which free-market economic logics rose to dominant influence, posed a major challenge to ideas about the limits of growth and ecological concerns. The concept of sustainability, which focused on self-interested movement towards production and development processes with both ecological and economic benefits, found its place on the international stage in this decade through the merger of environment and development concerns (E. W. Johnson & Greenberg, 2018). The United Nations adopted the concept of sustainable development in the 1980s and sponsored a series of conferences and committees notably the 1972 Stockholm conference, the 1980 report *World Conservation Strategy*, the 1982 *World Charter for Nature*, and the World Commission on Environment and Development that produced the report *Our Common Future (ibid)*. The latter popularized the notion that sustainability is about meeting current needs without jeopardizing the ability of future generations to satisfy their own needs.

Through initiatives such as the 1992 Rio Earth Summit, the 2005 Millennium Development Goals, and the 2015 Sustainable Development Goals, sustainability has become a mainstream concern. Now a standard feature of public and political discourse, most major institutions in the industrialized world have either a department or office of sustainability, and almost any business of a certain size has identified Sustainable Development Goals to which it contributes (Caradonna, 2018). The sustainability concept is seen by many as a critical reappraisal of the values of industrialism and growth-based capitalism, but has also received much criticism. A common critique of the concept, and particularly of the 'sustainable development' variant with its explicit focus on development, is that it represents little more than business-as-usual economic development that does not value the idea of living within biophysical limits (Caradonna, 2018; Purvis *et al.*, 2019; Robinson, 2004; Worster, 1993).

The tensions and critiques that have at times riddled the sustainability concept have a historical context. The sustainability concept has roots in ideologies of both economic growth and ecological limitations, intertwined in discourses on the maximization of natural resources use, the progress of nation states, environmental preservation, pollution and human health, ecological science, international collaboration and more, and has developed across multiple and shifting governance contexts and academic disciplines. As a consequence, sustainability has been conceptualized in multiple and shifting ways by different actors over time, including different understandings of the concept that stand in internal tension (Borowy, 2018; Caradonna, 2014; Mensah, 2019; Purvis *et al.*, 2019; Robinson, 2004; Warde, 2018). As such, there has never been consensus on what constitutes sustainability. However, the objective of avoiding environmental degradation that would lead to a worsening of human conditions in the future has to a large degree been a common denominator of the different conceptualizations. There has been less agreement on how this can be achieved, and whether, or to which degree, it can involve economic growth.

2.2.2.2 The conceptualization of sustainable use of wild species in international agreements

The Stockholm Declaration from the United Nations Conference on the Human Environment in 1972 contains no mention of the terms "sustainable", "sustainability", or "sustainable use" (Cooney, 2007). However, it states that natural resources, including fauna, flora and natural ecosystems, should be safeguarded for the benefit of present and future generations (Principle 2), and that the capacity of the earth to produce vital renewable resources should be maintained (Principle 3). Likewise, the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Ramsar Convention on wetlands, which both came into force in 1975, as well as the Convention on the Conservation of Migratory Species of Wild Animals, which came into force in 1983, were related to use of wild species (overexploitation through international trade, conservation and "wise use" of wetlands, and conservation and management of migratory species, respectively) without expressing it explicitly in terms of sustainability at the time. The United Nations Convention on Law of the Sea (1982) does refer explicitly to "sustainable yield" in both articles 61 and 119, in the context of status of harvested fish stocks, but does not extend the concept explicitly to more general biodiversity properties of the ocean. As is described further down, however, definitions in these conventions were developed in the following decades in parallel with the general development of the conceptualizations of sustainability and sustainable use.

The 1980 World Conservation Strategy, co-authored by the International Union for the Conservation of Nature, the United Nations Environment Program (UNEP) and the World Wildlife Fund, provided an early conceptualization of sustainable use as part of an overall conservation strategy. It recognized the essential role of use of nature and living natural resources in meeting the needs of all humans, and highlighted the importance of 'sustainable use' of living natural resources for conservation success. Similarly, the World Charter for Nature, that was adopted by the United Nations in 1982 and proclaimed five "principles of conservation", included the following conceptualization of sustainable use: "Ecosystems and organisms, as well as the land, marine and atmospheric resources that are utilized by man, shall be managed to achieve and maintain optimum sustainable productivity, but not in such a way as to endanger the integrity of those other ecosystems or species with which they coexist."

In 1987 the World Commission on Environment and Development (commonly referred to as the "Brundtland Commission") established the concept of sustainable development as a central vision and objective in international environmental policy, in *Our Common Future* (World Commission on Environment and Development, 1987). It had wide influence on the further understanding of sustainability in general, and on biodiversity conservation specifically. The sustainable use of wild species was mentioned explicitly in the report, but not thoroughly conceptualized. However, the report firmly established a specific conceptualization of biodiversity conservation related to sustainable use; first, it highlighted the importance of biodiversity for sustainable development, and second, it advocated the need to move beyond the "historical approach of establishing national parks that are somehow isolated from the greater society" (World Commission on Environment and Development, 1987: Part II, 6, V, 39), and address how development patterns affect biodiversity. Thus, the report emphasized the interdependency between biodiversity conservation and sustainable development.

In parallel with the development of the report from the Brundtland Commission, the Ramsar Convention's definition of wise use of wetlands was updated in 1987, as "their sustainable utilization for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem" (Ramsar Recommendation 3.3). The new definition reflected a similar understanding of the interactions between biodiversity conservation and use as the former report. Further, the 1980 World Conservation Strategy was updated in 1991, reiterating the importance of sustainable use of living natural resources for their conservation.

The sustainable use concept and its operationalization was given increasing attention within the International Union for the Conservation of Nature in the 1990s. A specific endorsement of the role of sustainable use in conservation strategies was made by the International Union for the Conservation of Nature General Assembly in Perth in 1990. Specifically, the International Union for the Conservation of Nature here endorsed the idea that under appropriate circumstances, use of living resources could itself contribute to their conservation. However, the specific meaning of sustainable use proved challenging to operationalize into recommendations at the time, because of the complexity of the issue and the balancing of environmental, social and economic aspects of sustainability (Cooney, 2007). The International Union for the Conservation of Nature sought to resolve these issues by the 1995 Sustainable use initiative and the formation of the sustainable use specialist group, as well as later efforts to identify the factors that influence the sustainability of use (Zaccagnini *et al.*, 2001).

The Rio Declaration adopted at the United Nations Conference on Environment and Development in 1992 further developed the concept of sustainable development from the Brundtland Commission's report, and included reference to "sustainable production and consumption", but did not make specific reference to sustainable use of wild species. However, the Convention on Biological Diversity was also an outcome of this conference, and sustainable use of biodiversity was granted a central position in it. Specifically, it constituted one of the three objectives of the Convention on Biological Diversity, which are the conservation of biological diversity (Article 1), the sustainable use of its components (Article 2), and the fair and equitable sharing of benefits from the use of genetic resources (Article 3). It was defined as follows: "Sustainable use means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations" (Article 2).

In 1994 the Convention on International Trade in Endangered Species of Wild Fauna and Flora adopted at its 13th Conference of the Parties Resolution 8.3: Recognition of the benefits of trade in wildlife. This constituted a recognition of some of the basic tenets of sustainable use, recognizing potential benefits of commercial trade to the conservation of species and/or ecosystems, and the potential of incentives for sustainable use of wild animals and plants to avoid conversion of wild landscapes to alternative land uses (Cooney, 2007). The resolution has been understood as a compromise, following intense debates over the position that the Convention on International Trade in Endangered Species of Wild Fauna and Flora should adopt in relation to sustainable use (Favre, 1993; Garrison, 1994).

In 1995 the Convention on Biological Diversity adopted the ecosystem approach as the "primary framework" of action to be taken under the convention (Decision II/8). The ecosystem approach was defined as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way" (Decision V/6). The approach directed attention to the structure, processes, functions and interactions within an ecosystem, rather than exclusively on specific elements such as single species or populations. This meant that the sustainable use of biodiversity is also considered from an ecosystem perspective, rather than understood narrowly as the maintenance of single species (Cooney, 2007).

At the second World Conservation Congress in 2000, the International Union for the Conservation of Nature adopted a Policy Statement on Sustainable Use of Wild Living Resources, as well as recommendation 2.92 on indigenous peoples, sustainable use of natural resources, and international trade. In 2001, the International Union for the Conservation of Nature presented the White Oak Principles of Sustainable Use, a short document establishing a definition, seven axioms and eight principles for sustainable use. The following definition was adopted for sustainable use: "Sustainable use, both extractive and non-extractive, is a dynamic process toward which one strives in order to maintain biodiversity and enhance ecological and socio-economic services, recognizing that the greater the equity and degree of participation in governance, the greater the likelihood of achieving these objectives for present and future generations". Thus, the conceptualization of sustainable use within the International Union for the Conservation of Nature was progressing towards the inclusion of social and economic aspects, emphasizing equity and participation in governance.

The Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity (see supplementary materials S2.1) were adopted in 2004, at the 7th Conference of the Parties to the Convention on Biological Diversity (Decision VII/12). They comprise a set of 14 "practical principles", each with associated operational guidelines. The conceptualization of sustainable use incorporated in these principles and guidelines indicate a progression towards inclusion of social and economic aspects similar to that within the International Union for the Conservation of Nature, and include topics such as supportive legislative and policy arrangements, empowerment of local resource users, removal of perverse incentives, adaptive management, and avoidance of impacts on nature's contributions to people.

A similar conceptualization of sustainable use was incorporated in the Aichi Biodiversity Targets, adopted in 2010 as part of the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011–2020. The targets addressed five strategic goals identified in the strategy, of which Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use, was directly related to the sustainable use of wild species. Aichi Biodiversity Target 6 addressed sustainable use and management of marine biodiversity (fish, invertebrate stocks and aquatic plants) in order to avoiding overfishing and other negative impacts on biodiversity. Target 3 addressed the removal of negative incentives, and development and application of positive incentives for conservation and sustainable use of biodiversity, while Target 18 addressed the integration in legislation and relevant international obligations of traditional knowledge, innovations and practices of indigenous and local communities relevant for ecosystem services and the conservation and sustainable use of biodiversity.

2.2.3 Current academic conceptualization of sustainable use by practice

2.2.3.1 Introduction

Although the history of expert research publications on the sustainable use of natured dates back a couple of centuries (section 2.2.2), publications with new interpretations of what constitutes sustainable use continue in all fields. Reviewing these evolving or new aspects of how sustainable use is conceptualized within each practice, and examining the commonalities and differences of these developments among the practices, is a crucial part of this chapter. It largely delineates the academic context within which the evaluations in the following chapters will be conducted, with implications for application of the conceptualizations as well.

This literature review summarizes widely agreed upon ideas of sustainable use up until 2010, and then reviews the post 2010 literature to identify new and emerging ideas. The review faced several challenges, related to the scope and size of the review; and the different publication rates among practices and between ecological and social aspects of sustainable use within practices. Those challenges are described, along with the review methodology that was designed to overcome them, in the data management report available at https://doi.org/10.5281/zenodo.6472995. As per IPBES protocol, the systematic reviews were focused on English language journals. Although these reviews include papers by authors from across the globe, trends reported here may not be representative across all regions and disciplines.

A challenge not discussed explicitly in the data management report was the many scales and value systems within which sustainable use may be conceptualized. Historically the research community has not been strongly focused on research on small-scale uses of nature. Nevertheless, it was important to this literature review (and this assessment) to capture developments in those areas. The academic literature has an intrinsic over-representation of reports from scientific types of knowledge, so thinking from other knowledge systems is under-represented. To deal with potential differences of coverage of various scales, the screening of "hits" was directed to be vigilant for papers with a focus on small-scale uses of nature, to ensure they would be well-represented in the papers evaluated in this review. Interpreting the findings of this literature review should be done with an awareness of these potential shortcomings in the academic literature, and should be complemented by information on the indigenous peoples and local communities' conceptualizations of sustainable use (section 2.2.4). The academic literature reviews for the five practices follow in sections 2.2.3.2-2.2.3.6. The outcomes of the literature review for each practice are presented separately, with the main findings summarized. Then a final subsection (2.2.3.7) highlights emergent patterns and messages that cut across all practices, as well as implications of any major differences that are present in the current academic literature on each practice.

2.2.3.2 Conceptualizations of sustainable fishing in the academic literature

The literature on sustainable fishing is particularly large. Consequently, even a high-level review of literature prior to 2010 has a relatively large number of influential references. Moreover, there is a policy benchmark in 2010 with Aichi Biodiversity Target 6, that gives a foundation presenting what the Parties to the Convention on Biological Diversity agreed as comprising sustainable use of fish stocks and the ecosystems in which they are found. Similarly, the very large number of post-2010 publications also influence the approach to both screening papers down to a feasible number to review, and allows the findings to be presented in a tabular as well as narrative format.

2.2.3.2.1 Conceptualization of fishing in academic and technical literature up until 2010

In fishing a parameterized conceptualization of sustainable use began as early as the 1950s, when benchmarks of sustainable or "optimal" use of the target species were identified (Beverton & Holt, 1957; Ricker, 1955). The biologically defined benchmarks such as Bmsy (the biomass producing maximum sustainable yield) were quickly adapted to reflect that economic aspects of fishing, such as cost per unit of fishing effort, were part of sustainability, with the benchmark of Bmey (biomass producing the maximum economic yield, Clark, 1973; Clark & Munro, 1975; Roedel, 1975). As the importance of precaution in uses of natural resources (Garcia, 1994; Richards & Maguire, 1998) gained traction, many papers subsequently challenged details of these benchmarks (Butterworth & Punt, 2003; Grafton *et al.*, 2007; Mace, 1994; Schnute & Richards, 1998). However, the conceptualization of sustainable use in fishing never abandoned the properties of both keeping biomass at or above a level producing a high yield (taking into account the productivity of a stock), and ensuring that macro-economically the costs of harvesting would be less than the revenues from the yield (Apkalu, 2009; Harris *et al.*, 2002; Holt, 2009; Martinet *et al.*, 2007). The latter resulted in early criticisms of subsidies as promoting unsustainable levels of fishing capacity; a criticism addressed with Aichi Biodiversity Target 3.

By the 1980s, fisheries management was challenged to include the ways that fishing impacted the food webs and habitats in which it occurred (K. P. Andersen & Ursin, 1977). This prompted development of analytical tools and models to assess the degree to which fishing on lower trophic levels might deplete the food supply of higher predators (Gislason & Rice, 1998; Hollowed *et al.*, 2000; Pope, 1991; Pope *et al.*, 2006; Sissenwine & Daan, 1991; Yodzis, 1994). or result in trophic cascades if populations of higher predators were depleted, allowing lower trophic levels to increase unchecked (Baum & Worm, 2009; Fogarty & Murawski, 1998; Gjosaeter, 1995; Sala *et al.*, 1998). The conceptualization of sustainable fishing correspondingly expanded to require consideration of both types of outcomes, and any other large or expanding alterations of trophic relationships (Fowler, 1999; Larkin, 1996).

Bycatches that depleted non-target species were also identified as a potential unsustainable consequence of fishing, and limiting bycatches to levels that did not deplete the populations of non-targeted species also became a standard for sustainable fishing by the 1990s (Alverson *et al.*, 1994). There was particular emphasis on minimizing, if not avoiding completely, the bycatches of marine mammals, seabirds, and other marine taxa with long life expectancies and low productivity (Dillingham & Fletcher, 2008; Niel & Lebreton, 2005; S. Zhou, 2008; Zydelis *et al.*, 2009). In parallel, the impacts of fishing, particularly with mobile bottom-contacting gears, on seafloor habitats and benthic species received substantial attention in the literature (Lindeboom & Groot, 1998; Rijnsdorp *et al.*, 1998).

Expert groups of the International Council for the Exploration of the Sea and other regional centres consolidated the burgeoning literature and developed standards and guidance for keeping such impacts within sustainable bounds (FAO, 1999; S. Zhou & Griffiths, 2008). Debate continued about whether the standards and benchmarks were set in the correct levels (Frid *et al.*, 1999; Furness, 2002; Kaiser *et al.*, 2000; J. C. Rice & Legacé, 2007; S. Turner *et al.*, 1999; J. L. Young *et al.*, 2006). However, there was no dispute within the expert literature that, as with trophic impacts of fishing, bycatches and habitat impacts had to be taken into account in evaluating the sustainability of fishing (FAO, 2009; Garcia & Cochrane, 2005).

By the later 1990s and 2000s, some contributions to a growing debate in the academic literature about ecosystem effects of fishing became strident and even adversarial, as disagreements about specific benchmarks, and the effectiveness of measures taken to achieve them, were debated (Corbin, 2002; Daan *et al.*, 2011; Jaenike, 2007; Mora *et al.*, 2009; Verweij *et al.*, 2010; Wilberg & Miller, 2007; Worm *et al.*, 2007; Worm & Myers, 2004). However, no fundamentally new ecological concepts were added to the conceptualization of sustainability of fishing. Rather, there was widespread interest in bringing the individual bio-ecological aspects of fishing together in what became known as the ecosystem approach to fishing (Bianchi & Skjoldal, 2008; Commission of the European Communities, 2008; European Union, 2008; Garcia *et al.*, 2003). This did change the dialogue regarding fishing sustainability from the presence or absence of individual properties in the fishery and its impacts to a dialogue about planning and conducting all the fishing in an area in coherent and compatible ways. This, too, became a part of the conceptualization of sustainable fishing (McLeod *et al.*, 2005; Ruckelshaus *et al.*, 2008). These conceptual advances were tracked and taken up by developments in fishing policy and practices, as reported in Chapter 6, section 6.4.1.

As the ecosystem approach to fisheries developed, there were important developments in global policy regarding social justice. The United Nations Conference on Environment and Development in 1992 (http://www.ciesin.org/docs/008-585/unced-home.html) and the World Summit on Sustainable Development (2002) (https://sustainabledevelopment.un.org/milesstones/wssd) brought the uses of wild species in planning development and poverty reduction to central places on the research and the policy stages (Berkes & Folke, 1998; Ostrom, 2009). In fishing, the developing ecosystem approach provided a ready setting for expanding the dialogue on the boundaries of an "ecosystem approach" to include social equity and community well-being as a part of any dialogue on the full "ecosystem" (Allison & Ellis, 2001; Andrew *et al.*, 2007; Berkes, 2003; C. de Young *et al.*, 2008; Schumann & Macinko, 2007). Guidance documents such as the Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fisheries in 1995 were found to give insufficient attention to social aspects of the sustainability of fishing. Publications such as Berkes *et al.*, 2001; Kurien, 2007; contributed to the guidelines on small-scale fisheries (FAO, 2015). Nevertheless, there continued to be calls for more input from experts on the social aspects of fishing outcomes and greater use of knowledge of indigenous peoples and local communities (Béné *et al.*, 2010; C. de Young *et al.*, 2008).

This was the landscape of points of general agreement in 2010 with regard to how sustainable use was conceptualized for fishing. This is affirmed in the very specific language of Aichi Biodiversity Target 6, in 2010. Among the first targets to be adopted at the 10th Conference of the Parties, it states: "by 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits."

It confirms in policy that sustainable fishing considers harvesting rate, provision for recovery of depleted stocks, bycatches and habitat impacts, particularly for species and habitats of special concern, and that the combinations of management measures and provisions can be integrated in an ecosystem approach; all themes which the expert literature had stressed as important. The benchmarks: "no serious adverse impacts" and "within safe ecological limits" came from earlier agreements, respectively the United Nations Sustainable Fisheries Resolution 61/105, which required bottom-contacting fishing gears to cause "no serious adverse impacts" on "vulnerable marine ecosystems" (https://undocs.org/A/RES/61/105), and the Marine Strategy Framework Directive of the European Union (https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm), which required impacts of uses of marine resources in waters of the European Union to be within "safe ecological limits". These benchmarks reflect the availability of evidence-based guidance on what comprised a serious adverse impact (FAO, 2013; J. C. Rice *et al.*, 2015), and "safe ecological limits" in general (European Commission *et al.*, 2011) and specifically for exploited species (Piet *et al.*, 2010), seafloor habitat and benthic species (J. Rice *et al.*, 2010), ecosystem processes (Rogers *et al.*, 2010) and biodiversity including threatened species (S. K. J. Cochrane *et al.*, 2010). Subsidies and other economic harmful incentives were not mentioned in Aichi

Biodiversity Target 6, but were addressed directly for all uses of biodiversity in Target 3.

Conspicuously absent in the Aichi Biodiversity Target 6 was reference to social outcomes as part of sustainable fishing. Those aspects were all covered in a single Aichi Biodiversity Target 14, with general language for all uses of biodiversity that "by 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable". The implications of actions to promote implementation of Article 8j of the Convention on Biological Diversity were a topic of debate throughout the 10th Conference of the Parties, such that consensus on the necessity of specific social outcomes was not reached.

2.2.3.2.2 Post-2010

The methods for the review of post 2010 literature is available at https://doi.org/10.5281/zenodo.6472995. **Table 2.1** presents the occurrence of the four traditional aspects of sustainable use in fishing in the over 400 papers considered for this analysis: the *target species* of the fishery, the *ecosystem context* in which the fishery occurred, the *economic context* and revenues from the fishery, and the *social context* in which the fishery occurred, supported livelihoods and distributed benefits. Comparable numbers of papers considered both the target species or species complex (126) and the ecosystem context in which the fishery occurred (117). Somewhat fewer papers considered the social context of the fishery (101) and fewer yet the economic context of fisheries (70).

Despite being the most common theme addressed, relatively little genuinely new thinking was presented about sustainable outcomes for the target species and species being incidentally harvested. Nearly half the papers presented new or revised methods for estimating the standard benchmarks for sustainable harvesting rates and/or sustainable levels of the populations being harvesting (Barneche *et al.*, 2018; Jusufovski & Kuparinen, 2020; Kindsvater *et al.*, 2020; Lassen *et al.*, 2013; Pilling *et al.*, 2016; Vasilakopoulos *et al.*, 2016; S. J. Zhou *et al.*, 2020).

The ecosystem context for the sustainability of fishing had a lower proportion of papers (<30%) simply elaborating alternative benchmarks for sustainable impacts, whereas a comparable proportion expanded the notion of "sustainable use" to broader ecosystem properties. Some of these are related to the harvest strategies, such as balanced harvesting of all sizes of fish and invertebrates in a community in proportion to their relative abundances (Garcia *et al.*, 2016; Law *et al.*, 2012, 2015; Plank *et al.*, 2017). Many were about the need to set harvesting benchmarks in the contexts of environmental dynamics, bringing climate change considerations directly into sustainable fishing. Only 15% of papers discussing sustainability of fishing in an ecosystem context addressed the social or economic aspects of fishing at the same time, with most of those dealing with ways to take into account the displacement of fisheries when applying spatial tools to protect some parts of the ecosystem from the impacts of fishing (Arkema *et al.*, 2015; Cinner *et al.*, 2019; Giron-Nava *et al.*, 2019; Lowerre-Barbieri *et al.*, 2019).

Fewer than 15% of all papers reviewed focused directly or indirectly on the economic context of fishing. Again, the single most frequently explored idea was simply alternative ways to estimate sustainability benchmarks for the economic performance of fisheries (e.g., Briton *et al.*, 2019; Brodziak *et al.*, 2015; Forrest *et al.*, 2018; Pascoe *et al.*, 2016; U. R. Sumaila & Hannesson, 2010) without actually reformulating economic sustainability. The detrimental aspects of subsidies are no longer a major point of debate suggesting that the intent of Aichi Biodiversity Target 3 has broad conceptual support, and the challenges now are on effective methods to reduce capacity-enhancing subsidies rather than debates about the benefits of doing so. However, papers on the potential benefits and possible negative social effects of formal eco-certification schemes as incentives for sustainable fishery activities showed a marked increase (Gutierrez *et al.*, 2016; Militz *et al.*, 2017), whereas eco-certification was still considered a feature restricted to economically elite fisheries prior to the 20-teens (Parkes *et al.*, 2010).

Nearly 20% of all papers reviewed looked directly at the social context of sustainability of fishing. This is a marked increase from 2010. Interactions of the social context of fisheries with environmental and economic considerations and the fishery itself all received attention, in contexts such as the role of socially well-adapted fishing in perpetuating particular ecosystem configurations (Caswell *et al.*, 2020; Tregidgo *et al.*, 2017) and the social status of fisher harvesters and traders in communities (K. L. Cochrane *et al.*, 2011; Pihlajamaki *et al.*, 2020; Twist *et al.*, 2016).

However, the importance of small-scale fisheries' contribution to community identity, livelihoods and overall wellbeing received the most focused attention (e.g., Asche *et al.*, 2018; Cinner *et al.*, 2016, 2019; Galland, 2017; Voyer *et al.*, 2017). These ideas were being discussed in the decades before the 20-teens (FAO, 2015) but in the 20-teens they have taken a central place in discussing sustainability of fishing. Correspondingly, fully 20% of the papers presenting new or adapted ideas of the social aspects of sustainable fishing deal directly with governance and or the use of alternative knowledge systems in sustainability of small-scale fisheries (Al-Humaidhi *et al.*, 2013; Groeneveld, 2011; Maravelias *et al.*, 2018; McClenachan *et al.*, 2014; O. R.

Young *et al.*, 2018). Primarily concerns in governance issues are how increasingly concentrated wealth and power can result in a small number of voices and perspectives having a disproportionate influence over governance processes (Cinner *et al.*, 2016; Hilborn *et al.*, 2020; Nielsen *et al.*, 2018; Osterblom *et al.*, 2017; Schultz *et al.*, 2015).

Prior to 2010, governance was conceptualized as an external factor that influences the sustainability of fishing in various ways whereas governance is now understood as an inherent aspect of sustainable fishing. Inclusiveness, equity and small-scale self-governance are widely argued to be essential to sustainability, which is a major development in the 20-teens. However, taking climate change directly into account in the prosecution and management of fisheries is still infrequent, with only 14 explicit mentions. It ranks well behind governance as an expanding concept in the conceptualization of sustainable fishing. Experts still primarily seem to consider climate change an external factor that needs to be taken into account in prosecuting and managing fisheries sustainably.

The identification and formal use of harvest control rules and quantitative or semi-quantitative benchmarks for the exploited stocks, species taken as bycatch, and impacts on seabed habitats has gained significant momentum through the 2010s, appearing in nearly 10% of all papers reviewed. The use of multiple knowledge systems is also being called for although not as a feature of how sustainability of fishing is conceptualized but rather, as a superior approach to evaluate any and all aspects of sustainability of uses.

Marine protected areas or their cognates are another frequent topic of literature on sustainable fishing in the 20-teens literature. Although highly protected marine protected areas by definition do not include fishing within their boundaries, proponents of high marine protected areas coverage argue that they are essential for conservation and the spill-over benefits from marine protected areas can be an important component of sustainability in fishing (Gjerde *et al.*, 2016; Laffoley *et al.*, 2021; Rochette *et al.*, 2014). Other experts argue that marine protected areas are simply one of many tools available to deliver sustainable outcomes from fishing. That tool needs to be planned and located with substantial care to deliver desired outcomes, particularly because marine protected areas often incur significant social and or economic costs, which frequently are distributed in very inequitable ways (Kockel *et al.*, 2020; Li *et al.*, 2020; Mizrahi *et al.*, 2020). Consensus is lacking on whether highly protected marine areas are sufficient or necessary to produce sustainable fishing, and their role in conceptualization of sustainable fishing is still unresolved.

Table 2 1 **Literature for fishing.**

Each paper was scored first on whether it addressed primarily the target species (population), the ecosystem impacts or sensitivity of a fishery (ecological), the value and financial incentives of the fishery (economic), or the social context in which the fishery operates (social). Then each paper was scored for which aspects of the other factors and whether the primary thrust of the paper was the performance and/or participation in the fishery itself (fishery), analytical methods (analytical), the role of governance (governance), a review of a relatively long historical time series (history), or the use of additional knowledge systems in evaluating the factor (knowledge).

“Traditional” aspects of sustainable fishing / Aspects of sustainable fishing in current literature	Population	Ecological	Economic	Social
Population	24	10	5	3
Ecological	8	35	5	13
Economic	13	5	11	13
Social	5	12	14	20
Fishery	3	17	4	15
Analytical	59	33	20	17
Governance	3	3	8	17
History	9	1	1	0
Knowledge system	2	1	2	3
Total number of papers	126	117	70	101

2.2.3.3 Conceptualizations of sustainable gathering in the academic literature

2.2.3.3.1 Introduction

Gathering encompasses a wide range of species (see Chapter 1), including plants and fungi, as well as animals such as frogs, turtles and crocodilians. Each of these is studied in disparate academic fields. The framing of gathering that has gained most attention in the academic literature is that of "non-timber forest products" or "non-wood products". This review focuses largely, but not exclusively, on the literature in this framing since it forms the bulk of published research on the topic. The data management report for this review is available at https://doi.org/10.5281/zenodo.6472995.

Discussions about the sustainability of gathering in the academic literature emerged in the late 1980s. Prior to this, there was a long history of research on the ecology, harvest, processing and trade of species that are gathered, but little mention of sustainability. When it did come up, ideas centered around tragedy of the commons (Sills *et al.*, 2011).

In the late 1980s the gathering of plants, algae and fungi began to be widely promoted in global conservation circles as a conservation strategy. It was considered an alternative to logging and livestock ranching – major causes of deforestation at the time – that could support local livelihoods while leaving the forest standing. As both governments and non-governmental organizations-initiated programs to promote plants, algae and fungi commercialization, academic discussions about the sustainability of gathering ensued. At first these discussions focused only on economic criteria, because the widely held assumption was that the ecological impacts of gathering were minimal (Sills *et al.*, 2011). Ideas and heated debates about sustainability centered on the economic contributions of gathering to rural livelihoods, including for subsistence, cash income and as safety-nets (Arnold & Perez, 2001; Belcher & Schreckenberg, 2007).

By 2010 however, the conceptualization of sustainable gathering had evolved to include economic, ecological and social components, with governance and management understood to be key components of the latter (Arnold & Perez, 2001; Belcher & Schreckenberg, 2007; Sills *et al.*, 2011; Ticktin, 2004). These components included supportive national policies, resource tenure to ensure benefits captured by those managing the resource, and strong institutions governing resource use including organization among producers, as well as equitable access and benefit sharing. In terms of management, effective inventory and monitoring, including strong community or local involvement in decision-making for management and monitoring, including co-management, adaptable resource management practices, and inclusion of traditional ecological knowledge in management plans were widely conceived to be critical aspects of sustainable use. Finally, transparency and integration along the value chain among producers, and inclusion of women were also recognized as key conditions for sustainable use (Arnold & Perez, 2001; Belcher & Schreckenberg, 2007; Sills *et al.*, 2011).

On the ecological side, most research conceptualized sustainability in terms of the maintenance of forest cover and/or the persistence of the harvested species. However, considerations of the effects of gathering on the broader ecological community, including of ecologically-related species and on measures of biodiversity and ecosystem processes were also discussed, if rarely measured (Ticktin, 2004).

The broad consensus however, which holds still today, was that given the vast array of species, life-histories, and types of use, and the widely different roles these play in local livelihoods, there is no one size fits all (Sills *et al.*, 2011).

2.2.3.3.2 Post-2010

Dynamic social-ecological systems

Conceptualizations of sustainable gathering have shifted in the past 10 years in multiple ways. First, sustainable harvesting is now frequently conceptualized in terms of dynamic social-ecological systems (Pezzuti *et al.*, 2018; Shackleton *et al.*, 2015), where ecological, economic, political and socio-cultural dimensions of gathering are both interdependent and inseparable (de Mello *et al.*, 2020). Similarly, sustainability is increasingly envisioned as a spatially and temporally dynamic phenomenon where harvest systems are in constant flux, with changes occurring at multiple levels and spatial scales and across the various components of the social-ecological system simultaneously (Pezzuti *et al.*, 2018). As such, conceptualizations of sustainability have shifted towards being context and scale-specific (Shackleton *et al.*, 2015).

Sustainability of multiple practices

In the social-ecological system framing, the sustainability of gathering is no longer considered in isolation from that of other land and resources uses with which gathering co-occurs. For example, scholars argue that sustainability of gathering cannot be conceptualized in isolation of the sustainability of logging and hunting, due to the feedback loops among these practices across many landscapes (Shackleton *et al.*, 2015; Ticktin, 2015). Similarly, sustainability of gathering is now frequently conceptualized in combination with that of interacting agricultural practices, including grazing and foraging of livestock, and associated fire regimes (Groenendijk *et al.*, 2012; Lybbert *et al.*, 2011; Sampaio *et al.*, 2012; Ticktin *et al.*, 2012, 2014). Consideration of feedbacks between gathering and invasive species has also emerged as a consideration for determining if a use is sustainable (Darabant *et al.*, 2016).

Sustainable use and ecosystem services

The effects of gathering on the provision of ecosystem services is now increasingly conceptualized as a component of sustainable use. This is usually framed as trade-offs across services, such as provisioning of plants, algae, fungi, timber, and carbon services (Granath *et al.*, 2018; Strengbom *et al.*, 2018; Triviño *et al.*, 2017), and the cost of production (Lambini *et al.*, 2018). Other authors argue that sustainable gathering could also include consideration of ecosystem services that have not been considered to date, for example the provision of services to other species, including food, shelter and resources used as medicine by non-humans (Shackleton *et al.*, 2018).

Socio-cultural dimensions

While the majority of studies on gathering that conceptualize sustainability from a social and economic science perspective emphasize economic and ecological trade-offs, more recent ideas about the sustainability of gathering include socio-cultural dimensions (de Mello *et al.*, 2020; Pezzuti *et al.*, 2018). Consistent with conceptualizations of sustainable use in indigenous peoples and local communities (see sections 2.2.4 and 2.2.8), the maintenance of social networks, including sharing networks and inter-community linkages, and social institutions are increasingly recognized in the academic literature as core elements of sustainable gathering. The relationship between gathering and health and wellbeing has also emerged as a critical element of social sustainability (Sills *et al.*, 2011). Wellbeing can be generated in multiple ways, including through: the physical and spiritual act of gathering, connection to place, cultural symbolism, and consumption of the products gathered (e.g., de Mello *et al.*, 2020; Rapinski *et al.*, 2018; Shackleton *et al.*, 2018). Although the contribution of gathering to community health and nutrition has been well recognized for some time, especially as nutritional safety nets of both foods and medicines, these considerations are more frequently being conceptualized as considerations for sustainable use (e.g., Morsello *et al.*, 2014). Both food justice and sovereignty and health justice are viewed as aspects of sustainable gathering in indigenous peoples and local communities as well as in urban settings (Poe *et al.*, 2013).

Coproduction

Finally, as discussed above, co-management approaches that include the integration of traditional and/or local ecological knowledge and science, have been recognized for some time as important for the sustainable gathering of commercialized species. However, sustainable gathering in changing contexts is now increasingly understood to depend not on the integration of knowledge systems, as was previously conceptualized, but rather on the coproduction of new knowledge (e.g., Davidson-Hunt *et al.*, 2013). The latter is understood to require institutional arrangements that provide community control, meaningful collaboration and partnerships, and significant benefit sharing.

2.2.3.4 Conceptualizations of sustainable terrestial animal harvesting (focus on hunting) in the academic literature

2.2.3.4.1 Pre-2010 conceptualizations of hunting

Hunting is defined as the act of searching, pursuing, collecting or killing wild animals (Lindsey *et al.*, 2006). Hunting is one of the earliest forms of interaction between humans and the environment (Kittenberger, 1929). Reasons for hunting range from subsistence to management, recreation, sport (trophy hunting) and cultural heritage or a combination of these (Lindsey *et al.*, 2006). Hunting can also be conducted for the purpose of trade of animal derivatives for making jewellery and sometimes for medicinal purposes under various contexts.

Prior to 2010, hunting was conceptualized in the literature as reflecting utilitarian and economic values (Eltringham, 1994; Sinclair, 1991), which could provide incentives for wild species conservation (Robinson & Bodmer, 1999). Conceptualizations of hunting identified in the literature prior to 2010 are in line with international conventions and guidelines like the Convention on Biological Diversity and the Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity, which confirm the right and the need for the sustainable use of natural resources (IUCN, 2006). The literature in this time period generally argued that sustainable use of wild species should contribute to both human needs and to the conservation of biological diversity (Baldus, 2008; McMichael *et al.*, 2003; Robertson, 1991). Well-managed hunting with efficient legislative mechanisms and scientific input, such as the case of American hunting, were viewed as sustainable while also providing many incentives for conservation of species and landscapes. It was also argued that hunting is an important conservation tool because the social and economic benefits derived from it provide incentives for people to conserve the sources of those benefits (IUCN, 2006). This concept was instrumental in stimulating several conservation initiatives, particularly initiatives where indigenous people and local community engagement, equity and community benefits are crucial. Hunting was regarded as having the potential to support sustainable utilization of wild species, particularly if management took into account harvested species' impacts on other species and on vegetation and was conducted in line with ecological principles applied across their natural ranges (IUCN, 2006).

Hunting and wild species population management

Prior 2010, hunting was described as an important animal population control tool which played a crucial role in maintaining animal populations at sizes that prevent stress on the rangelands supporting them (Williams, 1996). The occurrence of hunting around strict preservation areas such as national parks was accepted in terms of its ability to prevent the ballooning of wild species populations through the source sink relationship which occur between the hunting areas and non hunting areas. In addition, Allendorf & Hard (2009) also highlighted that the targeting of older animals past prime breeding age during hunting contributes to reducing pressure on resources leading to sustainable wild species habitats. The importance of hunting in controlling the population of animals such as elephants which may have significant undesirable impacts on habitats when their populations continuously grow, was generally accepted. In this regard, hunting was seen to have potential to contribute towards the conservation of several other species.

Hunting, economic development and tourism

The call for wild species to pay for their existence was present in early conservation narratives (Eltringham, 1994). Trophy hunting was presented as a wild species-based enterprise generating significant revenues for stakeholders and national economies (Lindsey *et al.*, 2006). Trophy hunting was viewed as an important foreign currency generating venture, contributing significantly to tourism revenues and gross domestic product for nations, and creating incentives for conservation where nature-based tourism was not viable (Freeman *et al.*, 2005). Hunting was presented as a lucrative wild species business with the potential to generate extraordinarily high revenues with minimal off take of individual game animals. Hunting tourism was considered to present opportunities to develop into an economic and social force of considerable impact in remote rural and agriculturally marginal areas (IUCN, 2006). However, tourism in remote and peripheral areas can be rather volatile because it depends heavily on transportation and accessibility. The literature generally supported viewing hunting tourism as a tool to diversify local economies, but not a replacement for other sources of income (Hall & Boyd, 2005). In addition, many papers documented that hunting activity can be a useful mechanism for financing preservation of natural ecosystems, in a context of wise use in line with key elements of sustainable use (Foote & Wenzel, 2007).

Community-based conservation, incentives and hunting

The role of hunting in community development and poverty alleviation was discussed by a number of authors as a key benefit of trophy hunting, creating incentives for conservation among rural communities. Contributions of hunting towards community development were reported in African countries such as Tanzania and Zimbabwe, where it formed the backbone of community based natural resource management programs (Lindsey *et al.*, 2006). By contributing towards community development, hunting formed an important feature of models for sustainable wild species management linking trophy hunting, wild species conservation and community sustainability in rural areas (Freeman *et al.*, 2005). The social and economic incentives from hunting promoted meaningful involvement of indigenous and local communities in wild species conservation, via incentives created by sustainable use for rural populations (Nilsen & Solberg, 2006). The social and economic benefits of trophy hunting also were acknowledged as cornerstones for incentive driven conservation practices (Hutton & Leader-Williams, 2003).

Hunting, ethics and rights in sustainable use

By 2010, the previously asserted conservation values of hunting were deeply contested. Polarized debates emerged as conservationists differed in opinion as to whether trophy hunting is an ethically legitimate conservation tool (Lindsey *et al.*, 2006). Other polarized discussions hinged on whether strict protection strategies based on exclusion of extractive methods are sustainable (Council of Europe, 2007; Kaltenborn *et al.*, 2005; Kiringe *et al.*, 2007). It was also argued that the sustainability of hunting is susceptible to abuse and malpractices, with hunting tourism inherently vulnerable to corruption, fraud, overshooting of best practices in quotas, bad management, and loss of wild species numbers and biodiversity. It was argued that community benefit from hunting revenues in community-based natural resource management programs where hunting is listed as a key use strategy, was also grossly affected by these misgovernance issues (Balint & Mashinya, 2008; F. A. Johnson *et al.*, 1997).

Hunting, trade and sustainability

A shift in the narratives about hunting and wild species trade reframed them as threatening the conservation of wild species (Darimont *et al.*, 2009; Zapata-Ríos *et al.*, 2009). The limitations of monitoring and control on wild species trade were highlighted as among the reasons commercial trade of wild species could be regarded as unsustainable. The contemporary and prehistoric extinction of thousands of wild species was attributed to hunting, including prominent species such as the quagga, woolly mammoth, sabre toothed cat and West African black rhinoceros. Populations of amphibian species have also declined as a result of collection and trade (Halliday, 2001; Kuzmin, 1996). Economic incentives such as the establishment of quotas without a scientific basis were observed to lead to unsustainable utilization patterns (Zhang *et al.*, 2008).

The motives for quota setting in trophy hunting were argued to be dominantly political and economic at the expense of conservation, with far-reaching consequences on the sustainable use of wild species (Rodrigues, 2004). Persistence of wild species markets was also cited as a major hindrance to efforts to stop poaching (Darimont *et al.*, 2009). Other negative impacts of commercial wild species trade such as the spread of invasive species and zoonotic diseases as a result of live animal sales were also highlighted by some authors (e.g., Smith *et al.*, 2009). Several authors suggested that there was need for conservationists and policy makers to find ways to reduce the magnitude of international wild species trade in order to save species from extinction (K. F. Smith *et al.*, 2009; Vercauteren & Hygnstrom, 1998). Approaches that were proposed to address the issue of wild species trade include awareness among governments to take proactive measures to address the impacts and risks of wild species trade (Nijman, 2010).

Effects of hunting on species populations and distribution

Simultaneously, the harvesting or removal of wild species through hunting was observed to have undesirable impacts on populations and the functioning and integrity of some ecosystems (Vermeulen *et al.*, 2009). Hunting, especially wild meat hunting, was often discussed as one of the major contributors to animal species population decline (Brashares *et al.*, 2004). Breeding was argued to be negatively affected as a result of the selection during hunts which harvest males at a faster rate than females (Fischer & Keith, 1974). Negative impacts of hunting were reported on small mammals (Nixon *et al.*, 1975), amphibian and reptile species such as crocodile and turtle (da Nóbrega Alves *et al.*, 2008; Powell *et al.*, 2000), and several bird species in the 19th century (Madsen & Fox, 1995).

Hunting was also identified as a threat to tropical forests (Bonaudo *et al.*, 2005). Citing evidence from Malaysia, Robinson & Bodmer (1999) argued that hunting could lead to the loss of wild species that are pivotal in the maintenance of ecosystem processes such as pollination and seed dispersal. Forms of hunting such as trophy hunting were argued to negatively impact species due to lack of proper research and science-based decisions, which create an opportunity for unsustainable harvests and threatens wild species (Salvatori *et al.*, 2002). In contrast, Stork (2007) described the importance of hunting as a habitat protection tool, which benefits tree dwelling insects and leads to stable insect populations. Most studies which had been conducted on coastal and wetland areas showed that hunting activities can greatly affect bird behavior and distribution as birds move to safer zones and alter known breeding, roosting or wintering sites (Barri *et al.*, 2008; Pack *et al.*, 1999; Robinson & Redford, 1994; Small *et al.*, 1991). In addition, Casas *et al.* (2009) suggested that human predation alters animal behavior as the former come to be recognized as a threat. However, other articles emphasised the benefits of hunting for non-target species. For example, Mateo-Tomas & Olea (2010) highlighted the importance of carcass meat for raptor and other carnivorous bird species success. In addition, the removal of individuals through hunting was argued to favor selection, thus maintaining balance and integrity of the ecosystem (Stenseth & Dunlop, 2009). Restrictive hunting regulations were credited with contributing to the stability and increase in survival rates of mallard duck populations in Canada and the United States of America, and goose populations in Europe as well as large scale habitat restoration by hunters (G. W. Smith & Reynolds, 1992). Thus, it was argued that populations can thrive under well monitored and effectively managed hunting systems (Burnham *et al.*, 1984; Casas *et al.*, 2009). Thus, the literature includes good illustrations of the success of hunting as a management tool. However, the measures contributing to successes in conservation of species and habitats were recognized to be context specific and should not have a blanket application across populations.

The development of assessment tools to measure the sustainability of hunting over the years was highlighted and the role of research acknowledged in a number of articles (Bennett *et al.*, 2002). There are many cases documenting the value of information from hunting in evaluating the status and trends of harvested populations (Robinson, 1971; Scillitani *et al.*, 2010; Struebig *et al.*, 2007; Tuttle, 1979), particularly if using information from both hunters' activities and removals (Alvard, 1995; Tallis *et al.*, 2008).

Multispecies hunting, wild meat consumption and perceived disease risk

The pre-2010 literature reported widespread wild meat hunting as one of the major threats to many mammals and birds in Africa, such as buffalo, kudu, and impala (Golden, 2009; Magige *et al.*, 2009; Rao *et al.*, 2005). According to Golden (2009), this was particularly the case for illegal hunting for wild meat and rampant collection and harvesting of birds, amphibians, reptiles and edible insects. Kumpel *et al.* (2009) pointed out that hunters are the critical link between demand and supply of wild meat. Although wild meat hunting was acknowledged to present a potential threat to species conservation, demand for wild meat was also highlighted as continuously increasing (Barnes, 2002; Robinson & Bennett, 2004). There were also some articles that discussed negative impacts of wild meat hunting on both wild species populations through harvests of threatened species and people`s livelihoods through the transmission of zoonotic diseases which may have serious consequences for exposed people and their communities (LeBreton *et al.*, 2006; Monroe & Willcox, 2006; Wilkie, 2006).

2.2.3.4.2 Post-2010 conceptualization of hunting

The post 2010 literature review identified 222 papers which were coded according to different aspects of sustainable use that fell into the broad groupings of ecological, socio-economic, governance, and socio-cultural. The data management report for this review is available at https://doi.org/10.5281/zenodo.6472995. In these papers, ecological aspects are the most represented and socio-economic aspects the least represented **(Figure 2.1)**.

Similar findings emerge when evaluating individual aspects of sustainable use. Among the ten most common aspects, half were ecological, followed by governance and socio-cultural aspects **(Table 2.2)**. The most common aspect is an ecological focus at the population level, which was covered in 98% of all analyzed documents, followed by contributions to subsistence or culturally established livelihoods, which was discussed in 27% of the articles.

Close to one third of the analyzed papers covered aspects from more than one broad grouping. Of the papers that focused on ecological aspects, approximately one quarter also included aspects from another category, usually socio-economic.

About 40% of analyzed documents considered "sustainable hunting" within the framework of the ecological aspects, which is narrowly in accordance with the understanding of "sustainable use" in article 2 of the Convention of Biological Diversity. However, such understanding of the concept of sustainable use of wild species through hunting is limited from the perspective of Addis Ababa Principles and Guidelines for the sustainable use of biodiversity or Guidelines on Sustainable Hunting in Europe (IUCN, 2006). A bit more than half of other sources considered sustainable hunting to go beyond ecological characteristics and impacts, although only 15% of all analyzed documents included features from all groups (ecological, socio-economic, governance and socio-cultural).

Hunting continues to be most frequently conceptualized by considerations of direct impacts on populations, biodiversity, and on endangered or threatened species and protected habitats over a portion of area. Adaptive management, frequent monitoring and evaluation, contributions to subsistence or culturally established livelihoods, and market value to support community wellbeing are other frequently discussed concepts (see **Table 2** at https://doi.org/10.5281/zenodo.6472995).

Within each broad category of sustainable use, the following ideas emerge as most prevalent:

- Ecological: direct impacts of use on wild species populations within a certain area, which takes into consideration preservation of habitat and endangered species, as well maintenance of biodiversity and structural habitat features.
- Socio-economic: hunter's bag has a market value, contributes to subsistence or culturally established

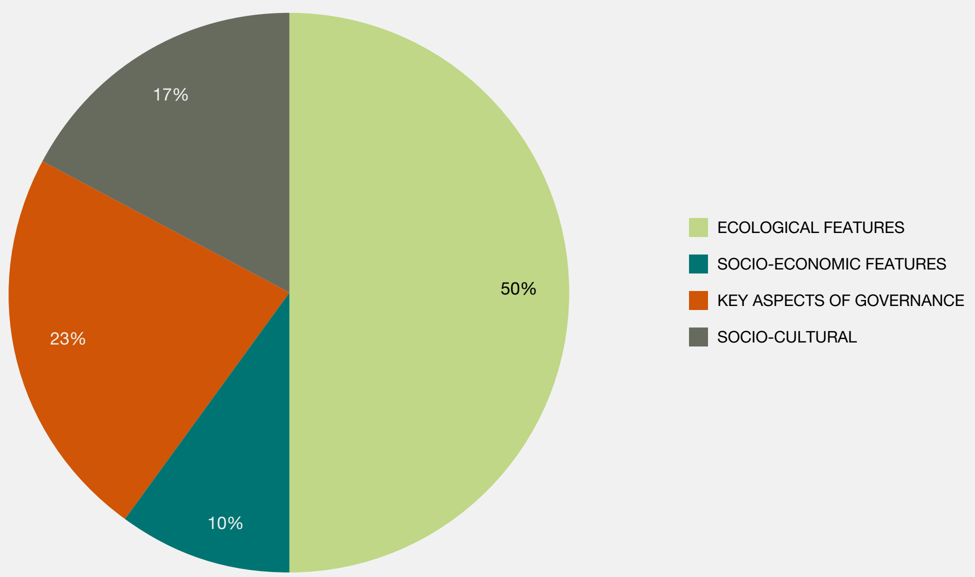


Figure 2 1 **Distribution of average scores per group of aspects of sustainable hunting, presented in percentages.**

Table 2 2 **Most represented aspects of sustainable use among 222 analyzed documents.**

Rank	Aspect	Category	% of papers that address issue
1	Populations used directly and intentionally, whether harvested in whole or part	Ecological	98
2	Contribution to subsistence or culturally established livelihoods	Socio-economic or socio-cultural	27
3	Impacts on Endangered, threatened, or protected species or habitats	Ecological	25
4	Aggregate spatial features (e.g., portion of area impacted by use)	Ecological	25
5	Adaptive management	Governance	25
6	Aggregate biotic community properties (e.g., biodiversity)	Ecological	23
7	Community wellbeing	Socio-cultural	22
8	Market value of intended product(s) harvested	Socio-economic	19
9	Monitoring, Evaluation and Review	Governance	18
10	Structural habitat features	Ecological	14
10	Contribution to stability of economy at local scale	Socio-economic	14
10	Inclusion of multiple knowledge systems in management plans or policies	Governance	14

livelihoods and supports household economy, and/or the local and national economy.

- Governance: implementation of adaptive management is supported with monitoring, evaluation and review of used populations. Indigenous peoples and local communities' customary rights and access to hunting are respected under management plans or policies, which incorporate multiple knowledge systems and allow transparent decision-making.

- Socio-cultural: sustainable hunting ensures community wellbeing, respects traditions and supports education.

In addition to the above, the following aspects of the conceptualization of sustainable hunting also emerged from review.

Hunting as a threat

Many papers address hunting as a threat, but usually do not go beyond considering the environmental impact of hunting. However, within the context of environmental impacts, sustainability of hunting is considered from diverse perspectives, including direct and indirect pressures on wild species populations and habitats. These include a focus on:

- Impacts on wild species: hunting is viewed as a limiting factor which affects wild species population numbers or abundance through harvest (Chamberlain *et al.*, 2012; Ciuti *et al.*, 2015; Proffitt *et al.*, 2010; Ramos *et al.*, 2016; Tagg *et al.*, 2020; Van Vliet & Nasi, 2019; White *et al.*, 2010). This conceptualization is present in a large majority of portion of the papers but usually does not go beyond ecological aspects. Hunting is considered to be sustainable as long it does not result in high pressure on wild species populations and does not threaten species survival.

- Trophy hunting: many papers also analyze hunting impacts on game species, especially charismatic or flagship species, and includes impacts on sex ratio, population age class structure or evolutionary disturbances, and discussion of efforts to make trophy hunting more sustainable (Brink *et al.*, 2016; Coulson *et al.*, 2018; Festa-Bianchet *et al.*, 2014; Miller *et al.*, 2016; Wanger *et al.*, 2017). Papers on this topic overlap with the group above, but are more likely to include additional aspects of sustainable use (e.g., X. Zhou *et al.*, 2020).

- Lead ammunition: the damaging consequences of lead ammunition use on environment, wild species and their habitats is addressed by multiple papers (Cartró-Sabaté *et al.*, 2019; Flint & Schamber, 2010; Kanstrup *et al.*, 2018).

- Hunting as a management tool: some papers take into consideration hunting as an instrument in wild species management in order to achieve sustainability (Crum *et al.*, 2017; Forti *et al.*, 2017; Simard *et al.*, 2013; Stien & Hausner, 2018). Hunting is conceptualized as useful in control of invasive species, zoonosis or overabundant populations.

Wild meat hunting

Use of wild species for subsistence or trade is a common topic in the post 2010 literature. This topic is addressed from the perspectives of sustainable or unsustainable hunting, the latter arguing that hunting threatens the existence of large mammal species and undermines conservation efforts (Hegerl *et al.*, 2017; Kamgaing *et al.*, 2019; Kouassi *et al.*, 2019; Pangau-Adam *et al.*, 2012; Spira *et al.*, 2019; van Velden *et al.*, 2020; Van Vliet *et al.*, 2015). Papers that address wild meat hunting usually go beyond ecological aspects and involve socio-economic and socio-cultural aspects, especially those related to contributions to subsistence or culturally established livelihoods and community wellbeing. Another common theme argues that placing market value on wild species is an unsustainable practice, which threatens species conservation. Literature on hunting for meat is mostly focused on Sub-Saharan Africa or Amazonia, whereas studies from other parts of the world are poorly represented.

Human dimensions of hunting

Social components of sustainable hunting are significantly less covered in comparison to the two previous categories. Studies that focus on human dimensions of hunting commonly address two subtopics:

- Hunters: papers address hunters as stakeholders important for contributing to the implementation of sustainable hunting. This research mostly addresses the role of hunters in various wild species management practices and their impact in environmental protection, but also studies their recruitment and retention (O. Andersen *et al.*, 2014; Breisjøberget *et al.*, 2017; Carvalho *et al.*, 2015; Gude *et al.*, 2012; Jacques *et al.*, 2011; Paulson, 2012; Schorr *et al.*, 2014). Research on trends in hunters' numbers are especially common among scientists from the North America, since the purchase of hunting licenses is linked with financial support to wild species management and conservation. Papers that address this topic also often address other various wild species management or conservation issues (e.g., Schraml, 2012).
- Human-wildlife conflict: an important focus is on conflict between local communities and wild animals, usually predators, and its impact on carnivores' conservation. These papers usually involve ecological aspects but also involve other aspects of sustainable use that are discussed separately here (e.g., Austin *et al.*, 2010; Goldman *et al.*, 2013; Hiller *et al.*, 2015; Thorn *et al.*, 2015).

Economic dimensions of hunting

A number of papers address the financial contributions of hunting to local or national economies, and market value of harvested products through different activities, for example hunting tourism or trade. This topic overlaps with wild meat hunting, or and trophy hunting, but goes further in considering both economic and ecological aspects of hunting (e.g., Arroyo *et al.*, 2016; Buckley & Mossaz, 2015; Deere, 2011; Soliño *et al.*, 2017).

Hunting and other land use activities

Few papers address hunting in the context of other land use activities. The topic was covered by reports and book chapters (Ehrhart *et al.*, 2020; Reimoser *et al.*, 2013), and focuses on the possibility of harmonizing hunting activities with other land uses such as agriculture, forestry or recreation. However too few papers were found for general themes to emerge.

Conclusions

Sustainable hunting is conceptualized as a multidisciplinary and complex issue and is being approached from different perspectives. Nevertheless, the majority of analyzed papers consider sustainable hunting within an ecological and wild species management framework. They find it feasible to keep hunting sustainable, but only with effective management approaches and measures, and adequate enforcement by coherent communities or appropriate authorities. However, papers challenging the ethical basis for hunting are increasing in the literature, as are papers arguing that weak implementation of policies and measures result in widespread unsustainable hunting. Sustainable hunting is evaluated in terms of population removal and natural replacement, levels of disturbance of population parameters (sex ratio, age classes, market suitability and trophy quality) and impacts on protected species and habitats. The market value of hunting products is recognized as an important component of sustainable use, especially the contributions towards income, gross domestic product and economic stability. Socio-economic features such as the contribution of sustainable wild species use towards community wellbeing are emphasized as an important aspect in their own right, but often framed as instrumental to creating incentives for biodiversity conservation. Governance issues are occasionally but increasingly mentioned and discussed as part of sustainable hunting, especially issues such as inclusiveness and distribution of power. There is some mention of monitoring, evaluation and review mechanisms of resource use, which is often emphasized as critical for the sustainable use of biodiversity. Additionally, adaptive management is sometimes emphasized as an essential management strategy key for sustainable utilization of wild species.

Issues related to the costs of hunting are infrequently discussed in the review articles. There was also very little mention or discussion of the viability of local communities in areas where hunting occurs, for example, protection of local communities from gentrification of area uses, ability to keep workforce etc. Finally, governance aspects regarding power and transparency in decision making were missing in most of the review articles, as was the issue of indigenous peoples and local communities' customary rights and access to resources.

2.2.3.5 Conceptualizations of sustainable logging in the academic literature

This assessment defines logging as a practice that removes whole trees or woody parts of trees from their habitat, often resulting in the death of the trees except for cases such as coppicing (see Chapter 1). Because trees and forests are inseparable in nature, there is a strong link between logging and forest management. However, logging is only a subcomponent of forest management that pursues other services and values, such as biodiversity, ecosystem services, income, livelihoods, and aesthetic and cultural values. Although this review acknowledges this practical difference between the two, it relies largely, but not exclusively, on forestry literature and treats the term "timber" and "forest" almost equally. This is because conceptualizations of sustainable logging developed as part of the efforts towards sustainability in forest management. Thus, the aim is not to define "sustainable logging" as a novel concept but to describe its dimensions under the conceptualization of sustainability in forest management.

2.2.3.5.1 Pre-2010 conceptualization of logging

Forestry is considered the first science to introduce the concept of sustainability in the western world. According to Glacken (1976), books representing the starting point of forestry science published in the mid-seventeenth century already discussed the importance of safeguarding finite timber resources for future generations. The term *Nachhaltigkeit* ("sustainability") first appeared in the early eighteenth century in a German book by Hans von Carlowitz. He advocated that no more wood should be felled than can grow back (von Carlowitz, 1713). Since then, sustainability in forestry science has generally maintained a strong focus on achieving a sustained timber yield (Innes, 2017b; Wiersum, 1995), and the views of forest experts who typically focused on the allocation of management resources for the maintenance of productivity dominated the discussion (Hahn & Knoke, 2010). Similar approaches to logging also emerged independently in Japan in the same era, where people managed the harvest of Japanese cypress *(Chamaecyparis obtusa)* based on inventory and production planning (Iwamoto, 2002). In the early ages of forestry science, timber production was set as the primary goal, and other forest values and services were often ignored (Hahn & Knoke, 2010). These timber-centric approaches to forestry are referred to as sustainable timber management, sustainable yield forestry, or other related terms (Hahn & Knoke, 2010; **Figure 2.2**).

In response to the environmental impacts caused by logging, forestry started to incorporate other uses and values of forests with the term "forest function" since the mid-nineteenth century (Bader & Riegert, 2011; Bončina *et al.*, 2019). The seminal work by George P. Marsh (1864), which is considered as the origin of the concept of ecosystem services (Mooney & Ehrlich, 1997), acknowledged functions like regulation of water and climate, soil conservation, decomposition, and pest control. Viktor Dieterich (1953) defined forest function as societal demand on forests, and the term has become common in forestry (Bader & Riegert, 2011). Acknowledgment of forest function was a reflection of growing public interests, but participatory methods in decision-making were not conceptually applied at this point (Hahn & Knoke, 2010), except for community-based participatory forestry that dates back to the 1970s in the tropics (FAO, 1992). This management approach that incorporates multiple forest functions and services is referred to as sustainable forestry, multiple-use forestry, or multifunctional forestry (Hahn & Knoke, 2010; **Figure 2.2**). In the United States of America, forest uses other than timber were acknowledged by the Organic Act in 1897, and equal weight was given to all types of uses by the Multiple-Use and Sustained-Yield Act in 1960 (Bowes & Krutilla, 1989; Hoogstra-Klein *et al.*, 2017). Similar shifts in the scope of forest management occurred in Europe (Bončina *et al.*, 2019) and the tropics (e.g., Wadsworth, 1952) since the 1950s.

The turning point of conceptualizing sustainable logging was reached in the 1990s when the concept of "sustainable forest management" emerged (Hahn & Knoke, 2010; Innes, 2017b). The notions of "sustainable development" and the outcomes of the United Nations Conference on Environmental Development held in 1992 prompted forest management to consider ecological sustainability, social values, and intra- and intergenerational equity (Hahn & Knoke, 2010). Participation of various stakeholders beyond conventional shareholders – the fundamental component of

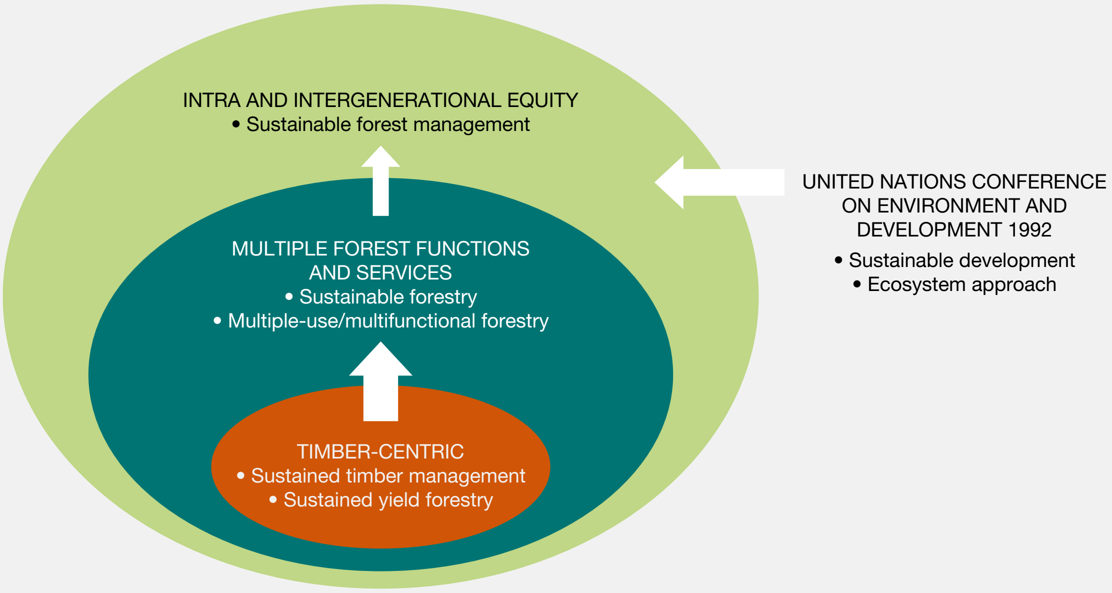


Figure 2 2 **Conceptual development of terms related to sustainability in forestry.**

The width of the arrows qualitatively reflects the impact of the former on the following stages leading to the emergence of sustainable forest management. Modified from Hahn & Knoke, 2010. CC-BY-NC – License number 5275361479074.

sustainable development – has become the indispensable attribute of sustainable forest management (FAO, 2003; Hahn & Knoke, 2010). Additionally, the "ecosystem approach" endorsed at the 5th Conference of the Parties to the Convention on Biological Diversity in 2000 also introduced new approaches to forest management. These included adaptive management, conservation of biodiversity and ecosystem services, and considering forests as part of the larger landscape (FAO, 2003; Hahn & Knoke, 2010; Innes, 2017b). Sustainable forest management can be viewed as an application of the ecosystem approach (or ecosystem management) in forest landscapes, and the two are often used interchangeably (FAO, 2003; Hahn & Knoke, 2010; Innes, 2017b). Over time, the goal of forest management has shifted from maximizing yield and profit from timber to balancing various needs and values of forests by incorporating public participation **(Figure 2.2)**.

After the emergence of sustainable forest management, the academic conceptualization of sustainability in logging increasingly became transdisciplinary, covering ecological, economic, and social components (Wang, 2004). By 2010, ecological aspects of sustainable logging attracted the most attention in terms of the number of publications (Dobbertin & Nobis, 2010). The environmental sustainability of harvesting methods, such as reduced impact logging, has been a popular topic in the tropics since the 1990s (Boltz *et al.*, 2003; Putz *et al.*, 2008; Wang, 2004). In Europe and Asia, discourse on ecosystem management, including forest conservation and evaluation of ecosystem services, became common (Schober *et al.*, 2018). Topics related to forest stand management (e.g., harvest, regeneration, and growth) have been popular in the temperate and boreal regions and South America (Schober *et al.*, 2018).

The economic discourse of sustainable logging had shifted from being timber-centric to considering various needs and values of forests and woodlands, including the gathering of non-timber forest products and hunting (García-Fernández *et al.*, 2008; Panayotou & Ashton, 1992). The contribution of forests and trees to rural livelihoods and poverty alleviation has become widely acknowledged across the tropics (Shackleton *et al.*, 2007; Sunderlin *et al.*, 2005). Ecological economics has brought new developments in evaluating forests in different forms of capital assets, including their flow, stock, and trade-offs (Wang, 2004). New forest markets for ecosystem services known as payment for environmental/ecosystem services schemes were developed to compensate service providers for the cost of maintaining healthy forest ecosystems (García-Fernández *et al.*, 2008). At the macro-scale, economic theories have been applied to explain the underlying mechanism of a country's transition from net forest loss to net forest gain (known as "forest transition") (Meyfroidt & Lambin, 2011; Rudel *et al.*, 2005).

The introduction of participatory approaches brought the most extensive changes in discussions on the social dimension. The empowerment of forest communities was often examined under community forestry and related schemes testing whether they brought ecological and/or community benefits (Charnley & Poe, 2007; García-

Fernández *et al.*, 2008). Topics included decentralization and devolution of forest management, participation in decision-making, tenure security over forest land and resources, equitable access and benefit-sharing, and customary institutions. Increased transparency and adaptability of forest management have been sought by developing criteria and indicators at two different scales. National criteria and indicators of sustainable forest management have been developed by several international and regional processes, such as the International Tropical Timber Organization, the Montreal Process, and the Pan-European Process, since the 1990s. These initiatives promoted supportive forest policies and monitoring and inventory at the national scale (Innes, 2017a; Linser *et al.*, 2018). Pushed by green consumerism, forest certifications developed ecological and socio-economic criteria and indicators applicable at the scale of forest management unit and to the chain of custody (Auld *et al.*, 2008; Rametsteiner & Simula, 2003). Forest certifications function as means of participation to respond to greater consumer awareness on the environmental impacts imposed on overseas forests (Hahn & Knoke, 2010).

2.2.3.5.2 Post-2010 conceptualization of logging

The conceptualization of sustainable logging during the past ten years has continued to build on the notions of sustainable forest management. Topics have slightly shifted over the years in response to societal needs and have shown regional variation.

Among the 72 papers reviewed (see data the data management report for this review is available at https://doi.org/10.5281/zenodo.6472995), the sustainability of timber resources was discussed in about 70% of the articles, with higher frequency observed in the boreal regions. Timber production was the main topic, but a considerable number of papers also discussed the maintenance of standing forest stock, which supports a wide variety of ecosystem services. Ecosystem services (including 'forest functions,' the synonymous term in forestry), such as climate regulation, water sequestration and purification, nutrient cycling, and sediment control, attracted equal attention. Many papers examined the sustainability of logging, gathering, and other ecosystem services simultaneously (e.g., Nambiar, 2019; Piabuo *et al.*, 2018; Sheppard *et al.*, 2020), suggesting a certain degree of conceptual overlap between the sustainability of logging and gathering. About half of the reviewed papers discussed the conservation of biodiversity. These trends indicate that the sustainability of logging is increasingly conceptualized with the diversified values of forests and woodlands entailing complex trade-offs and synergies among them (Chhatre & Agrawal, 2008; Luyssaert *et al.*, 2018; Timko *et al.*, 2018; Visseren-Hamakers *et al.*, 2012; Wagner *et al.*, 2014).

Sustaining the productivity of timber

The single-dimensional discourse on timber production has continued to explore conditions of sustainable harvest. Despite being a rather conventional topic, the relationship between soil impacts and forest productivity has caught great attention in boreal and temperate regions. Increasing use of heavier machinery in industrial forestry has raised concerns over soil compaction and erosion, loss of soil carbon, and soil surface disturbance, leading to reduced forest regeneration and productivity (N. Clarke *et al.*, 2015; Nave *et al.*, 2010; Picchio *et al.*, 2020).

The resilience of forests as social-ecological systems

Greater uncertainty and rapid changes in biophysical and socio-economic conditions surrounding forest management have driven the adoption of social-ecological systems theory (Messier *et al.*, 2016). The concept of resilience connected different narratives. Some discussions emphasized the ecological notion of resilience, i.e., the role of biodiversity for service provisioning and ecosystem stability against disturbances, including climate change (Thompson *et al.*, 2013; Wagner *et al.*, 2014). Other studies have highlighted biocultural approaches to socio-cultural resilience, including the role of traditional ecological knowledge, governance systems of indigenous peoples and local communities, and sense of place (DeRoy *et al.*, 2019).

Sustainability of wood-based bioenergy supply chain

In Europe and North America, the rising demand for wood-based bioenergy for achieving climate mitigation targets has called for the need to assess the sustainability of wood supply chains (Cavalett & Cherubini, 2018; Santos *et al.*, 2019). According to the review by Santos *et al.* (2019), most assessment and optimization studies have focused on the economic (i.e., overall costs of the supply chain) and/or the environmental (i.e., greenhouse gas emissions) dimensions, while the social component has been largely overlooked. Other ecological impacts included forest cover loss (Ceccherini *et al.*, 2020) and soil nutrient deficiencies (Pare & Thiffault, 2016) caused by increased biomass removal. Enabling environments for the transition to a sustainable bio-based economy have been explored concerning forest governance systems (Johansson, 2018) and natural resource legislation (Borgstrom, 2018) of producer countries.

Multiple dimensions of sustainable use revisited under REDD+

The emergence of REDD+[2] (Reducing Emissions from Deforestation and forest Degradation) since the mid-2000s has introduced results-based carbon payment mechanisms

2. Formally defined as "reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries".

to sustainable forest management and forest conservation in the tropics. Before REDD+, climate mitigation measures in the forest sector focused on the role of forest plantations by promoting afforestation and reforestation under the Kyoto Protocol. REDD+ came in as an alternative approach spotlighting the value of natural forests for carbon sequestration and storage functions. However, valuation of forests through the single lens of carbon provoked active discussions for the need to account for multiple values and perspectives and to ensure environmentally and socially appropriate approaches to forest management (Corbera, 2012; J. Gupta, 2012; Hein & van der Meer, 2012; Visseren-Hamakers *et al.*, 2012). The expected non-carbon benefits of REDD+ consist of biodiversity, ecosystem services, and social livelihoods, all of which require careful cross-sectoral planning and implementation for delivery (Visseren-Hamakers *et al.*, 2012; Wallbott *et al.*, 2019). Social benefits of REDD+ include social justice, equity, equitable sharing of benefits, and improvement of community well-being, which are enabling factors of REDD+ at the same time (Adam & Eltayeb, 2016; Kenfack Essougong *et al.*, 2019; Mwangi *et al.*, 2011; Nambiar, 2019; Palmer *et al.*, 2020; Pokorny *et al.*, 2013). In addition, REDD+ brought forests under renewed and often re-centralized forms of government control (J. Gupta, 2012). In response to this governance reform, scholars have actively discussed the importance of devolution of forest management to local institutions (Adam & Eltayeb, 2016; Chhatre & Agrawal, 2008; Wright *et al.*, 2016), respect to customary rights and practices (Pokorny *et al.*, 2013; Walker *et al.*, 2020), and participation of indigenous peoples and local communities (Palmer *et al.*, 2020). The multiple dimensions of sustainability discussed under REDD+ are not new and largely overlap with the discussions when sustainable forest management emerged.

Human health and forest management

The health and safety of forest occupations have been classic but common topics concerning forest certifications and supply chain assessments (Santos *et al.*, 2019; Yovi & Nurrochmat, 2018). In areas with weak social security systems, forest producer organizations might play essential roles in providing healthcare and health insurance to forest workers (Tirivayi *et al.*, 2018). The health-related conceptualization extends to forest communities not employed by the forest sector. Forests support the food security and nutrition of the local communities directly through the provision of food and indirectly through ecosystems services, such as crop pollination (Timko *et al.*, 2018). Traditional medicine collected in forests are means of primary healthcare, especially where public health services are absent (Nambiar, 2019; Timko *et al.*, 2018). Furthermore, forest conservation programs and community forestry schemes have started to acknowledge access to healthcare as an indispensable component of community well-being (Duguma *et al.*, 2018; Palmer *et al.*, 2020; Piabuo *et al.*, 2018). A recent study has demonstrated that a healthcare intervention can simultaneously reduce illegal logging and improve the local health status (Jones *et al.*, 2020).

2.2.3.6 Conceptualizations of sustainable non-extractive practices (focus on wildlife watching)

2.2.3.6.1 Introduction

This section focuses on wildlife watching as a non-extractive practice in principle. Understanding sustainability in the context of wildlife watching is a relatively new field of academic research compared to the traditional extractive activities of fishing, gathering, hunting, or logging. Wildlife watching has emerged as a significant niche tourism activity starting from around the 1980s and has rapidly increased, up until the recent travel restrictions due to the COVID-19 pandemic.

Conceptualizations of sustainability in wildlife watching practice have undergone several transformations during the recent decades. Initially wildlife watching practice was framed as an inherently sustainable alternative to extractive practices. This coincided with the 'golden era' of tourism after the World War II, where tourists were viewed in an overwhelmingly positive light. Over the years, better understanding of the larger context of the unfulfilled promises of a growth-oriented green economy called attention to a wide range of both positive and negative impacts related to wildlife watching practice, in the broader perspective gave rise to more critical views of the sustainability of this practice. Along with this, understandings of sustainability of wildlife watching have been largely framed in terms of minimization of negative environmental impacts on wild species and maximization of economic opportunities for the local population. Social sustainability has been largely represented fairly narrowly in terms of education opportunities provided to wider audiences thorough participating in wildlife watching practice.

In addition, over this period the research field focusing on tourism and outdoor recreation has matured and become more institutionalized. Together these trends of broader understanding and more focused expert study resulted in a transition to a greater awareness of complexities surrounding wildlife watching practice, and a shift away from simplistic conceptualization of sustainability as management of a handful of key impacts. Nevertheless, the research of wildlife watching practice is still dominated by discrete case studies, which makes generalizations challenging. In addition, absence of global and regional regulating authorities results in weak top-down governance of this practice. These and other insights are discussed in more detail in the review of academic literature below. The data management report for this review is available at https://doi.org/10.5281/zenodo.6472995.

2.2.3.6.2 Pre-2010

Systematic research attention to sustainability in the context of wildlife tourism and tourism in general started to become noticeable with the emergence of the global sustainability agenda in the last decades of the 20th century. Early literature on wildlife watching was dominated by a largely optimistic outlook on the role of tourism in species conservation, emphasizing the supposedly 'win-win-win' model of tourism industry, which simultaneously delivers benefits to the tourists themselves, local communities, and conservation goals (Mowforth & Munt, 2009). This is present, for example, in the rhetoric of the United Nations International Year of Ecotourism 2002 (Butcher, 2006). Wildlife watching and the tourism industry in general, were positioned as non-extractive, "light", "clean" and relatively harmless alternatives to extractive heavy industries (Ateljevic *et al.*, 2007; Mowforth & Munt, 2009).

Despite the wide-spread adoption of the "triple bottom line" model of sustainability in tourism, in practice it was primarily conceptualized by authors in the natural sciences in terms of management of environmental impacts, such as minimizing negative impacts on wild species populations in question (Green & Higginbottom, 2000; Higham & Bejder, 2008; Lambert *et al.*, 2010; Tremblay, 2001). The other two pillars of sustainability remained weakly addressed, with the social dimension receiving the least attention. Mowforth & Munt (2009, p.18) for example, explicitly state that "… sustainability, a notion that at its most basic encapsulates the growing concern for the environment and natural resources, though sustainability has also had increasing resonance in social and economic issues." In addition, consistent with the relative theoretical and methodological immaturity of the tourism studies field prior to the 2000s, the literature was dominated by discrete case studies, making generalizations challenging. Nevertheless, some key elements of sustainability emerged. First, the importance of educational activities, appropriate training and capacity building are widely stressed as a key element of sustainability in wildlife watching. Education has been directly identified as "the most important wildlife management strategy" (Newsome *et al.*, 2005, p. 209), as ignorance is identified as one of the key barriers to sustainability *(ibid.)*. This includes provision of both formal and informal education to tourists, local guides, local communities and larger public in general, often formulated in codes of conduct for tourists. However, minimal attention was paid to the inclusion of multiple knowledge systems and indigenous knowledge into educational activities. Interpretation can be conceptualized as aiming to "stimulate interest, promote learning, guide visitors in appropriate behavior for sustainable tourism and encourage enjoyment and satisfaction" (Moscardo *et al.*, 2004, p.231). The intent is for interpretation to add emotional and experiential dimensions to education, making it more memorable and impactful.

Early approaches to sustainability of wildlife watching were widely conceptualized in terms of impact management, with the goal of minimizing negative impacts (primarily environmental) and maximizing positive ones (primarily economic). Negative impacts acknowledged included direct injury or death to animals, disruption of their normal activities and increased stress, as well as habitat alteration, whereas positive impacts included financial flows from tourism, economic incentives to conservation, and education of visitors (Green & Higginbottom, 2000). Contributions from natural sciences in assessment of negative impacts were dominating such research efforts (e.g., Green & Higginbottom, 2000; Higham & Lück, 2007; Lambert *et al.*, 2010; Roe *et al.*, 1997; Tremblay, 2001).

In the context of economic impacts, provision of income to the local communities as well as provision of financial support to conservation projects are prioritized (e.g., Glowinski, 2008; Green & Higginbottom, 2000; Newsome *et al.*, 2005). Articles addressing aspects of social sustainability in the context of wildlife watching are scarce (Moore & Rodger, 2010). although these perspectives can be found in comprehensive books on wildlife watching (Green & Higginbottom, 2000; Higham & Lück, 2007; Newsome *et al.*, 2005). Aspects of social sustainability are much more elaborated in the literature on nature-based tourism and tourism in general, than in the literature focused specifically on wildlife watching tourism (Mowforth & Munt, 2009). Overall, prior to 2010 research literature on sustainable wildlife watching prioritized improvement of education and scientific knowledge regarding possible negative tourism impacts on wild species populations, while simultaneously increasing and appropriately distributing financial flows generated from tourism.

2.2.3.6.3 Post-2010

In the literature after the 2010 the optimistic era of sustainable development, green growth and ecological modernization, dominating scientific and public discourses since the 1980s, is declining (Gómez-Baggethun, 2020; Mowforth & Munt, 2009). Expectations for the "marriage" of growth-oriented neoliberal economics and environmental agendas as a way to attain sustainability, have largely not been met. However, wildlife tourism has been argued to contribute directly to global challenges such as biodiversity decline, climate change and transformation of the environment (Higgins-Desbiolles *et al.*, 2019).

Overall, over the last decade the research literature on tourism demonstrates increasing awareness as well as concerns over the sustainability of wildlife watching. Literature on nature-based tourism and wildlife watching becomes more in-depth, mature and diversified, placing tourism and wildlife watching within the context of a complex set of global transformations, i.e., Anthropocene

(Fredman & Margaryan, 2020; Hall, 2016). There also is an explosion of publications with more species-focused, detailed, sophisticated, fine-tuned, and critical approaches to a wide multiplicity of topics in wildlife watching. Several key themes in conceptualizations of sustainability in this context are discussed below.

Socio-cultural aspects

Importance of knowledge-related themes remains key for sustainability of wildlife watching. This includes importance of scientific research for adequate understanding and assessment of watching impacts on wild species. The lack of reliable scientific evidence, particularly the lack of baseline data and longitudinal studies (D'Lima *et al.*, 2018; Newsome *et al.*, 2012; Steven *et al.*, 2011), is presented as one of the main hindrances for sustainability of this practice (Burgin & Hardiman, 2015; DeLorenzo & Techera, 2019; D'Lima *et al.*, 2018; Higham & Shelton, 2011; Kubo *et al.*, 2019; Muntifering *et al.*, 2019; Newsome *et al.*, 2012).

Education and awareness raising for the local communities

Many articles stress the need for education and awareness raising among the local communities on how to engage in wildlife watching tourism business on their own terms, benefit from it and contribute to conservation (Buultjens *et al.*, 2016; D'Lima *et al.*, 2018; Markwell, 2015; Newsome *et al.*, 2012). Shortcomings highlighted in the literature include that traditionally tourism is perceived as a low entry barrier industry, yet employment nevertheless often lacks necessary competence. There are many reports of local and indigenous communities, often disenfranchised from the tourism industry due to lack of other skills, such as language, marketing or management of tourist expectations, despite having vast knowledge related to wild species. Importance of skilled guides, who face the challenging task of balancing minimization of negative impacts of wild species with facilitation of satisfactory tourist experiences, has been repeatedly emphasized in tourism studies (D'Lima *et al.*, 2018; Margaryan & Wall-Reinius, 2017; Muntifering *et al.*, 2019; Newsome *et al.*, 2012; Patroni *et al.*, 2018; Tarver *et al.*, 2019). Importance of skilled staff to enable facilitation of nature and wild species as experience, promotion of experiential education of nature to encourage sustainable behavior, has been one of the key themes in tourism studies in general (Fredman & Margaryan, 2020).

Education and awareness raising for the tourists

Providing environmental education to the tourist has historically been one of the main missions of wildlife watching practice, especially clearly spelled out in ecotourism ethics. There are many cases showing that through educational wildlife watching experience tourists may raise their awareness of nature and potentially adopt more sustainable behaviors (Apps *et al.*, 2018; Bentz *et al.*, 2013; Markwell, 2015; Patroni *et al.*, 2018; Tarver *et al.*, 2019). Proliferation of information technology and social media has also given a new "twist" to the wildlife watching, as wild species can now be watched vicariously. This greater presence of wildlife watching in social media can both raise awareness and increase ethical reflexivity. Recent controversial killings of Cecil the lion, Marius the Giraffe, and Harambe the Gorilla have received global media attention and raised public debates about people's relationships with wild species, including that in the tourist context (Mkono & Holder, 2019).

The growing awareness of wild species stemming from tourism, education, and social media, has increased attention towards the diversity of human-animal interactions. Nevertheless, there is still a comparative lack of attention towards integration of traditional and indigenous knowledge into scientific and educational enterprises (Markwell, 2015). Wondirad *et al.*, (2020, p. 159) for example, state that "further empirical studies can explore how modern scientific knowledge that is advocated by non-governmental organizations can be better integrated with antique indigenous knowledge so that the foundations of ecotourism can be strengthened".

Governance

Monitoring, evaluation, review and adaptive management

Current challenges stressed in the literature include absence of global governance and regulatory authorities of wildlife watching even for highly migratory species, such as whales (Bentz *et al.*, 2013; D'cruze *et al.*, 2017; Decker *et al.*, 2017). Significant effort in this research is dedicated to understanding negative impacts on wild species, such as behavior change, direct harm to animals or habitat alteration, and management outlook of these impacts (Buultjens *et al.*, 2016; Dimmock *et al.*, 2014; D'Lima *et al.*, 2018; Higham & Shelton, 2011; Markwell, 2015; Newsome *et al.*, 2012). Additionally, ethical concerns regarding sustainable management of wild species for watching are of growing importance, focusing on the issues of rights and well-being of animals (Bertella, 2019; Carr & Young, 2018; Markwell, 2015).

Growing importance of social dimensions

Importance of social sciences and qualitative perspectives has significantly increased in the last decade even though truly interdisciplinary contributions are still rather rare. Research is increasingly giving attention to social aspects, such as inclusivity in decision-making and meaningful participation of local communities in sustainable wildlife watching practice (Decker *et al.*, 2017; Mayer *et al.*, 2018; Mutanga *et al.*, 2015; Spenceley *et al.*, 2019; Spenceley

& Snyman, 2017; Wondirad *et al.*, 2020). Decker *et al.* (2017) emphasize that application of these governance elements contributes to sustainable use because mutual understanding and respect among various interests is more probable if all such interests are engaged in an inclusive discourse about goals of wild species conservation. Growing attention also is paid to the importance of cross-sectorial collaboration as well as inclusivity of a wide range of stakeholders in governance processes (Dimmock *et al.*, 2014; Spenceley & Snyman, 2017; Wondirad *et al.*, 2020).

Socio-economic aspects

Income generation as the main positive impact
The role of wildlife watching as a source of economic income supporting both the sustainability of local livelihoods and conservation projects has been one of the central themes in wildlife watching research. Alternative income generation through wildlife watching is being framed as the key positive impact of this practice and raison d'être of many wildlife watching enterprises (Burgin & Hardiman, 2015; Kubo *et al.*, 2019; Mayer *et al.*, 2018; Mutanga *et al.*, 2015; Spenceley *et al.*, 2019; Tarver *et al.*, 2019). At the same time, there is a persistent criticism of prioritizing the economic "pillar" of sustainability at the expense of the other two (Hall, 2016).

Equity
Although the aforementioned economic narrative has been very strong since the dawn of tourism research, more recent literature incorporates critical perspectives on the role of wildlife watching in local economies, especially when it comes to the equity of income distribution as well as revenue and other benefit sharing. There have been many cases where communities have been offered limited involvement in wild species conservation, and see a minimal share of the benefits of tourism, yet bear the costs of living with wild species, resulting in conflict and low levels of sustainability (Ahebwa *et al.*, 2012; Spenceley *et al.*, 2019). Despite this, it has been pointed out extensively that the problem is not with tourism revenue sharing as a concept per se, but with the difficulties in implementing it into real-world practice (Spenceley *et al.*, 2019). Growing demand for innovative arrangements in this context has been quite visible (Ahebwa *et al.*, 2012; Spenceley *et al.*, 2019).

Conclusions

Overall, the following conclusions can be made regarding conceptualizations of sustainable wildlife watching practice in the scientific literature. First of all, understanding of sustainability has moved away from simplistic understanding of minimization of negative environmental impacts and maximization of the positive economic ones. Complexities around implementation of these key elements together with the importance of social sustainability is being addressed more deeply and thoroughly than before. A growing acceptance of wildlife watching as a part of larger socio-cultural and environmental transformations, i.e., the Anthropocene, is rather noticeable. At the same time, there is still comparative lack of attention towards social sustainability when it comes to wildlife watching. It is especially noticeable given the tremendous progress that has been visible in this area in tourism literature in general (Fredman & Margaryan, 2020). In addition, there is still relatively little attention to the issues of indigenous peoples and local communities' rights and indigenous knowledge. At the same time, there is a widespread agreement on the importance of wildlife watching practice for education and stimulation of sustainable behavior. However, approaches to strengthen these benefits currently relies almost exclusively on scientific knowledge, underutilizing the knowledge of indigenous people and local communities. Wildlife watching research also faces a tremendous challenge of keeping up with the ever-expanding number of wild species and local communities being integrated into tourism enterprises. New trends pose new sustainability challenges, such as proliferation of social media and high demand for "selfies" with wild species (see Chapter 3, section 3.3.5.2.3). The lack of reliable and longitudinal scientific data is a major threat to designing sustainable management approaches. Finally, one sees increasingly critical perspectives on wildlife watching as a "benign", "soft" or "non-consumptive" practice of commercializing wild species, as more evidence is accumulated on the detrimental impacts of tourism on biodiversity (Hall, 2016).

2.2.3.7 Summary: conceptualization of sustainable use over time and across practices

Ideas and conceptualizations of sustainability have a long and complex history, developing across multiple governance contexts and diverse academic disciplines. Consequently, sustainability has been conceptualized in multiple and shifting ways by different actors over time. Nevertheless, the objective of avoiding environmental degradation that would lead to a worsening of human conditions in the future has been a common thread. Thus, conceptualizations of sustainable use reflect an increasing understanding over time of the interconnectedness of human societies and natural environments.

The individual practices differ in when an expert literature proposing conceptualizations of sustainable use began to develop, with literature on sustainable logging appearing by the 17th century, and literature on sustainable wildlife watching only appearing in the latter part of the 20th century. However, for the most part, the literature on sustainability broadened along similar pathways for each practice. Initial focus was on avoiding excessive harvests or stress on the specific populations being harvested, expanding next to avoiding excessive pressures on other species also affected by the practice, generally through incidental mortality but occasionally through changes to ecosystem processes and habitat suitability. Interest in the economic performance of the practice generally followed, as did a growing accommodation of concern for more inclusive ecosystem properties that might be altered. Social concerns were usually a minor or neglected factor in how sustainability was conceptualized until the latter part of the 20th century. These social concerns generally appeared first in terms of supporting employment and livelihoods, and as these factors became included in "sustainability" of the practice, typically governance aspects also became part of the discussion, largely in the contexts of inclusiveness and equity in decision-making. Only quite late in the development do the more fundamental matters of culture, identity, community wellbeing and spiritual values appear outside the indigenous peoples and local communities' context, where they have always been central.

In the 21st century social and broad ecological aspects of sustainable use dominate literature on what comprises sustainability for all practices. Ecological aspects of sustainability still dominate over other considerations in the aggregate literature on sustainability of each practice, although the focus is often on just the need to improve performance on the various ecological aspects, and not on expanded (or more restricted) conceptualizations of ecological sustainability. Small-scale fisheries and logging are very active parts of the expert dialogue on sustainability, with comparable priority given to the dependence of local community well-being and culture in sustainability. This has occurred in parallel with a marked shift in attention of literature away from classical economic performance features such as profit and efficiency of obtaining economic returns on investments. The issues of governance and socio-cultural aspects of sustainability are becoming more common in the broader literature, but are not yet fully mainstreamed. Generally, uptake of new ideas spreads across practices more swiftly than in earlier times.

At present, the literature in each practice is giving substantial attention to the interplay of the multiple aspects of sustainable use, and the need to take these interdependencies into account when plans are made to improve sustainability of any of the practices. With the social aspects of sustainability increasingly a focus of attention in all practices, small-scale commercial and community livelihoods are becoming a central consideration in sustainable use. This in turn has made governance issues, including equity and social justice, more prominent in conceptualizations of sustainable use. Another increasing trend in the literature is to both critically re-examine previously accepted benchmarks for single aspects of sustainability of uses, in light of these more holistic views of what constitutes sustainability of the practices, and acknowledge the need to integrate information across diverse knowledge systems. The influence of the 2015 Sustainable Development Goals on the benchmarks and the integration across the aspects of sustainability is beginning to appear in the literature on each practice. There is high agreement in the literature that these factors are central to sustainability of each practice, but vigorous debate among experts of where the correct answer lies.

Overall, across practices, sustainable use of wild species is increasingly understood as a dynamic, social-ecological process, with socio-cultural aspects of sustainable use – including community identity, wellbeing and health – representing elements of sustainable use that are fundamentally interrelated and inseparable from the ecological and social aspects of sustainable use that have long been recognized.

2.2.4 Diversity of indigenous and local conceptualizations and perspectives on sustainable use

The following section highlights a suite of diverse conceptualizations and perspectives held by indigenous peoples and local communities around the world. Indigenous peoples and local communities' worldviews, including those that relate to interactions with wild species, are encoded in cosmologies, myths, stories, songs, rituals, and numerous other forms of cultural expression (IPBES, 2019a, 2019b). These worldviews and their accompanying indigenous and local knowledge are situated in place-based practices and lifeways that have been developed and refined over centuries and generations. Together they carry key insights to enhance the way people understand the natural world and the ways people conduct meaningful research and resource management (Ban *et al.*, 2018). Accordingly, this section draws from peer-reviewed academic literature together with other forms of knowledge expression as identified by contributing authors. The method for this section is presented in the data management report available at https://doi.org/10.5281/zenodo.6049358.

Perspectives on the global marine environment

Viewed as totemic ancestors (P. A. Clarke, 2001; Hickey, 2006; Leblic & Teulières-Preston, 1987; Morphy, 1991) or spirits of nature (Lewthwaite, 2017; Martínez Mauri, 2019; Rambelli, 2018), certain aquatic species are indeed pivotal in the distribution of watery spaces. Their role, decisive in maintaining social equilibrium, has even been used to justify their qualification as "keystone cultural species" (Dounias & Mesnil, 2007; Garibaldi & Turner, 2004). Fishing, as practiced by indigenous peoples and local communities, can never be separated from this socializing network that links them to non-humans. These privileged relationships between indigenous peoples and local communities and aquatic species can be expressed in many ways. For example, the Baniwa, who live in the Brazilian Amazon rainforest and who have a vigorous ichthyological cosmology, believe that fish share with humans a set of distinctive cultural traits. Like the Baniwa, the fish learnt to dance and build large communal houses *(malocas)* alongside the first original beings of Baniwa culture (Albuquerque & Garnelo, 2018). For the Moken in Burma, all important customary figures (shamans or performers) have a maritime double, often a cetacean or dolphin, whose shape they occasionally adopt. These close ties with aquatic beings considered original relations (turtles are considered by the Moken as mythical sisters; see Ivanoff, 1992), do not preclude their fishing but it does lead to numerous precautions and prohibitions when these species are targeted.

Perspectives from Mexico

For the Mayan communities of the Yucatan peninsula in Mexico, the sustainable use of plants and animals is nurtured and reproduced by a cosmovision of nature as part of a sacred universe, with no clear separation between the wild and the domesticated *(milpa)*, as these interrelate in the cosmogonical and survival space. For the Mayan and peasant communities of the Yucatan, mountains and water bodies, along with the wild animals that inhabit them, and that serve as food or medicine for the communities, have owners. These forest owners – or masters- are spiritual beings who can punish in case of overuse of wild species, e.g., if they are over-harvested for market sale or if the species' habitats are destroyed. These beings are inanimate deities known as Yum K'ax (Quintanilla, 2000). Forest owners and a multitude of other beings, such as the *aluxes* or forest helpers, are thought to inhabit the forest and Mayan communities perceive this space as belonging to the supernatural world and not to the humans. For the ancient Maya, the entire universe comes from sacred, invisible and impalpable energies, and these are capable of manifesting themselves in natural beings and phenomena (De la Garza Camino & Nájera Coronado, 2012). To date, these symbolic representations of the sacred in nature have allowed peasants and Mayan communities to continue practicing rituals, such as the chá-chaac ritual for asking rain, and other rituals of thanksgiving for a bumper harvest and for a successful hunt. To maintain harmonious relationships with the wild species and with the crops of the *milpa*, a principle of asking for permission and making appropriate use guide Mayan communities hunting and gathering practices, as well as the access and visits to the forest and the cenotes (pits or sinkholes). Mayan communities continue to make offerings to give thanks for the harvest, as well as entrusting the owners of the forest to collect wild plants that are used as medicine, as it is believed that if one enters the forest without asking for permission one can get lost and never be able to find the way out of the forest. Although there is no clear separation between the wild and the domesticated, it is notorious that wild animals can be sent as messengers or punishment for bad behavior, for example, pests that destroy crops such as stilts and gophers. However, when offerings are made and permission is asked for to the *aluxes* and the owners of the animals, Mayan communities think pests can be chase away from the *milpa*. These rituals that authorize and allow Mayan communities to get closer and even penetrate the sacred dimension of the forests have important implications for the preservation of the forest by mediating the contradiction between the need to conserve and the need to consume natural resources (Quintanilla, 2000).

Perspectives from the Brazilian Amazon

The wild harvest of palm tree products (e.g., edible, protein-rich fruits and other natural materials – such as leaves for construction and wood for fabrication) is an important component of nutritional, material and spiritual well-being for Amazonian indigenous communities. Several palm species are also spiritually significant – often regarded as guardians of other forest resources, animals and plants (Virtanen, 2011b, 2011a, 2015), and are associated with power and protection. Among the Arawakan-speaking Apurinã and Manchineri in the Purus River Basin (Brazil), various species of palm trees are thought to have powerful master (owner) spirits, associated with ancestors. For the Apurinã people *(Pupỹkarywakury)*, moriche palms, acai *(Euterpe oleracea)*, and patauá *(Jessenia bataua)*, are especially valued; while for the Manchineri, the most important include the peach palm *(Bactris gasipaes)*, uricuri *(Attalea phalerata)*, and jarina *(Phytelephas macrocarpa)*. Many of these species appear in their origin stories and some species even have dedicated ceremonial songs that are performed during important communal festivities (Virtanen, 2011b, 2011a, 2015, 2016).

Perspectives from the Andes

Wild species play a key role in the daily lives of Andean quechua- and aymara-speaking people. In addition to being directly used as food, medicine, fodder, or construction material, wild plants and animals are prominently featured in cultural expressions such as traditional textiles and in rituals to the *Pachamama* ("Mother Earth") and other entities of the spiritual and natural worlds. Andean people's complex knowledge systems about wild species is transmitted from generation to generation, and is constantly enriched by external sources (Mathez-Stiefel & Vandebroek, 2012).

Andean people establish a relational rather than an instrumental interaction with their natural environment, which is characterized by respect, love, and the fundamental principle of reciprocity, or *ayni* (Mathez-Stiefel *et al.*, 2007; Walshe & Argumedo, 2016). The *Pachamama*, as source of plant and animal life, is considered to be herself alive (Mamani-Bernabé, 2015)[3]. For instance, activities such as sowing, harvesting, gathering or hunting are always accompanied by rituals of *q'owa* and *ch'alla* ("feeding" and "giving to drink to" the *Pachamama*, respectively) (Mathez-Stiefel *et al.*, 2007) (see photo below). The *Pachamama*, in turn responds through climatic and biological signs – such as the phenology of plants and the behavior of animals – that enable Andean people to forecast the weather and guide agricultural decisions (Mamani-Bernabé, 2015).

The Andean worldview is characterized by a deep interconnection between the human, spiritual, and natural spheres of life. The local world *(pacha)* is understood as a "living landscape" inhabited by a community – or extended family – of human, spiritual, and natural entities (Rist & Dahdouh-Guebas, 2007; Walshe & Argumedo, 2016). As expressed by Santo Vilca Cayo, an elder from the Aymara community of Aynacha Wat'asani (district of Tilali, Puno, Bolivia): "For us, all those of us who live in this pacha (…) are persons: the stone, the soil, the plant, the water, the hail, the wind, the diseases, the sun, the moon, the stars, we all are a family. To live together we help each other. We are always in continuous conversation and harmony" (Ishizawa, 2006).

Andean people make a clear distinction between wild and domesticated species: while the latter are considered the responsibility of people, the former are "sown by the *Pachamama*" and may usually not be used for commercial purposes (Boillat *et al.*, 2013). Community norms regulate thus the use of wild species (Boillat *et al.*, 2013). Interestingly, by "nurturing" the *chacras* (cultivated fields) through agricultural practices and rituals, Andean people do not only maintain a diversity of cultivated crops such as Andean grains and tubers, but also of their wild relatives and other related species (Ishizawa, 2006). Andean worldview, knowledge systems and practices thus directly contribute to the conservation of biodiversity in these living landscapes (Boillat *et al.*, 2013).

Photo: Offering of coca leaves *(Erythroxylum coca)* and flowers to the *Pachamama*; Pitumarca district, Cusco, Peru.

Perspectives from indigenous/aboriginal Australia

For indigenous/aboriginal Australians, ancestral beings, animals, and plants, are essential connections to territories of life. Wild harvest values are nested in the "biophysical, human and supernatural worlds" (J. T. Johnson & Murton, 2007) where plants, animals, ancestral beings and humans are part of the interconnected web of relationships that comprise an indigenous world (Battiste, 2007). Ways of knowing are bound to connections to country, which is more than a "named geography; it is a totality of emotive, physical, intellectual and metaphorical connections that has its own agency and influences" (*Tebrakunna* country; see Lee, 2017). Country is created as a world in which people live concurrently with their ancestors and ancestral beings. Ancestral beings then mediate the relationships between themselves, as ancestors, and us, as the carers of them and their law (Munn, 1970). Many of their ancestral beings are the plants and animals that are understood to reside in both biophysical and supernatural worlds. In this worldview, plants and animals can be thought of as kin: they are brothers and sisters, parents, grandparents, and extended family. In this view, there are no "wild species". Instead, plants and animals hold a place in relation to ourselves and are articulated as "belonging to country".

Perspectives from French Polynesia

Across Oceania, the wild harvest of terrestrial and marine food species is an important mechanism for *in situ* biodiversity conservation (Glamann *et al.*, 2017). While subsistence is a key motivation, the sustainable use of wild species takes many forms in the region, for instance, in Hawai'i upland harvesting of non-tree species for diverse cultural practices (C. K. Blair-Stahn, 2010; Kamelamela, 2019; Wichman, 2012) and the gathering of marine medicinals (Friedlander *et al.*, 2013; Titcomb *et al.*, 1978), or in Papua New Guinea the collection of bird plumage for culturally-salient performances of status and personhood

3. This understanding of the Pachamama as a living being is translated into the legal recognition of its rights in Bolivia and Ecuador (Humphreys, 2017).

in the highlands (Nugi & Whitmore, 2020; Supuma, 2018) and the collection of a wide variety of marine moluscs for purposes of craft and daily use (Kinch, 2003). French Polynesia has a long history of resource extraction of wild marine molluscs, including the management, and governance of *Pinctada magaritifera*, for shell and pearl resources. French Polynesia's black pearl industry accounts for 90% of the world production of black pearls and is managed in coordination with the national government, industry leaders, and local farmers. The pearl sector in French Polynesia, which is currently undegoing a significant transformation to re-center on the sustainable well being of both the ecological and social setting, provides significant insights on the relationships between the well being of local communities and the sustainable development of malacological marine resources with respect to indigenous and local communities' culturally specific engagement and global economic forces (Rapaport, 1996; Rey-Valette *et al.*, 2016). Accordingly, the environmental and social impact assessment of resource extraction or farming of black pearls and *Pinctada* shell nacre has become a lever for sustainable development as a tool of public policy, linking social and environmental issues for transformation towards sustainability (Mazé *et al.*, 2019).

Perspectives from Hawai‘i

Several studies describe place, practice, or plant-focused Native Hawaiian plant gathering practices led or informed by indigenous and local community members (C. G. Blair-Stahn, 2014; Matsuoka *et al.*, 1994; McGregor, 1995a, 1995b, 2007; Ticktin, Fraiola, *et al.*, 2006; Ticktin, Whitehead, *et al.*, 2006). These studies emphasize a strong cultural connection to gathering wild resources for use. The relationship betwen humans and wild species are of high importance, for instance among hunters and wild boars (Luat-Hu‘eū *et al.*, 2021) and among gatherers and non-timber forest products like plants used in cultural practices (Kamelamela, 2019). Individuals who engage in wild harvesting and gathering practices in Hawai‘i describe values and motivations surrounding strengthened personal identity, continuation of practices and traditions, and a sense of cultural responsibility for the harvested resources. Harvester perspectives on the sustainable use of wild species continue to be impactful for policy engagement, in particular their knowledge of resource availability and demand, and are an important source of information for future management of wild resources (plant, animal, minerals).

Native Hawaiian cosmology also plays an important role in the sustainable use of wild species by codifying relationships between human and non-human relatives. For example, the Native Hawaiian creation and origin chant " ‘O Wākea" is well-known for describing the birth of the Hawaiian Islands through the union of Papahānaumoku, Earth Mother, and Wākea, Sky Father. However, the same chant has a lesser-known second half which continues on to describe the first taro plant, Hāloanakalaupakalili, as the older sibling of the first Hawaiians. The inextricable genealogical connections between celestial, plant, and human relatives codified in this worldview provide important context for present-day environmental decision-making, for example when significant public backlash in Hawai‘i derailed plans for patenting and genetic modifications to taro. Although oral transmisison continues to play a central role in the perpetuation, transmission, and present-day interpretation of Native Hawaiian knowledge, the Hawaiian language text of this creation chant is provided below, expanding upon an original excerpt published by seminal Native Hawaiian scholar David Malo in 1903.

‘O Wākea (A Native Hawaiian creation chant, expanded from Malo, 1903)

> ‘O Wākea noho iā Papahānaumoku
> Hānau ‘o Hawai‘i he moku
> Hānau ‘o Maui he moku
> Ho‘i a‘e ‘o Wākea, noho iā Ho‘ohōkūkalani
> Hānau ‘o Moloka‘i he moku
> Hānau ‘o Lāna‘ikaula he moku
> Lili‘ōpū punalua ‘o Papa iā Ho‘ohōkūkalani
> Ho‘i hou ‘o Papa noho iā Wākea
> Hānau ‘o O‘ahu he moku
> Hānau ‘o Kaua‘i he moku
> Hānau ‘o Ni‘ihau he moku
> He ‘ula a ‘o Kaho‘olawe
> Noho hou ‘o Wākea iā Ho‘ohōkūkalani
> Ua hānau kā Wākea keiki mua
> He keiki alualu, ‘o Hāloanaka ka inoa
> A make ua keiki alualu la
> Kanu ‘ia ihola ma waho o kala o ka hale
> I lalo i ka lepo, ma hope iho
> Ulu mai ua keiki la, kalo nō
> ‘O ka lau o ua kalo la, ua kapa ‘ia ‘o Laukapalili
> ‘O ka hā o ua kalo la, ua kapa ‘ia ‘o Hāloa
> Hanau mai he keiki hou
> Kapa lākou i kona inoa ma ka hā o ua Kalo la ‘o Hāloa
> Nāna mai ko ke ao nei a pau
> ‘O Hāloa ho‘i. Hā.

Perspectives from China

There are 55 officially recognized ethnic minority groups in China in addition to the Han majority. While the Han majority is in large guided by the orthodox Confucianism, the ethnic minorities in contrast embrace a vast variety of religious, spiritual and traditional beliefs, including Buddhism, shamanism, polytheism, and/or a synergy of the above-mentioned. These diverse worldviews are usually reflections of and intricately intertwined with the relationship between ethnic minorities and their surrounding nature environments.

Photo: Akha farmer harvesting honey (wild *Apis cerana*).

Given the high conservation value of being a biodiversity hotspot, Yunnan province in southwest China has received significant international attention. It is also home to 26 ethnic groups including Han, different ethnic groups regard many landscapes as sacred (Pei & Luo, 2000). For example, the Dai people in Xishuangbanna, believe gods reside on the forested holy hills known in the Dai language as *Nong* (Liu *et al.*, 2002; Pei, 1985). All the plants and animals that inhabit these hills are either companions of the gods or sacred living things within the gardens of the gods. In addition, the Dai believe that the spirits of great and revered chieftains reside in the holy hills. Holy hills are therefore a key component of local ecosystems, and studies have found that a high concentration of endemic and endangered species in the holy hill forests, which include 15 species listed in the Plant Red Data List of China, such as *Magnolia henryi, Homalium laoticum*, and *Antiaris toxicaria* (Liu *et al.*, 2002; Xu *et al.*, 2006).

Aside from having sacred landscapes, many ethnic minorities in Yunnan practice animal worships and plant worships, which are usually documented and reflected in their own ancient historical records. Taking Yi people as an example, in their traditional folklore of *Mei Ge*, the universe was made from tiger (the head of the tiger formed sky, the belly skin of the tiger formed the land, the left eye formed the sun, and the right eye formed the moon and so on) and everything on the earth planet thrived from there. Tiger is considered as the ancestor of the Yi and until nowadays, it is still highly respected and protected in Yi culture. Moreover, ancient historical record of *Quan Shan Jing* (Good Behaviors) also guides the Yi people to live with wild species in harmony, never take more than needed. This kind of behavior or guidance is also imbedded in everyday life of Akha people, who are farmers residing in the mountainous regions and having a long tradition of beekeeping (see photo below). Even with the commercialization of honey, Akha people still follow the traditional ways of 'never take too much and always leave some for the bees', they believe in practicing such sustainability, the bees (wild *Apis cerana*) would not attack people when harvesting the honey.

The many different beliefs in ethnic minorities leading to the peaceful co-existing with the nature are on the edge of being comprised by policy interventions, technology development, the rise of market economy, and cultural assimilation.

Perspectives from India

The high cultural, geographic and ethnic diversity of India reveals both anthropocentric and ecocentric worldviews with regard to the sustainable use of wild species by indigenous and local communities. Anthropocentric worldviews are apparent in local communities' interactions with wild species, especially plants. The diversity in wild edible species foraged from forests and agricultural lands, their nutritive and curative values, and associated traditional knowledge, all reveal utilitarian, practical and instrumental values. However, more ecocentric worldviews emerge when scaling up from individual wild species to their habitats and to interactions at the ecosystem level. Such worldviews are grounded in various cosmological and ontological frameworks, in which dominant religions in the Indian context may play a role, as in Hinduism many species are considered sacred because of their association with gods and goddesses and in Buddhism, the Bodhi tree *Ficus religiosa* under which the Buddha attained enlightenment is held sacred and considered the tree of life (N. Gupta *et al.*, 2016). Research have shown that ritual obligations and related daily practices and interactions with wild species may lead to a control over harvest of algae, fungi and plants and various species of animals, fishes and insects, thus leading to a sustainable use of these species (Behera & Patel, 2008). Ecocentric worldviews are also evident in community interactions with faunal species, for example religious and customary values are attached to fish conservation (N. Gupta *et al.*, 2016). Studies of people's attitudes towards snow leopards and wolves in Ladakh India, show that even though religion solely by itself is not an indicator of an individual's attitude toward large carnivores, the extent to which they practiced it (i.e., religiosity) had a positive correlation with pro-carnivore attitudes in Buddhist communities (Bhatia *et al.*, 2017). In the Indian subcontinent, sacred groves are also recognized as playing a role in conserving and making available key medicinal and edible plant species for local populations (Boraiah *et al.*, 2003; Ormsby & Bhagwat, 2010), while this observation cannot be generalized (Uchiyamada, 2008), partly because of a fast-changing context which increases pressure on such sites (Rath & Ormsby, 2020).

Perspectives from Poland

For local communities in Poland, wild harvest practices like gathering berries and mushrooms helped to supplement the rural economy. Gathering practices, which are primarily conducted by Polish farmers, often coincided with the Catholic church calendar and dates of patron saints. For example, in some rural communities the 2nd of July was called *"Matka Boska Jagodna* (lit. Virgin Mary of Berries)" and marked the appropriate time to collect bilberries *(V. myrtillus)*. It is believed that harvesting no sooner than this date allowed the berries to properly mature. A similar tradition existed on the 8th of September called *"Matka Boska Siewna* (lit. Virgin Mary of Sowing)". This date marked the appropriate time to collect hazel nuts *(Corylus colurna)*. On that day, groups of boys and men went to the woods together to harvest the nuts. This was thought to ensure the equitable collection of mature nuts and prevented the collection of immature fruits (Ogrodowska, 2004; Łuczaj, unpublished data).

Perspectives from Kyrgyzstan

Wild harvest worldviews and perceptions can be shared via diverse forms of expression. For instance, among the Kyrgyz of Central Asia, the epic legend of Kojojash encodes local and cultural worldviews on hunting. The legend, which is a popular story for children, is studied in schools and is often depicted by artists in Kyrgyzstan. It describes the downfall of a skilled and successful hunter (named Kojojash) who succumbs to greedy and wasteful harvest practices. The legend outlines the consequences of Kojojash's wrong-doing, but ultimately ends with reconciliation of nature and people (Aitpaeva, 2006).

Perspectives from East Africa

The pastoralist Barabaig of Hanang District (Tanzania) have deep and sophisticated relationship with their environment guided by a complex web of rules and knowledge which avoid the depletion of pastoral resources (Lane, 1993). For example, they practice grazing cycles established through strict regulation of access to land, water and other pastoral resources. These regulations are based on deep traditional knowledge of soil types, topography and groundwater in each area of their territory, and the location and condition of the vegetation that these factors imply at every moment of the year. This is accompanied by a cultural belief that territory is not owned, but carries a right of usufruct inherited from ancestors that must be preserved for following generations. The Pokot of Baringo County (Kenya) have neighboring councils *(Kokwo)* for decision-making, including for decisions regarding access to common resources, such as grazing lands (Bollig *et al.*, 2014). They are located in traditional places, usually under particular large trees, and they are composed of all initiated men living in the area at that moment, under the control of a few prestigious elders. Similar temporary grazing exclusion reserves *(Milaga)* exist among the Gogo agro-pastoralists of Dodoma region, Tanzania (Mwamidi & Dominguez, 2019). Pastoral governance practices also extend beyond the care for the herd. For instance, in the Daasanch community (northern Kenya), elders protect indigenous trees by all possible means because they conceive of both humans and trees as all belonging to one family – the Daasanach community. A curse will fall upon anyone who destroys trees that are used to cure diseases among their people. In their worldview, cutting a tree is like killing a person, because the medicine the trees provide saves the lives of the sick. These are just a few examples of cultural representations and community practices that aim to sustain local ecosystems through a relational ethos.

Perspectives from Eastern Europe

The communistic political regime of Eastern Europe caused considerable erosion to the customary norms, practices, and traditional knowledge of indigenous peoples and local communities. Despite this significant obstacle, many elements of sustainable use practices and knowledge survived in remote local areas. Whereas in the western part of Eastern Europe the Cartesian dichotomy strictly demarcating nature from culture is prominent, the Eastern part often has animistic worldviews where plants and animals possess a soul (Descola, 2013). While nuanced across communities in the Eastern Europe region, this juxtaposition in worldviews manifests in several ways. For example, understanding of sustainable grazing by traditional

Hungarian steppe herders is different from the view of nature conservationists (Molnár, 2014; Molnár *et al.*, 2016), because the indicators used to determine impact of grazing are different (resprouting ability of dominant forage grasses vs. survival of sensitive threatened species). Knowledge of local species is also critical in supporting sustainable use, for instance among the Csángó people in the Eastern Carpathians who depend on summer forage grass and winter hay fodder as resources. Csángó peoples' in-depth knowledge of >240 folk plant taxa and >140 folk habitat types (Babai & Molnár, 2014) enable sustainable harvest, while creating and maintaining one of the most diverse meadow systems of European importance (Csergő *et al.*, 2013). Worldviews can also have unique impacts on landscape modifications, for instance among the Sakha horse and cattle breeders (northeastern Siberia) who both accept and reject the dichotomization of nature and culture (Mészáros, 2012a). For example, while most meadows and lakes are human like animate entities with unique character traits, forests are opposed to the human realm (Mészáros, 2012b). Consequently, while lakes are closely monitored, deforestation is an important tool to support their pastoral practices.

Concluding remarks

In summary, indigenous and local social-ecological systems, including their associated sustainable use and harvesting practice and knowledge, vary greatly over space and time but also share strong commonalities. The examples provided here demonstrate that reciprocal connections between humans and non-humans and relational values associated with wild harvest are defining characteristics of sustainable use across indigenous peoples and local communities. So, too, is the importance of overall well-being, social networks of sharing, ceremonial and ritual practices, and indigenous and local knowledge of wild harvested species. The ontological foundations of sustainable use can also result in adaptations or refinement over generations of practice, for instance according to lived and experienced knowledge, and in response to evolving social, cultural, environmental and economic pressures. Several other pressures can transform worldviews and values surrounding the ways in which indigenous and local communities understand and relate to wild species. These pressures include post-colonial processes (including land-loss and exploitation), integration into national societies and schooling, along with many other multifaceted pressures (Gadamus & Raymond-Yakoubian, 2015; Gambon & Rist, 2019; Gombay, 2014, 2015; Gómez-Baggethun & Reyes-García, 2013). Although these examples provide a brief glimpse into the peer-reviewed academic literature together with other forms of knowledge expression as identified by the contributing authors, there are many other pertinent perspectives on this topic including those described in section 2.2.10.

2.2.5 Conceptualizations of sustainable use in the international policy arena: Definitions from international conventions

Today many international conventions and agreements that relate to the conservation of wild species also make reference to their sustainable use. Some provide definitions of "sustainable use", whereas others only refer to it. Although emphases vary, a clear commonality across definitions and vision statements is that the idea of sustainable use refers both to conserving/ not causing serious or irreversible harm to biodiversity as well as to supporting people who depend on it, whether the dependence is in reference to needs, aspirations, socio-economic services or cultural values **(Table 2.3)**.

This table is illustrative. It does not include all existing agreements, and new agreements and amendments to older ones continue to emerge, with shifting definitions.

In addition, many of the agreements suggest that the sustainable use of wild species itself can be a central part of conservation. For example, the Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity state that, "sustainable use is a valuable tool to promote conservation of biological diversity, since in many instances it provides incentives for conservation and restoration because of the social, cultural and economic benefits that people derive from that use". Similarly, Axiom 4 of the IUCN White Oaks Principles states that "sustainable use is a means of bringing about conservation of species and habitats". This notion is echoed across practices. For example, the European Charter on Hunting and Biodiversity (2007) states that "sustainably managed hunting can contribute to the conservation of biodiversity, the preservation of rural lifestyles and local economies. In this context hunting can provide strong incentives for conservation through use of biodiversity *sensu* the Convention on Biological Diversity".

2.2.6 Key elements of sustainable use in global and regional standards, agreements and certification schemes

2.2.6.1 Approach taken

Any picture of conceptions of sustainable use in the global conservation arena requires, among other tasks, identifying the ideas in the principles endorsed in global and regional agreements regarding sustainable use. In sustainable use agreements, a "principle" is commonly formulated around a core concept based on social ethics, values, and tradition as well as on scientific knowledge of outcomes for different

Table 2 3 **Definitions of sustainable use of wild species in some international conventions and agreements.**

Convention on Biological Diversity (1992)	Definition of "sustainable use"	"use of the components of biodiversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations"
IUCN White Oak Principles (2001)	Definition of "sustainable use"	"a dynamic process toward which one strives in order to maintain biodiversity and enhance ecological and socio-economic services, recognizing that the greater the equity and degree of participation in governance, the greater the likelihood of achieving these objectives for present and future generations"
Ramsar Convention on Wetlands (1975)	Definition of "Wise use"	"the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development"
United Nations Forest Instrument (2007)	Definition of "sustainable forest management"	"… a dynamic and evolving concept, aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations".
International Union of Forest Research Organizations (IUFRO) and Collaborative Partnership on Sustainable Wildlife Management (CPW)	Definition of "sustainable hunting"	"the use of wild game species and their habitats in a way and at rate that does not lead to the long-term decline of biodiversity or hinder its restoration. Such use maintains the potential of biodiversity to meet the needs and aspirations of present and future generations, as well as maintaining hunting itself as an accepted social, economic and cultural activity".
European Charter on Hunting and Biodiversity (2007)	Definition of "wildlife management"	The application of science-based and local knowledge in the stewardship of wild (including game) animal populations and their habitats in a manner beneficial to the environment and society.
European Charter on Hunting and Biodiversity (2007)	Definition of "sustainable hunting"	The use of wild game species and their habitats in a way and at a rate that does not lead to the long-term decline of biodiversity or hinder its restoration. Such use maintains the potential of biodiversity to meet the needs and aspirations of present and future generations, as well as maintaining hunting itself as an accepted social, economic and cultural activity (based on the definition of "sustainable use" in Article 2 of the Convention on Biological Diversity).
Convention on Migratory Species	Vision statement	"Living in harmony with nature – where populations and habitats of migratory species (along with all biodiversity) are valued, conserved, restored and wisely used, thereby contributing to global sustainability
UNESCO World Heritage Convention	Operational guidelines (2015)	World Heritage properties "may support a variety of on-going and proposed uses that are ecologically and culturally sustainable

degrees of change imposed on nature. Differences in principle can reflect, *inter alia*, differences in the relative value placed on different aspects or elements of sustainable use. An analysis of principles can highlight commonalities as well as differences in the global conceptualization of sustainable use across practices.

2.2.6.2 Materials and methods

To identify how sustainable use is conceptualized at the international level, and how it may vary across practices, a search for international or regional agreements, standards and certification schemes for sustainable use (hereafter referred to as "standards" for simplicity) was conducted and a comparison of the ideas in their principless was carried out. The methodology is described in the data management report available at https://doi.org/10.5281/zenodo.6473133. Twenty-five standards are included in this analysis (see **Table 2.1** in the data management report). This list captures many of the widely-used standards across all practices. Not all standards, guidelines or certification schemes contain principles. For example, multiple international and regional standards for sustainable forest management contain only criteria and indicators, including the Montreal Process, Forest Europe, Amazon International Tropical Timber Organization, the Association of Southeast Asian Nations' Criteria and Indicators for Sustainable Management of Tropical Forests, the Tehran Process for low forest cover countries, and Programme for the Endorsement of Forest Certification, among others. Consequently, these are not included this analysis. Indicators are discussed in section 2.3. Also, depending on their placement in an agreement, the principles themselves may not be binding, even if the agreements are.

To identify the different ideas about sustainable use present in the principles, the principles in each standard were sorted into one or more themes or "key elements". To develop the list of possible key elements, those explicit in the Addis Ababa Principles and Guidelines for Sustainable Use of Biodiversity were used as a starting point and new themes were added for ideas that are not captured in the Addis Ababa Principles and Guidelines, but are present in other standards. Any given principle may capture one or more key element.

A total of 18 key elements were identified from the principles listed across the 25 standards **(Figure 2.3)**. In this assessment, this compiled list is referred to as the "key elements of sustainable use". It is this aggregated list that is used in the policy analysis in section 2.2.7.

The standards range in terms of their scale (e.g., national level *versus* management unit), context (subsistence *versus* recreational *versus* commercial harvest; resources harvested from commons *versus* from private property) and purpose (e.g., binding *versus* voluntary agreements *versus* certification schemes). Some standards include many key elements whereas others have few **(Figure 2.3)**. In addition, clearly not all key elements are relevant to all standards. Nonetheless, when viewed together, the range of key elements covered across the diverse standards sheds light on how sustainable use of wild species is conceptualized in the international conservation arena, and a broad comparison of key elements provides insight into commonalities and differences in these conceptualizations **(Figure 2.3)**.

The key elements span five broad categories: governance, management and monitoring, ecological impacts, socio-economic benefits, and education. Most standards include elements of the first four of these categories, indicating that in this arena, sustainable use is widely conceptualized to include social, economic and ecological components. Exceptions to this are some of the older legally binding multilateral agreements, which center on monitoring, management and ecological impacts.

For both voluntary agreements and certification schemes, most standards include key elements that refer to the need to: respect existing laws and policies; respect the access and use rights of local communities; implement adaptive management and monitoring plans; minimize ecological impacts – including those on the species harvested, the surrounding ecosystem and on ecosystem services – and foster socio-economic benefits. Many standards also include key elements related to the need to build capacity among resource users. These appear to be the broadly shared key elements for sustainable use. These key elements encompass (sometimes explicitly stated and other times not), both the ecosystem approach and the precautionary approach. At the other end of the spectrum, few standards include key elements related to minimizing waste.

There are also some differences. For example, almost all of the voluntary standards refer to common-pool resources, and in addition to the themes mentioned above,

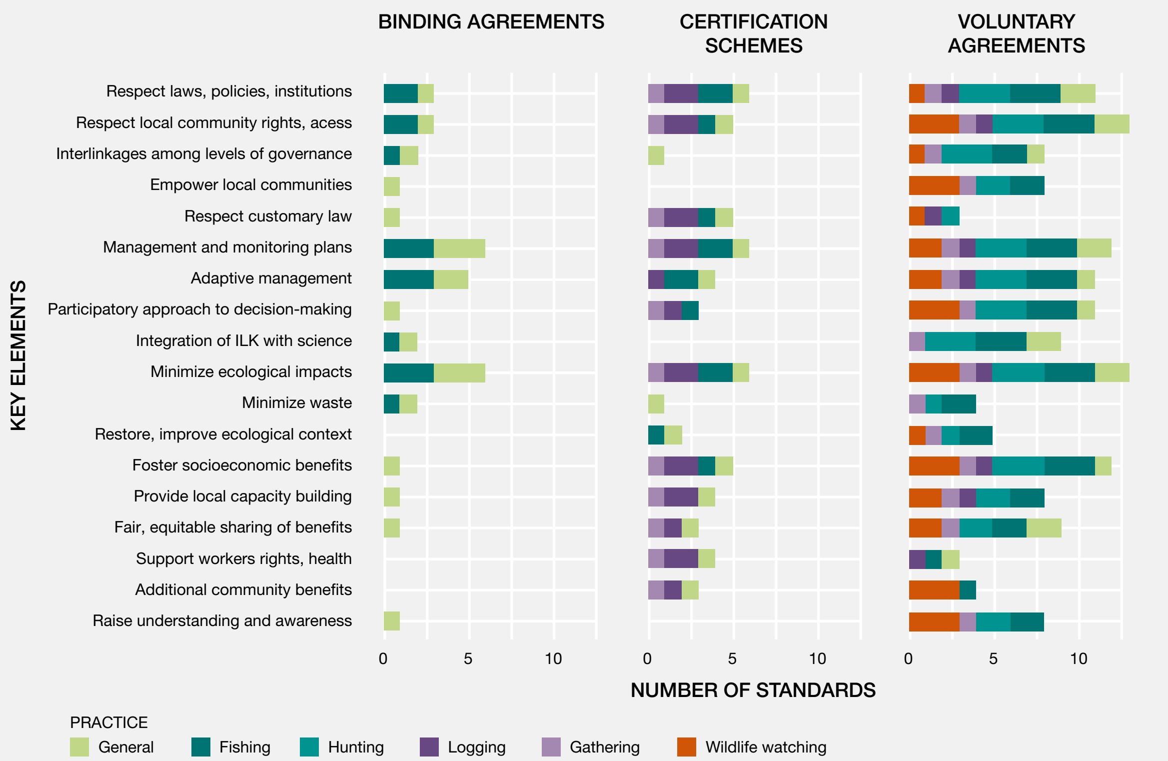


Figure 2 3 **Key elements of of sustainable use of wild species in international and regional agreements, including binding agreements (n=6), certification schemes (n=6) and voluntary agreements (n=13).**

most also include key elements that relate to: ensuring interlinkages among levels of governance; empowering local communities in the management of wild resources, including through a participatory decision-making process; integrating indigenous and local knowledge and science in the development of sustainable management plans; the fair and equitable distribution of benefits; and raising public understanding and awareness. These concepts are clearly perceived to be important to sustainable use in these voluntary agreements. Many certification schemes, which are aimed largely for commercial operations, include key elements related to respecting local customary law, including indigenous peoples and local communities' access for food, nutritional and livelihood security, and to workers' rights and health.

All standards include key elements related to minimizing ecological impacts, but some voluntary agreements and certification schemes go one step further, by explicitly including the restoration of past damage and/ or improvement of ecological status as a key element of sustainable use. Similarly, although most standards include key elements relating to socio-economic benefits, some, in particular those related to watching, include key elements or guidelines that stipulate the need for additional intangible socio-cultural benefits for indigenous peoples and local communities, such as promoting community-solidarity, safety or social-pride. One gathering certification standard included a premium for community social development. Overall, though, there do not appear to be any broad differences across practices in terms of key elements of sustainable use.

2.2.7 Crosswalk of key elements and policies on sustainable use of wild species

This section identifies the extent to which the key elements of sustainable use identified in section 2.2.6 are captured in formal policy provisions intended to guide practice. Policy provisions articulate commitments or requirements for delivering specific goals or outcomes when a policy is applied in real-world contexts. Provisions can range from aspirational to highly operational, but generally have some evidentiary basis.

2.2.7.1 Global Policies

2.2.7.1.1 Approach taken and rationale

This section focuses on global organizations and agencies that set policies to regulate or guide activities in each of the practices reviewed in the IPBES assessment of the sustainable use of wild species. These organizations and agencies were associated with four different "perspectives" on sustainable use, where "perspective" is a general expression of both the formal mandate of each organization or agency and the background and interests of its professionals, experts, and members: the business or corporate perspective, environmental non-governmental perspective, the intergovernmental organizations perspective, and the indigenous peoples and local community perspective. The fifteen organizations and agencies reviewed here included five organizations or agencies from each of the three perspectives, with a mix considered representative for each perspective **(Table 2.4)**.

Table 2 4 **Organizations whose policy documents were considered for the analysis.**

Business	Forest Stewardship Council
	International Chambers of Commerce
	Marine Stewardship Council
	Natural Capital Coalition
	World Business Council
Environmental non-governmental organization	FairWild
	International Union for Conservation of Nature
	The Nature Conservancy
	TRAFFIC World Wildlife Fund
Intergovernmental organizations	Convention on Biological Diversity (Convention and Annexes)
	The Convention on Biological Diversity Guidance Document on Sustainable Use
	FAO guidance on fisheries
	FAO guidance on forestry
	International Council Game and Wildlife Conservation

Following a preliminary review, it was determined that the quantitative scoring process applied to the four classes of organizations and agencies identified above would miss core elements and provisions in documents issued by global federations of indigenous peoples and local communities such as the United Nations Permanent Forum for Indigenous Peoples and the International Indigenous Forum on Biodiversity. As a consequence, analysis of key elements and provisions in documents issued by these federations (see supplementary materials S2.2) are presented in sections 2.2.4 and 2.2.8. Those sections of this chapter are an essential complement to the quantitative policy evaluations presented here.

This crosswalk of high-level policies with the key elements of sustainable use articulated by global organizations and agencies is not equally straightforward for all practices. For example, in the case of fishing and logging, there are United Nations intergovernmental organizations that national governments have agreed globally to give oversight for development of policy and guidance on acceptable practices. In both cases it is the FAO, although different departments within it. At the other extreme there seems to be no global and in some cases little national policy oversight for some aspects of gathering and/or non-extractive practices, although individual countries may have specific regulations for specified parts of nature.

The five institutions evaluated for each type of organization provide insight into uptake of the emerging global key elements of sustainable use. The analysis also offers an opportunity to look for consistent differences among the perspectives in terms of key elements receiving greater or lesser attention in major policy documents (see **Table 2.2**. of the data management report here for the list of documents reviewed at https://doi.org/10.5281/zenodo.6473133.

2.2.7.1.2 Categories and scoring approach

Policy provisions relevant to each key element were evaluated using a five-category rating system (see supplementary materials S2.3).

Absent – there are no provisions in the policy document that are directly relevant to a specific key element.

Inconsistent – there are individual provisions in the policy document that contradict or are directly in opposition to a specific key element.

Inferred – Although the language of the key element is not present in the individual provision of the policy, it can be reasonably inferred that the *intent* of the element is behind some provisions in the policy.

Partial – Language in the provision of the policy represents clearly the intent of a key element, but only some aspect(s) of the element are captured in the policy provisions.

Complete – The intent of the key element is clearly and fully captured in the provisions of the policy document.

Absent is assigned to a policy-key element combination only, but always, if none of the other categories is relevant for that combination. While unlikely in well-crafted policy documents, inconsistent can apply in combination with inferred, partial or complete. Where a policy document separates the intent of a single key element into multiple policy provisions the aggregate treatment within the document as a whole was scored.

2.2.7.1.3 Policy analysis – global results

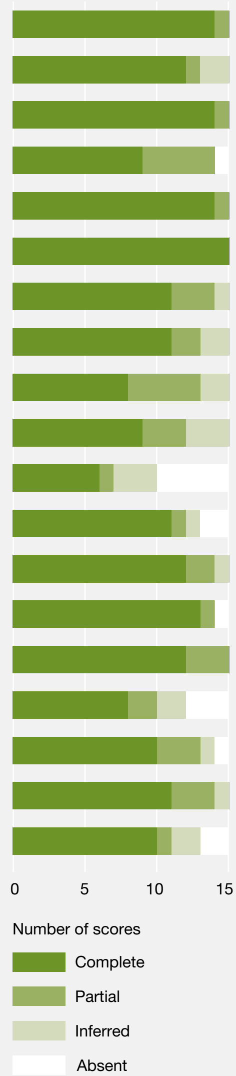
The policy documents reviewed display high uptake of the key elements of sustainable use. A median of 15 of the 19 key elements were fully present in all of the policy documents reviewed for each organization or agency. The range from as few as 9 to as many as all 19 key elements completely addressed suggests there are some differences among agencies and organizations in degree of uptake **(Figure 2.4)**. However, when complete and partially present scores are combined, the aggregate uptake score is higher overall, and consistency across agencies and organizations increases substantially.

The number of key elements found to be absent in an agency's or organization's policy documents ranges from 0 to 3, with 0 being the modal value. Only one agency does not address 3 key elements in part or whole. The number of key elements addressed in ways considered inconsistent also ranges between 0 and 3 among agencies and organizations, again with a modal value of 0 key elements. Inconsistent and absent scoring tended to be reciprocal rather than additive. When aggregated, absent and incomplete key elements range between 0 and 4, with a median and mode of 2 per agency or organization.

Uptake of the key elements of sustainable use is high in all the agencies' and organizations' policy documents. This is a welcome and somewhat remarkable finding given that a number of the key elements identified in section 2.2.6 were broadly accepted as core elements after some of the policy documents had been adopted by their respective agencies and organizations. Nevertheless, the fact that uptake is not complete presents scope to explore where there is less than full uptake.

Looking first at the key elements that were scored as absent in **Figure 2.4**, the overall probability that an element is absent is quite low (P = .0526). However, two key elements account for 8 of 15 absent scores, minimize

Type	BUS					ENGO					IGO				
PRINCIPLE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Respect laws, policies and institutions	C	C	C	C	C	C	C	C	C	C	P	C	C	C	C
Respect local community rights and access	C	C	I	C	C	C	C	C	I	C	C	C	C	C	P
Effective interlinkages among levels of governance	C	C	C	C	C	C	C	C	C	C	C	C	C	P	C
Local communities empowered	C	P	P	P	C	C	C	C	C	C	A	P	C	C	P
Respect customary law	C	P	C	C	C	C	C	C	C	C	C	C	C	C	C
Management and monitoring plans in place	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Adaptive management specified	C	C	C	I	C	C	C	P	C	P	C	C	C	C	P
Participatory approach to decision-making	C	C	P	P	C	C	C	C	I	C	C	C	I	C	C
Use of multiple knowledge systems – ILK & Science	C	P	P	I	C	C	C	P	C	C	I	C	P	C	P
Minimize ecological impacts	C	C	C	P	C	C	C	P	C	C	I	I	C	P	I
Minimize waste	A	C	C	P	C	A	I	I	A	C	C	I	A	C	A
Restore and/or improve ecological context	A	C	C	P	C	A	C	C	C	C	C	C	C	C	I
Foster socioeconomic benefits	C	C	I	C	C	C	C	P	C	C	C	P	C	C	C
Provide local capacity building	C	C	A	C	C	C	C	C	C	C	C	C	C	P	C
Fair and equitable sharing of benefits	C	P	P	C	C	C	C	C	C	C	C	C	C	C	P
Workers rights and health supported	C	C	P	C	C	C	A	P	C	C	I	I	A	C	A
Sociocultural benefits	C	C	P	C	C	C	A	C	C	C	C	P	C	I	P
Raise understanding and awareness	P	C	C	C	C	P	C	I	C	C	C	P	C	C	C
Financially responsible business practices	C	C	A	C	C	C	A	I	C	C	C	P	C	I	C



Name of Organization or Agency

BUS
1 FSC
2 ICC
3 MSC
4 WBC
5 WCC

ENGO
6 FAIRWILD
7 IUCN
8 TNC
9 TRAFFIC
10 WWF

IGO
11 CBD (Con)
12 CBD (SU)
13 CIC
14 FAO-Fish
15 FAO-For

Figure 2 4 **Key elements of sustainable use in global policy documents.**

Stacked bar graphs to the right of each table row display the frequency of occurrence of each score. C = complete; P = partial; I = inferred; A = absent. BUS = business; ENGO = Environmental Non-Governmental Organization; IGO = Intergovernmental Organization. See data management report at https://doi.org/10.5281/zenodo.6473133.

waste (5 absent scores) and support workers' rights and health (3 absent scores). Two other key elements, restore or improve ecological context and apply responsible business practices, were absent in two agencies' or organizations' policies.

Treating a key element inconsistently within or across a series of policy documents also is problematic for an agency or organization. A total of 36 occurrences of either inconsistent or absent key elements were found in the analysis.

When absent and inconsistent scores are aggregated, the same key elements emerge as having less uptake: minimize waste, support workers' rights, restore or improve ecological context, and apply responsible business practices. Minimize ecological impacts also was absent or inconsistent in three cases. There was no statistically significant difference in the likelihood that a key element would be absent or inconsistent in policy documents by perspective (e.g., business organization, environmental non-governmental organization or intergovernmental agency).

Some cautions are in order when interpreting results of the evaluation. The generally low rate of absent or inconsistent treatment of key elements is encouraging. It may be the case, however, that the various perspectives on sustainable use accord lower priority to some key elements. The inclusion of five different agencies or organizations from each perspective was intended to allow the such potential differences to be evaluated. Two additional design factors in the choice of organizations and agencies also are to be kept in mind.

First, although serious efforts were made to evaluate the most prominent policy documents of each agency or organization, some relevant documents may not have been included in the analysis. Second, as previously noted, the perspectives of indigenous peoples and local community perspective are not included in these scorings.

Overall, this evaluation finds that at the global scale, across a range of organizations and agencies with business/ corporate, environmental non-governmental organization and intergovernmental perspectives, all have taken on most of the key elements of sustainable use, including:

- Respect laws, policies and institutions;
- Respect local community rights and access;
- Effective interlinkages among levels of governance;
- Local communities empowered;
- Respect customary law;
- Management and monitoring plans in place;
- Adaptive management specified;
- Participatory approach to decision-making;
- Use of multiple knowledge systems;
- Foster / provide socio-economic benefits;
- Provide local capacity building;
- Fair and equitable sharing of benefits;
- Provide socio-cultural benefits;
- Raise understanding and awareness

Collectively these agencies and organizations address many aspects of healthy species and ecosystems, generating and sharing economic benefits, and prosperous stable communities. Aspects of equity, governance, knowledge and capacity-building also are elaborated in their policies. The few key elements not included in this list are still widely taken up and none are frequently overlooked. Together these results indicate that global organizations have been progressing in directions consistent with the evolving consensus on key elements for sustainable use.

2.2.7.2 Regional Policies

2.2.7.2.1 Introduction and intent

A number of regional governance bodies also set policies and standards for sustainable use. Serving governance functions between nation states and global agencies and organizations, regional bodies generally are established for one or both of two reasons: (1) harmonization of objectives for species and natural features that cross national boundaries, and (2) coordination of policies and measures for their governance and management (Boyd *et al.*, 2015; Granberg *et al.*, 2019; Prager, 2010).

Regional coordination is pursued and facilitated through diverse governance approaches and arrangements. Some regional arrangements are strictly sectoral, others are multi-sectoral. Some are bilateral while others are multilateral. Some are enabled by binding agreements, others by a variety of mixes of mandatory and voluntary provisions. In the case of fishing the fact that stocks being harvested and biodiversity features impacted extend or are restricted to areas beyond national jurisdiction adds further complexity to their governance. However, the United Nations Convention on the Law of the Sea (1982) and "Fish Stocks Agreement[4]" (1995) enable States to come together to form regional fisheries management organizations, and develop policies and regulations that are binding on its members. Earlier fisheries conventions include the International Commission of the Conservation of Atlantic Tuna.

An exhaustive review of all types of regional arrangements for promoting sustainable use of wild species was beyond the capacity of this assessment. Rather, given the important role of regional arrangements as a link between global and national policies and actions, this section presents a few illustrative examples of how regional governance bodies address the key elements of sustainable use examined in more depth in the global (preceding) and national (following) sections of this chapter.

Five regional intergovernmental organizations were chosen for an exploratory review. The methodology for the analysis is described in the data management report available at https://doi.org/10.5281/zenodo.6473133.

4. Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks

- The International Tropical Timber Organization is an intergovernmental organization established in 1983 for developing policies on the economy and trade of tropical timber. Membership is open to all countries producing or importing tropical timber. Current members include 36 producer countries and 38 consumer countries and regions, which represents more than 80% of the world's tropical forests and about 90% of international tropical timber trade.

- The Carpathian Convention was established in 2003 to guarantee protection and sustainable development of the Carpathians. It is the only multilateral agreement addressing multi-level governance in the whole of the Carpathian area and it was, after the Alpine Convention, the second regional treaty-based regime for the protection of a mountain region worldwide. Specific substantive obligations are defined by protocols, which function as means to operationalize the key elements of sustainable use constituted in the Convention. There are five Protocols adopted up to date, including one on biodiversity generally, and one on sustainable forest management.

- The European Federation for Hunting and Conservation was established in 1977, to represent interests of European hunters as an international non-profit-making non-governmental organization. The European Federation for Hunting and Conservation works with its partners on a range of hunting-related matters, from international conservation agreements to local implementation issues with the aim of sustaining hunting across Europe.

- The International Commission for the Conservation of Atlantic Tuna is a formal regional fisheries management organization, first formed in 1966 to manage harvesting of all tuna stocks in the Atlantic, and promote sustainable practices. Membership is open to all interested countries. From the group of 17 original signatories, the Convention has grown to 52 member Parties, among them countries with Atlantic coastlines and countries with distant water fishing fleets.

- The Western and Central Pacific Fisheries Commission was established by the Convention for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean and entered into force on 19 June 2004. The Convention seeks to address problems in the management of high seas fisheries resulting from unregulated fishing, over-capitalization, excessive fleet capacity, vessel re-flagging to escape controls, insufficiently selective gear, unreliable databases and insufficient multilateral cooperation in respect to conservation and management of highly migratory fish stocks. It currently has 26 members, seven participating territories, and nine "cooperating non-members", with most Pacific small island developing States participating, as well as several countries without borders on the Pacific but with distant water fleets that harvest large pelagic stocks in the region.

2.2.7.2.2 Results and Interpretation

Figure 2.5 contains the results of the scoring of the selected documents for the regional intergovernmental organizations. On initial inspection there appears to be a higher proportion of absent scores for regional organizations than for global organizations. This is an artifact of the analytical approach, however. For the global analyses scores were the aggregate of five documents evaluated for each agency or organization. Had scores been presented for every individual document, absent scores would have been much more numerous in the global analysis. When the aggregate scores for each regional intergovernmental organization are considered, only 13 absent scores are present in the 114 cells, which is not significantly different to the 15 absent scores among the 285 aggregate scores in **Figure 2.4**.

The International Tropical Timber Organization stands out among regional and global entities for the number of key elements scored as complete. Every element except socio-cultural benefits received complete treatment in the International Tropical Timber Organization Voluntary Guidelines. Further, community benefits are fully present in other International Tropical Timber Organization guidelines. Complete coverage of every key element made the scorings for the International Tropical Timber Organization significantly different from both the forestry standards in the Carpathian Convention ($P< 0.01$), and standards for logging, hunting and fishing set by all other regional bodies included in the evaluation ($P < 0.01$). In contrast, overall patterns of scores were not significantly different between the pairwise contrasts of hunting ($P > 0.40$) and fishing ($P > 0.10$) regional organizations, or among the five other regional bodies collectively ($P> 0.15$). However, collectively this analysis indicates that complete coverage of the key elements of sustainable use differs substantially among practices and regional bodies ($P < 0.001$), with most complete coverage for logging and least for fishing.

It appears from this examination that regional scale intergovernmental organizations acknowledge the key elements of sustainable use as readily as do global agencies and organizations. However, phrasing of commitments to key elements of sustainable use in most regional intergovernmental organizations' documents tended to be indirect rather than explicit. The fact that the International Tropical Timber Organization consistently included clear and complete acknowledgement of all principles demonstrates that full commitment to the key elements of sustainable use is possible at the regional scale. The fact that the fishing regional bodies reviewed had the lowest rates of complete coverage does not necessarily reflect a lesser overall commitment to sustainable use. The responsibilities of regional fisheries management organizations for waters outside national jurisdictions, where the United Nations Convention on the Law of the Sea constrains policies of Parties and regional organizations, may mean that some key elements (e.g., integration of indigenous and local knowledge with scientific assessments) may not be within their competencies. The small sample renders any inferences from these findings speculative. However, these exploratory analyses demonstrate the potential for regional intergovernmental organizations to promote and facilitate sustainable use of wild species.

Supplementary material S2.4 contains additional interpretation and information about fishing, hunting and logging regional organizations, and their policy contexts.

Practice	LOGGING							HUNTING							FISHING					
Body	ITTO				Carp. Conv.			FACE				Carp. Conv.			ICCAT			WCPFC		
PRINCIPLE / Document	1	2	3	Agg	4	5	Agg	6	7	8	Agg	9	5	Agg	10	11	Agg	12	13	Agg
Respect laws, policies and institutions	c	c	c	C	c	c	C	c	p	p	C	c	c	C	p	a	P	c	c	C
Respect local community rights and access	c	c	a	C	a	i	I	p	i	a	P	a	i	I	p	a	P	c	c	C
Effective interlinkages among levels of governance	c	c	c	C	c	p	C	c	p	i	C	c	p	C	c	a	C	c	c	C
Local communities empowered	c	c	a	C	p	i	P	c	i	a	C	a	i	I	a	a	A	p	i	P
Respect customary law	c	c	a	C	a	i	I	i	i	a	I	a	i	I	i	a	I	p	a	P
Management and monitoring plans in place	c	c	c	C	c	c	C	c	c	c	C	c	c	C	i	c	C	c	c	C
Adaptive management specified	a	c	a	C	a	p	P	c	p	p	C	a	p	P	i	i	I	c	p	C
Participatory approach to decision-making	c	c	a	C	c	c	C	i	i	i	I	c	c	C	p	p	P	c	p	C
Use of multiple knowledge systems - ILK & Science	i	c	i	C	c	c	C	i	p	i	P	c	c	C	i	i	I	a	a	A
Minimize ecological impacts	c	c	c	C	c	c	C	c	p	c	C	c	c	C	a	a	A	c	c	C
Minimize waste	c	c	i	C	c	a	C	c	i	a	C	a	a	A	a	c	C	c	c	C
Restore and/or improve ecological context	c	c	c	C	c	c	C	c	c	p	C	c	p	C	a	p	P	p	p	P
Foster socioeconomic benefits	c	c	c	C	c	p	C	c	i	p	C	a	c	C	a	i	I	c	c	C
Provide local capacity building	c	c	c	C	a	c	C	p	c	c	C	a	p	P	i	a	I	c	c	C
Fair and equitable sharing of benefits	p	c	a	C	a	a	A	i	a	a	I	a	a	A	a	c	C	p	i	P
Workers rights and health supported	c	c	c	C	a	a	A	a	a	a	A	a	a	A	a	p	P	c	c	C
Sociocultural benefits	c	a	c	C	c	i	C	p	c	a	C	a	i	I	a	p	P	p	a	P
Raise understanding and awareness	a	c	c	C	c	c	C	c	c	c	C	c	c	C	a	a	A	a	a	A
Financially responsible business practices	a	c	c	C	a	a	A	p	i	a	P	a	a	A	a	p	P	i	p	P

Name of Organization or Agency

ITTO: International Tropical Timber Organization
Carp. Conv.: Carpathian Convention
FACE: European Federation for Hunting and Conservation
ICCAT: International Commission for the Conservation of Atlantic Tuna
WCPFC: Western and Central Pacific Fisheries Commission

Number of scores

- Complete
- Partial
- Inferred
- Absent

Figure 2 5 **Key elements of sustainable use in regional policy documents.**

C/c = complete; P/p = partial; I/i = inferred; A/a = absent (uppercase shows the overall score of each organization, while lowercase indicates the scores of individual documents). See data management report at https://doi.org/10.5281/zenodo.6473133.

2.2.8 Local and customary norms and rules

While sections 2.2.6 and 2.2.7 cross-walked key elements and policies for sustainable use in the global conservation arena, this section reviews a range of primarily place-based customary rules and regulations used to govern access to and use of wild species. The methodology is presented in the data management report document available at https://doi.org/10.5281/zenodo.6049358. Based on the review of the available literature and key takeaways from the IPBES Indigenous and Local Knowledge Dialogue Reports (IPBES, 2019b, 2019a), results focus on customs and norms surrounding harvest, waste, sharing, stewardship, spirituality, taboos and rest periods, sanctions, social status/significance, physical access, and gender roles.

2.2.8.1 Results

Findings from the systematic review illustrate that sustainable use cultural norms and practices in indigenous peoples and local communities are heterogenous and dynamic in nature – encompassing socio-cultural, spatial, and temporal variation, and including mechanisms to support adaptation strategies and actions when necessary (Muir *et al.*, 2010; C. K. Turner & Lantz, 2018). Despite this variation, there are also many overarching similarities within and across indigenous peoples and local communities. For instance, spirtual customs and norms play a significant role in shaping sustainable use practices in indigenous peoples and local communities, based on their epistemologies, ontologies, and conceptualizations of relationships between humans and other than human (wild) species (IPBES, 2019b, 2019a; Nadasdy, 2007; Virtanen *et al.*, 2020).

Long-term sustainability of many interactions and relationships with wild species are guided by a complex set of cultural norms involving regulations, sanctions, and taboos. For example, saltwater fishing restrictions/taboos of the Nicobarese and Shompen indigenous tribal communities of Asia are "embedded in a range of belief systems that link fishing in restricted areas with the [limited] success of land-based crops, disease and ill-fortune, etc." (Patankar *et al.*, 2016). Sanctions and punishments vary by community and include both *de jure* (officially sanctioned) and *de facto* (unofficial) measures. For example, the consequences of felling a tree in culturally protected forests range across five villages in southeast China from "self-criticism in front of the villagers, replanting trees, or paying fines" to taking possession of the offender's family pig and distributing the meat to the other families in the village (Gao *et al.*, 2018). An increasing number of sustainable use interactions are also codified and mandated via present-day legal tools and mechanisms such as legal personhood and recognized rights of nature (Cano Pecharroman, 2018; Gombay, 2015; Youatt, 2017).

Consistent with what contemporary scholars describe as a strong "sustainability ethos", indigenous peoples and local communities from geocultural regions around the world place strong emphasis on harvesting or collecting only what is needed. Examples can be found among the Izoceño indigenous peoples of Central America (Noss & Cuellar, 2001), the Buriat of Central Asia (Pratt *et al.*, 2004), the Aotearoa Maori of Oceania and Haida of Coast Salish North America (Stephenson *et al.*, 2014), and many other indigenous peoples and local communities. For example, for the Denésôliné (Chipewyan) community of the Northwest Territories in Canada, wasting caribou meat is considered a "marked show of disrespect to the caribou", which should be avoided at all costs (Kendrick *et al.*, 2010). Similarly, traditional healers and herbalists of the Nharira community of Zimbabwe harvest a few leaves of the desired medicine rather than uprooting the desired plant or, when tubers or roots are required, they carefully remove a small portion and recover the remaining sections with soil (Mavhura & Mushure, 2019). While many of the customary norms surrounding waste are motivated by the avoidance of social or cultural stigmas, they also serve to ensure the long-term sustainability of wild harvest practices.

Sharing what was harvested or collected is similarly important – exemplified, for example, through ritual and communal feasting practices of the North America Iñupiat (Sakakibara, 2017) and Kluane First Nation (Nadasdy, 2007), through customary gifting "to create bonds with kin and kith" among the Tsimane' of South America (Reyes-García & Fernández-Llamazares, 2019), and through complex, kinship-based wild meat distribution networks of the Xavante (A'uwẽ) of South America (Welch, 2014).

Customary norms and practices surrounding are also entrenched in spirtual and ritual practices, which extend across several stages and processes involved in maintaining long-term sustainable use ranging from advanced preparations all the way through properly caring for what remains after use. Among the Nicobarese and Shompen of Asia, ritual plays a strong role in determining the appropriate timing for access to wild harvest target species or the places they inhabit, for example, some reef areas are protected as no take or no go areas except for important cultural festivals (Patankar *et al.*, 2016). In the Quinault Indian Nation of North America, the bones of the first caught salmon are returned to the home river during a ceremony to encourage an abundant harvest the following year (Amberson *et al.*, 2016). Ritual practices surrounding harvest and preparation can also be found in gray literature and cultural texts, for example in Oceania within the Native Hawaiian epic saga of Pele and Hi'iaka (Emerson, 1997). While this seminal myth is situated in time immemorial, the sustainable harvest rituals contained in the story emphasize the importance of proper protocol and etiquette when handling wild- harvested foods that were gathered for specific guests or special occasions (i.e., when feasting in the presence of a deity) and for the proper disposal of the unconsumed portions of wild harvest species (i.e., burning and burying fish tails, fins, bones, and scales).

When engaging in sustainable use practices, many communities request access or protection from guardian spirits. For example, in the Sebitoli area of Kibale National Park, Uganda it is understood that if hunters ask permission from *Kaliisa* (who is described as a forest hunter spirit), then Kaliissa will provide safe passage (Bortolamiol *et al.*, 2018). For the Nharira of Zimbabwe, accessing the Chirozva and Daramombe hills requires mandatory ritual practices to request permission from *midzimu yevaNjanja* (ancestral spirits of the vaNjanja clan). Failure to follow these ritual practices are thought to result in "huge misfortunes including droughts or long dry spells and reduced crop yields. Given droughts and reduction in crop yields affect the entire community, the villagers do their best to observe the laid down rules and regulation" (Mavhura & Mushure, 2019).

The maintainence and transmission of indigenous and local knoweldge and practices associated with sustainable use are an important enabling factor of local and customary norms and rules. For example, among the Karen indigenous community of Thailand, rotational farming practices and daily rituals revolve around a central objective to "maintain and recover the culture, belief, traditional knowledge and spirituality of the community" (Mellegård, 2017). Similarly, in the War Khasi community of Meghalaya, India, in-depth knowledge of fish behavior has informed seven discrete forms of customary fish-harvesting practices: *Buh Kroh, Riam Kriah, Riam Khohka, Riam Kyllong, Ring Khashiar, Buh Ruh and Bia Dohpieh* (Tynsong & Tiwari, 2008). Knowledge of these practices, together with indigenous and local knowledge of fish habitat, reproductive behaviour, food preferences and life cycle, is shared and maintained intergenerationally through oral transmission. In many instances, the indigenous and local knowledge that drives daily norms and rules around sustainable use practices are key components for successful construction of sustainability, biodiversity, and conservation policies across local to global scales (Sterling *et al.*, 2020).

2.2.8.2 Concluding remarks

Cultural norms and practices surrounding the sustainable use of wild species are heterogenous and dynamic across indigenous peoples and local communities, but they share important commonalities. In many indigenous peoples and local communities, sustainable use practices are often guided or informed by intricate and nuanced combinations of spiritual customs and ceremonial practices, regulations, sanctions, and taboos, respect for wild species as kin, sharing across social networks, and maintaining and transmitting indigenous and local knowledge. As socially situated and living governance systems (Whyte, 2013), the dynamism of the values, practices and associated knowledge of indigenous peoples and local communities can also occur through accommodation and hybridization of new forms of knowledge and by setting aside norms and practices that become less useful in daily life (Gómez-Baggethun *et al.*, 2013; Gómez-Baggethun & Reyes-García, 2013) to suit their own needs (L. R. Simpson, 2004). Although continuity and dynamism of customary management plays a central role in the continued sustainability of harvesting practices, cultural values and their contributions to wild species stewardship can be undermined by accelerated social-ecological changes from global to local scales (Brondízio *et al.*, 2021; Cunha *et al.*, 2021; Fernández-Llamazares *et al.*, 2021; Pardo de Santayana *et al.*, 2012). For example, the erosion of customary institutions, including the loss of the spiritual values underpinning sacred sites, can compromise the effectiveness of traditional norms and regulations (Fernández-Llamazares *et al.*, 2018; Maru *et al.*, 2020; Osei-Tutu, 2017). Many other pervasive pressures, including direct threats to indigenous territories and collective lands from industrial-scale development (Forest Peoples Program *et al.*, 2020), and the expansion of the commodity extraction frontiers (Natcher & Brunet, 2020; Temper *et al.*, 2018) challenge indigenous and local communities' lifeways and access to resources. Many communities look to the integrity of indigenous and local leaders that resist and work to counter these threats (Brondízio *et al.*, 2021; Forest Peoples Program *et al.*, 2020; Scheidel, 2020). Efforts to counter environmental injustices may also result in unanticipated favorable contributions, such as the revitalization of indigenous and local communities' practices, ties to land and non-human relatives, and indigenous and local knowledge systems more generally (Fernández-Llamazares *et al.*, 2021; McGregor *et al.*, 2020). The existence and persistence of local and customary norms and rules are fundamental to conceptualizing sustainable use, and require individual programs to be tailored to local contexts to achieve stewardship, management, and care for wild species across local to global scales (see Chapter 6).

2.2.9 National laws and regulations across practices

2.2.9.1 Introduction and intent for this section

International conceptualizations of sustainable use described in this chapter become more concrete as countries adopt and integrate them into their legal and institutional frameworks. Adoption and integration reflect national circumstances, including the status of biodiversity and ecosystem services, socio-economic status, resources for implementation, existing policy contexts, and the diversity of knowledge and value systems and management approaches within countries.

Consequently, the conceptualizations framed in global policy commitments are adapted sometimes substantially to accommodate national cultures and capacities, and interpreted into national conceptualizations of sustainable use of wild species in relevant national laws, policies, and programs.This diversity of factors potentially influencing national legislation and related regulations and practices makes a consistent and comprehensive review of all national policies challenging Nevertheless, some global agreements help structure the policies of most countries, notably the Convention on Biological Diversity. Thus, this section reviews conceptions of sustainable use of wild species as expressed in a sample of national biodiversity strategies and action plans relative to provisions of that convention.

As reviewed in section 2.2.7 in this chapter, many global policy documents address sustainable use of wild species from diverse perspectives. Generally, however, they are rooted in a common set of key elements (see section 2.2.6), particularly the Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity. In addition, Article 6(a) of the Convention on Biological Diversity requires all Parties to develop national biodiversity strategies and action plans for fulfilling the requirement of Article 6(b) to integrate sustainable use practices into relevant plans, programs and policies. This intent of the national biodiversity strategies and action plans is to draw in diverse, relevant government sectors at national and sub-national levels, and engage all economic private sectors and other stakeholder or rights holder groups who have interest in or impacts on use of wild species.

National biodiversity strategies and action plans are key instruments for countries to coordinate and operationalize sectoral and cross-sectoral sustainable use policies. National biodiversity strategies and action plans developed before the adoption of the Aichi Biodiversity Targets in 2010 did not consistently address sustainable use of biodiversity due to factors such as the lack of sectoral and cross-sectoral policy coordination or engagement (Prip *et al.*, 2010). However, one of the intents of Aichi Biodiversity Target 17 was to reinforce the commitment to informative and effective national biodiversity strategies and action plans, and encourage them to address a common range of issues related to sustainable use (Convention on Biological Diversity Decision X/2 Para. 3(c)). After 2010, national review and revision of national biodiversity strategies and action plans in the context of Aichi Biodiversity Target 17 have both increased the consistency of issues covered in national biodiversity strategies and action plans and strengthened the role of national biodiversity strategies and action plans as key policy instruments for promoting sustainable use practices by each country. These efforts have been augmented by oversight from the Conference of the Parties to the Convention on Biological Diversity, reviewing national biodiversity strategies and action plans for consistency with the Aichi Biodiversity Targets and other high-level commitments. As of June 2019, 155 countries have submitted a national biodiversity strategy or action plan that takes into account the Strategic Plan for Biodiversity 2011–2020, including the Aichi Biodiversity Targets.

In this section, the national biodiversity strategies and action plans are used as the information base for this review and analysis, because they are provided by almost all Parties to the Convention, and consistent with Article 10 of the convention, are specifically mandated to report on sustainable use of biodiversity and have some consistency of thematic coverage as encouraged by Aichi Biodiversity Target 17. The methodology for this analysis is available in the data management report, available at https://doi.org/10.5281/zenodo.6473133.

One to three analytical questions for each Addis Ababa Principle were developed to assess how the elements of sustainable use presented in each of the Addis Ababa Principles are reflected in national actions reported in the national biodiversity strategies and action plans. An additional question was set to see how many countries explicitly refer to the Addis Ababa Principles and Guidelines for the development of the strategies and action plans. A science-policy interface is not explicit in the Addis Ababa Principles and Guidelines but is important for most policy development, including for sustainable use. Consequently, four additional questions were set to analyze the degree to which a) science – policy interactions have played roles in developing national policies for sustainable use, and b) these interactions are recognized in national biodiversity strategies and action plans.

The questions are all linked to specific Addis Ababa Principles but for purposes of analysis and interpretation of patterns, they were grouped into seven themes. The degree to which each relevant Addis Ababa Principle is addressed in a national biodiversity strategy and action plan was assessed using a series of questions. These questions were grouped into seven themes:

- Governance A (policy and legal frameworks and institutions),
- Governance B (decentralization and empowerment of decision-making),
- Management systems,
- Ecological considerations,
- Socio-economic considerations,
- Education, and
- Science-policy interface.

A complete description of the methodology used for this review is available in the data management report (https://doi.org/10.5281/zenodo.6473133). The list of countries whose national biodiversity strategies and action plans were analyzed is available in supplementary materials S2.5.

2.2.9.2 Results

The results of the evaluation of the above-mentioned questions are presented in **Figure 2.6** and described in more detail below.

Governance A: Policy and legal framework and institution questions

The evaluation of governance A principles addresses national frameworks through questions following on Addis Ababa Principles 1, 3 and 8 **(Box 2.1)**, with one question about international aspects of the national policies. Sub-questions in each case ask how more local scale practices are at least acknowledged, if not protected, in the higher-level policies, regulations, and related governance aspects.

Several patterns emerge from this examination of how well the national biodiversity strategies and action plans that were evaluated address larger-scale governance issues. Q1-1a and Q1-1b addressed supportive policies in place for the national biodiversity strategies and action plans, including acknowledgement of the rights and generally sustainable practices of indigenous peoples and local communities. Over half of the national biodiversity strategies and action plans fully addressed these governance aspects. The national biodiversity strategies and action plans that were evaluated as partially addressing these two questions often were ones focused overall on detailed treatment of selected sectors or types of policies and regulations. Terser national biodiversity strategies and action plans expressed general and unqualified commitments to address these governance

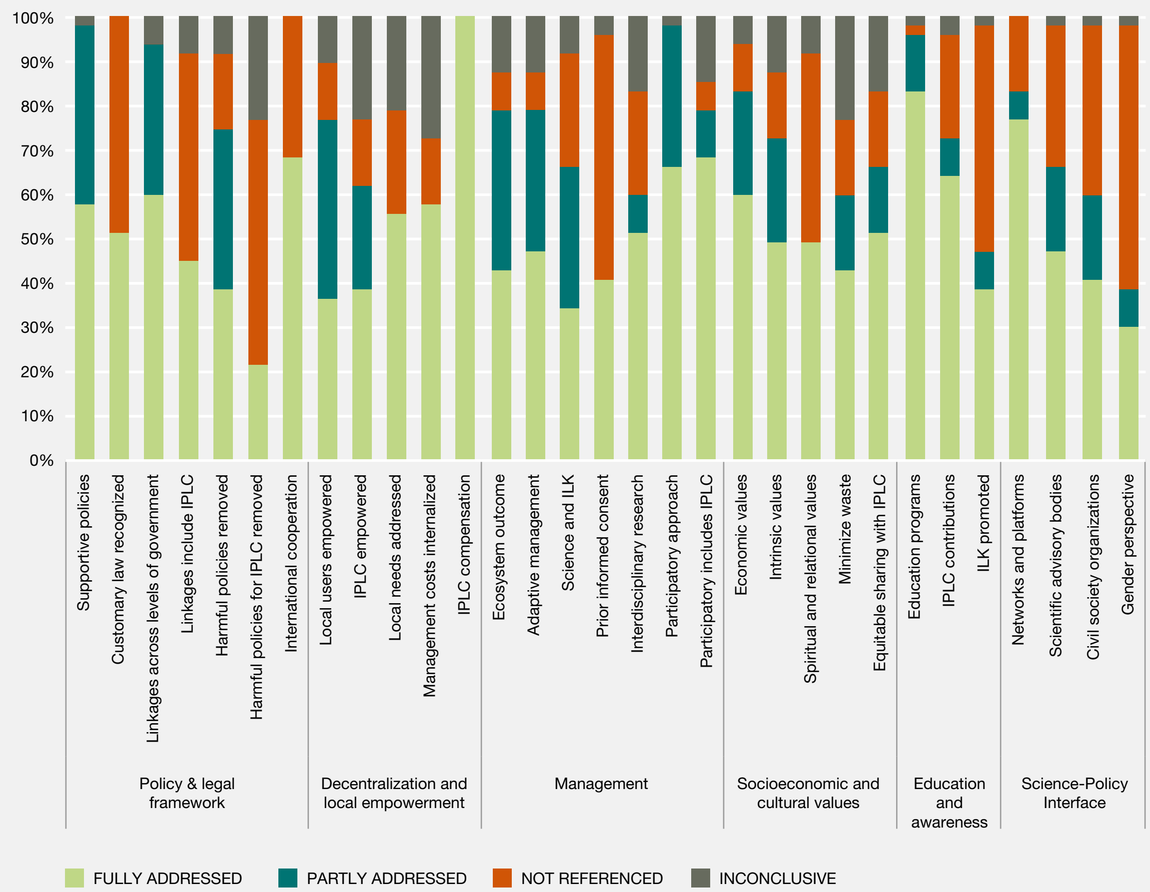


Figure 2 6 **Key elements of sustainable use in national biodiversity strategies and action plans.**

The y axis represents the proportion of national biodiversity strategies and action plans (n=47). IPLC = Indigenous peoples and local communities. The data for this figure are available at https://doi.org/10.5281/zenodo.6473133.

Box 2 1 **The Addis Ababa Principles related to governance A: Policy and legal frameworks and institutions**, and corresponding questions include:

Addis Ababa Principle 1: Supportive policies, laws, and institutions are in place at all levels of governance and there are effective linkages between these levels.

Q1-1a. Supportive policies, laws and/or institutions are in place?

Q1-1b Local customs and traditions (customary law) are recognized and described within these policies, laws and/or institutions?

Q1-2a. Different levels of governance and their linkages are addressed in the policies, laws and/or institutions assessed in Q1-1?

Q1-2b. Levels of governance for which linkages are addressed include customary laws, local traditional and customs?

Addis Ababa Principle 3: International, national policies, laws and regulations that distort markets which contribute to habitat degradation or otherwise generate perverse incentives that undermine conservation and sustainable use of biodiversity, should be identified and removed or mitigated.

Q3-1a. Policies, laws and/or regulations that undermine sustainable use of wild species, are identified and (will be) removed or mitigated?

Q3-1b. Laws and regulations that adversely affect sustainable use by indigenous peoples and local communities and therefore need to be removed or mitigated are described in the report (e.g., displacement of indigenous peoples and local communities by Protected Areas development) and/or harmful impacts of biodiversity funding on indigenous peoples and local communities and their lands and territories have been or will be removed or mitigated?

Addis Ababa Principle 8: There should be arrangements for international cooperation where multinational decision-making and coordination are needed.

Q8-1. Bilateral or multilateral coordination for management of transboundary biodiversity resource are in place.

issues. For question 1-2a many cases evaluated as "partially addressed" were cases in which indigenous peoples and local communities were not mentioned explicitly. However, references to citizenry or similar phrasings may be intended to acknowledge indigenous peoples and local communities, especially where such communities make up a large proportion of a nation's population (e.g., small island developing states). Explicit recognition of the rights and practices of local communities and indigenous peoples is made in half or fewer of the national biodiversity strategies and action plans (Q.1-2b) evaluated. In cases where recognition of the rights of indigenous peoples and local communities are still evolving, several national biodiversity strategies and action plans imply that efforts to negotiate access to and uses of nature may serve as an opportunity for national governments and communities to make progress on these complex governance issues. This was particularly evident in some Asia-Pacific and Latin American and Caribbean national biodiversity strategies and action plans.

Commitments to review a broad range of policies, regulations and practices for perverse incentives and other potentially negative biodiversity impacts are less common (Q.3-1a and 3-1b). In two-thirds or more of the national biodiversity strategies and action plans examined, expressions of intent to review sectoral and other polices are generic or absent. Explicit acknowledgement of the need to review existing policies and regulations with regard for potentially negative impacts on the contributions of nature to indigenous peoples and local communities' livelihoods and cultures is particularly infrequent.

In the minority of cases when national biodiversity strategies and action plans contained substantial information on plans for individual sectors or practice, these were usually the countries where a yes was recorded for 3-1b, and where many of the "fully addressed" and "partially addressed" evaluations were made for 3-1a. At least two possible interpretations may explain these patterns. Countries may be more willing or able to conduct such policy evaluations for specific sectors (often fishing or forestry) than for the broad spectrum of policies, including economic and social policies. Alternatively, national biodiversity strategies and action plans commonly are prepared by environment ministries in collaboration with ministries responsible for sectors that use biodiversity, such as agriculture, forestry and fishing. Understandably, these ministries may emphasize their own policies and management measures. The information available from the national biodiversity strategies and action plans was insufficient to identify which, if either, of these factors is determinative.

Nearly a third of the national biodiversity strategies and action plans did not explicitly reference bilateral or multilateral agreements (Q8-1), even though every country submitting a national biodiversity strategy or action plan is at least a party to the multilateral Convention on Biological

Diversity. However, the text of the national biodiversity strategies and action plans suggested that countries differ greatly in how they view the relationship of their resource management policies and practices to international agreements. Nevertheless, in cases where the resources being managed are themselves transboundary, such as many marine fish stocks, explicit acknowledgement of the importance of international agreements and cooperation was usually present.

Governance B: Decentralization and empowerment questions

Governance B questions **(Box 2.2)** provide insight into ideas about decentralization, accountability and empowerment in decision-making. Fewer than half of the countries evaluated fully addressed empowering local communities and supporting them through rights to be responsible and accountable for sustainable use (Q2-1). Approximately an additional one third of countries partially addressed the issue by broadly or generally discussing the importance and/or promotion or participation of local communities in decision-making without mention of rights and/or the mechanisms through which communities are or could be empowered. A few countries (7 and 6, respectively), discussed local and community rights and empowerment in the context of particular sectors (e.g., logging, hunting and/or fishing) but not as a general principle applying to all types of uses of wild species. Most discussion of empowering and supporting the rights of indigenous peoples and local communities (Q2-2) in the national biodiversity strategies and action plans centered on protecting and encouraging customary use of biological resources. Few countries explicitly mentioned legal recognition of customary or traditional rights. As with Governance A, countries differ greatly in how much explicit recognition is given to the identity of indigenous peoples and local communities.

The question associated with Addis Ababa Principle 7 (Q7-1), which stipulates that the spatial and temporal scale of management should address the ecological and socio-economic needs of the use, were difficult to evaluate. Slightly over half of the countries addressed this principle in some way, but almost always through general mention of the need for conservation while meeting socio-economic needs and/or of involving stakeholders in the decision-making process. There was little mention of individual sectors, or of approaches or scaling mechanisms to link responsibility and accountability to the spatial and temporal scale of use.

Slightly over half of the national biodiversity strategies and action plans explicitly addressed Addis Ababa Principle 13, which refers to internalizing the costs and the distribution of costs and benefits from biodiversity conservation and management (Q13-1a and Q13-1b). However, their narratives often were relevant to the principle without explicitly addressing it. Almost all discussion in this arena focused on providing economic incentives, especially payments for ecosystem services, with some national biodiversity strategies and action plans also mentioning mechanisms for funding conservation initiatives, entry and license fees, taxes or fines. In some rare instances, the principle was addressed for the forestry or hunting sectors. Seven countries mentioned compensation for indigenous peoples and local communities for the socio-cultural costs and impacts arising from the establishment and maintenance of protected areas.

Box 2 2 **The Addis Ababa Principles related to Governance B: Decentralization and empowerment of decision-making**, and corresponding questions include:

Addis Ababa Principle 2: Recognizing the need for a governing framework consistent with international, national laws, local users of biodiversity components should be sufficiently empowered and supported by rights to be responsible and accountable for use of the resources concerned.

Q2-1. Local users of wild species are empowered and supported through rights to be responsible and accountable?

Q2-2. Indigenous and local communities are empowered and their rights supported?

Addis Ababa Principle 7: The spatial and temporal scale of management should be compatible with the ecological and socio-economic scales of the use and its impact.

Q7-1. Spatial and temporal scale of management addresses the ecological and socio-economic needs of the use?

Addis Ababa Principle 13: The costs of management and conservation of biological diversity should be internalized within the area of management and reflected in the distribution of the benefits from the use.

Q13-1a. The costs of management and conservation of biological diversity are identified and internalized within the area of management?

Q13-1b. State yes if compensation for indigenous peoples and local communities for the socio-cultural costs and impacts arising from the establishment and maintenance of protected areas are described?

Management approach questions

Questions following on Addis Ababa Principles 4, 6 and 9 were used to examine management systems and approaches reported in the national biodiversity strategies and action plans **(Box 2.3)**. The questions are divided between two subjects. The first include aspects of adaptive management and the nature and sources of information to inform adaptive responses. The second centers on the inclusiveness of the actual management of activities (in contrast to the inclusiveness of choosing management strategies and policies addressed in governance B).

Adaptive management is widespread as a way to maintain or improve sustainability of uses of natural resources (Q4-1). Provisions for adaptive management are present to some degree in more than 90% of national biodiversity strategies and action plans, although in some cases the language may be ambiguous or open to interpretation. Feedback from indigenous peoples and local communities is considered in over two-thirds of the national biodiversity strategies and action plans reviewed, although formal mechanisms for acquiring and using such information are not explicitly mentioned in the majority of such cases (Q4-2a and Q4-2b). This omission is noteworthy given that nearly half of all national biodiversity strategies and action plans examined reference the need for, and sometimes processes for, acquiring the scientific and technical information needed for management (Q6-1). However, one third of the national biodiversity strategies and action plans, commit to or acknowledge the need to acquire indigenous and local knowledge to inform adaptive management.

A trend towards greater inclusiveness in knowledge systems and participation in management at the national and sub-national scales is further evidenced by reports in two thirds of national biodiversity strategies and action plans' reports that management is largely participatory, with the remaining third reporting that it is partially participatory (Q9-1a). The inclusion of indigenous peoples and local communities in these participatory processes is explicitly or implicitly acknowledged in all but three of the national biodiversity strategies and action plans evaluated (Q9-1b). Regional differences were not apparent in any of these patterns, indicating that participatory management has broad uptake globally. When individual sectors were mentioned in the national biodiversity strategies and action plans, it was usually for fishing or logging, and sectoral reports were positive with regard to inclusive management.

Socio-economic and cultural values questions

The questions in **Box 2.4** were used to evaluate how the Addis Ababa Principles associated with accommodating social and economic outcomes desired by the countries (principles 10, 11 and 12), were reflected in national biodiversity strategies and action plans.

The questions primarily addressed how a range of values were taken into account in policies and programs within the country. Additional questions asked about the efficiencies of policies and programs to deliver benefits and avoid waste, and to distribute benefits equitably throughout society and particularly to indigenous peoples and local communities.

Box 2 3 **The Addis Ababa Principles related to management**, and corresponding questions include:

Addis Ababa Principle 4: Adaptive management should be practiced, based on:

1. **Science and traditional and local knowledge;**
2. **Iterative, timely and transparent feedback derived from monitoring the use, environmental, socio-economic impacts, and the status of the resource being used; and**
3. **Adjusting management based on timely feedback from the monitoring procedures.**

Q4-1. Adaptive management of the use is practiced based on feedback from monitoring?

Q4-2a. Adaptive management of the use incorporates not only scientific knowledge but also traditional and local knowledge?

Q4-2b. Process to obtain approval from the knowledge holders (PIC/FPIC) is mentioned (yes/no)?

Addis Ababa Principle 6: Interdisciplinary research into all aspects of the use and conservation of biological diversity should be promoted and supported.

Q6-1. Interdisciplinary research on the use is promoted and supported?

Addis Ababa Principle 9: An interdisciplinary, participatory approach should be applied at the appropriate levels of management and governance related to the use.

Q9-1a. A participatory approach is applied to the management and governance of the use?

Q9-1b. Participation of indigenous and local communities is addressed?

Box 2 4 **The Addis Ababa Principles related to socio-economic and cultural values, incentives and benefit sharing**, and corresponding questions include:

Addis Ababa Principle 10: International, national policies should take into account:

1. **Current and potential values derived from the use of biological diversity**
2. **Intrinsic and other non-economic values of biological diversity and**
3. **Market forces affecting the values and use.**

Q10-1. Policies take into account current and potential values derived from the use in relation to market forces affecting the values and use?

Q10-2a. Policies take into account intrinsic and other non-economic values associated with the use?

Q10-2b. Spiritual and/or relational values are described (y/n)?

Addis Ababa Principle 11: Users of biodiversity components should seek to minimize waste and adverse environmental impact and optimize benefits from uses.

Q11-1. Policies that seek to minimize waste and adverse environmental
impacts and optimize benefits from uses are addressed?

Assis Ababa Principle 12: The needs of indigenous and local communities who live with and are affected by the use and conservation of biological diversity, along with their contributions to its conservation and sustainable use, should be reflected in the equitable distribution of the benefits from the use of those resources.

Q12-1. Indigenous and local communities are identified as stakeholders and mechanisms that ensure equitable sharing of benefits are in place.

Nearly 90% of countries evaluated were considered to fully or partially address the expectation that policies should take into account current and potential values derived from the use in relation to market forces affecting the values and uses (Q10-1). These countries acknowledge the economic values of the use of biodiversity and wild species and have implemented or are in the process of implementing mechanisms for economic valuation and ecosystem services approaches in national policies. Of the countries that only partially address Q10-1, use values are appreciated but descriptions are not provided on how these are going to be taken into account in policies. More than three-quarters of the national biodiversity strategies and action plans acknowledged that policies would take into account intrinsic and other non-economic values associated with the use (Q10-2a), but fewer than half stated how this would be accomplished. This is in contrast to a more complete specification of the mechanisms and valuation methods specified for economic and use values. Approximately half of the countries evaluated explicitly acknowledge spiritual and/or relational values, or their role in uses of biodiversity (Q10-2b).

About 40% of the national biodiversity strategies and action plans include an intent to develop and implement policies that actually see to minimize waste and adverse environmental impacts and optimize benefits from uses (Q11-1), leaving open how fully these considerations will influence policies. On the other hand, over two-thirds of the national biodiversity strategies and action plans examined explicitly or implicitly acknowledge the special role of indigenous peoples and local communities and include commitments to have mechanisms in place that ensure equitable sharing of benefits (Q12-1).

For all questions in this group, sector-specific provisions were most likely to be provided for logging and fishing, especially by countries for which those uses of biodiversity are important, in general, and/or for indigenous peoples and local communities, in particular.

Ecosystem outcomes questions

Addis Ababa Principle 5 directly addresses ecosystem status and outcomes from uses of biodiversity, in particular the need to avoid or minimize adverse impacts on ecosystem services, structure and functions. Of the national biodiversity strategies and action plans evaluated, close to three quarters fully and/or partially addressed threats to ecosystem services, structure and functions (Q5-1). Key issues specified in this regard included invasive species, effects of tourism on biodiversity, impact of climate change, and human-induced impacts on ecological systems. To a larger extent than for many of the other questions, sector-specific information was provided. Again, fishing and logging were the sectors most frequently addressed, and generally full or partial commitments to deliver outcomes consistent with Principle 5 were present.

Education and awareness-raising questions

These questions explore the provisions in the national biodiversity strategies and action plans that are intended to increase public awareness of the importance of biodiversity to human well-being, and ways that the pressures on biodiversity can be reduced (Addis Ababa Principle 14; **Box 2.5**). This is one of the best represented themes in the national biodiversity strategies and action plans. All but one of the countries in the sample have paid significant attention to the importance of education and public awareness programs (Q14-1). There is, however, a difference when it comes to the importance of two components of this question: "conservation" and "sustainable use". The lion's share of attention goes to education and awareness raising about biodiversity and its conservation in general, as well as inventories, monitoring, production and distribution of knowledge about particular species. Comparatively less attention is paid to education and public awareness of sustainable use. Conservation and sustainable use, are of course, connected and it is possible that sustainable use is included in the aforementioned programs, but there are concrete examples focusing explicitly on sustainable use.

There is general acceptance that indigenous and local knowledge is important when it comes to biodiversity conservation (Q14-2) and a substantial majority of the countries evaluated included a statement stressing this. However, there are few examples of concrete initiatives to raise awareness of the practices and innovations of indigenous and local communities, and nearly a quarter of the national biodiversity strategies and action plans do not explicitly mention the importance of indigenous or local knowledge.

Use and revitalization of indigenous languages and traditional knowledge is one of the most underrepresented points in the national biodiversity strategies and action plans (Q14-3). None of the countries have included revitalization of indigenous languages as an objective in their national biodiversity strategy or action plan. National biodiversity strategies and action plans usually acknowledge the importance of traditional knowledge but lack concrete examples of activities targeted at revitalizing it.

Scientific and policy interface questions

The intent of these questions was to investigate the extent to which there were commitments and structured processes to facilitate the inclusion of expert knowledge as inputs to development and implementation of national and subnational policies on sustainable use of wild species as articulated in Addis Ababa Principles 15 and 16 **(Box 2.6)**. The three parts of Question 15 investigate commitments to networks or other vehicles for bringing knowledge from outside policy-making agencies into their dialogues (Q15-1); specifically, processes for engaging scientific and technical expert knowledge (Q15-2) and for community-based knowledge, particularly of indigenous peoples and local communities (Q15-3). Q16-1 asked specifically about acknowledgement of gender considerations in the knowledge being sought and the impacts of the policies being developed. These questions were particularly hard to score as "complete" or "partial". It can always be argued that there is scope for greater inclusiveness and structure in advisory processes and for accountability of policymakers to their advisory processes. Thus, for Q15-1 and Q15-2 a score of fully addressed was awarded whenever there

Box 2 5 **The Addis Ababa Principles related to education and awareness-raising**, and corresponding questions include:

Addis Ababa Principle 14: Education and public awareness programmes on conservation and sustainable use should be implemented and more effective methods of communications should be developed between and among stakeholders and managers.

Q14-1. Education and public awareness programmes (including promotion of communication among stakeholders and managers) on conservation and sustainable use are in place?

Q14-2 Initiatives to increase awareness of the contributions of knowledge, practices and innovations of indigenous and local communities for the sustainable use of biological diversity are in place (y/n)?

Q14 -3 The use and revitalization of indigenous languages and traditional knowledge are promoted (y/n)?

Box 2 6 **The Addis Ababa Principles related to scientific and policy interface** and corresponding questions include:

Q15-1. Structured groups, networks or platforms for the sustainable use of biodiversity are mentioned and/or described (e.g., National biodiversity platforms or networks).

Q15-2. Scientific advisory bodies (or persons) to the Government are mentioned and/or described.

Q15-3. Indigenous and local communities and civil society organizations (e.g., networks, syndicates, confederations, associations) that play a role in the governance and sustainable use of biodiversity are mentioned and/or described.

Q16-1 Mechanisms, instruments and/or strategies to incorporate a gender perspective are described.

was explicit commitment to such networks and processes and some indication, they were either in place or under development. A score of partially addressed was awarded if it was implicit that such advisory pathways were functioning or assumed, but specific acknowledgement of their existence and value was lacking.

A majority of countries recognize the need for mechanisms to bring external expert knowledge into policy-making processes and have made explicit commitments to either establish and strengthen such mechanisms or to ensure their existing ones are supported and used. The few national biodiversity strategies and action plans missing such acknowledgements tended to be short and focused more on outcomes than processes and mechanisms. When it came to the nature of such advisory processes and mechanisms, however, the documents more often were vague about the types of mechanisms to be established and knowledge that would have input into policy making. Countries that explicitly or partially addressed scientific advisory mechanisms also tended to address indigenous peoples and local communities and civil society advisory mechanism more often than would be expected if these two aspects of the knowledge – policy interface were treated independently. This suggests that when countries think about how to bring external advice into the policy-making processes they think broadly about what types of knowledge input to seek. An equal number (9) of countries scored yes (or partial) on 15-2 and no, and no or yes (and partial) on 15-3, respectively, suggesting there is no bias towards either scientific experts or towards indigenous peoples and local communities and civil society if countries are only considering one of those sources of input.

Less than a third of countries explicitly included gender issues in their national biodiversity strategy or action plan. However, eleven of the thirteen that did were countries classified as economies in transition. Countries classified as fully developed countries were significantly less likely to include gender issues in their national biodiversity strategy and action plans.

2.2.9.3 Conclusions on representation of Addis Ababa Principles for Sustainable Use in national biodiversity strategies and action plans

Overall, the review of national biodiversity strategies and action plans indicated that at the national level there is substantial consistency between how countries are approaching the uses of biodiversity within their country and the Addis Ababa Principles for Sustainable Use, although some principles have greater uptake than others. Management that is adaptive (Principle 4) and participatory (Principle 9) and education and knowledge-sharing (Principle 14) have seen particularly high uptake by nations, and the reported interpretations of these principles has often reflected the negotiated language of the principles, as reflected by the frequency of “fully addressed” scores in this evaluation.

Uptake of the relevant Addis Ababa Principles regarding governance models for development (Principles 1, 3 and 6) and implementation (Principles 2, 7 and13) of national policy frameworks has been nearly comparable to that for management and education. However, interpretation of these frameworks has been broader, as reflected in the more frequent evaluations of “partially addressed” or “inconclusive”. Aspects of the Addis Ababa Principles that directly focus on indigenous peoples and local communities appear to have the least explicit uptake in national biodiversity strategies and action plans.

The pattern was much the same in the evaluation of questions related to Addis Ababa Principles reflecting the socio-cultural and economic aspects of sustainable use (Principles 10, 11 and 12). Many of the comments accompanying the evaluations highlighted that countries were found to differ greatly in how they acknowledged indigenous peoples and local communities in their overall governance, some as an explicit and distinct component of their national population, some as being undifferentiated from the full citizenry of the countries, and some nearly silent on any explicit status for indigenous peoples and local communities. Differences in scorings across all the governance and the socio-economic questions often followed those differences in the degree of explicit acknowledgement of indigenous peoples and local communities in the national biodiversity strategies and action plans as a whole.

Only questions related to ecological outcomes (Principle 5) could be scored by practice (e.g., fishing, gathering, logging). The fact that “fully addressed” scores were particularly frequent is welcome, but should be interpreted cautiously. It could not be determined if countries were selectively reporting practices for which policies and management were particularly effective at promoting sustainability, or calling for more effective sectoral policies and management because current ones were not delivering sustainable ecological outcomes. Both would be positive developments, the former showing successful outcomes on this consideration and the latter showing a willingness of countries to address unsustainable uses of wild species. Nevertheless, the ambiguous interpretation here highlights the importance of Chapters 3 and 4 of the present assessment.

Further, when specific practices were discussed in the national biodiversity strategies and action plans, logging and fishing were most frequently cited, with hunting and wildlife watching mentioned in a few cases. Almost none of the national biodiversity strategies and action plans reviewed contained any practice-specific information on gathering, despite its importance to subsistence, local livelihoods and well-being (see Chapters 1 and 3) and despite specific principles on the sustainable harvest of plants being part of the Convention on Biological Diversity's Global Strategy for Plant Conservation.

The preliminary finding of this review is that the conceptualizations of sustainable use contained in the national biodiversity strategies and action plans of a representative sample of countries are broadly consistent with the Addis Ababa Principles for Sustainable Use, but are not fully comprehensive in addressing all principles. No striking differences were found among United Nations economic groupings of countries or uses of biodiversity. The national biodiversity strategies and action plans are by name and nature only plans. However, much they reflect the Addis Ababa Principles for Sustainable Use, implementation of national biodiversity strategies and action plans could be incomplete for many reasons. This evaluation cannot address national implementation of these plans, making the information in the rest of the assessment of great importance.

2.2.10 Synthesis of conceptualizations of sustainable use of wild species

The review of academic literature found that the conceptualizations of sustainable use of wild species have been changing and expanding both overall and for each practice, over the course of decades (sections 2.2.2, 2.2.3). Key elements of sustainable use in global and regional standards can vary greatly depending in their purpose and scope, but taken together, they largely capture these ideas in the literature (section 2.2.6). Some of the more recent, widely accepted ideas in the literature, including that of sustainable use of wild species as a dynamic, social-ecological system, where ecological, social/governance and cultural components are interconnected, are present in the key elements and also consistent with some aspects of indigenous peoples and local communities' conceptualizations. However, some of the broad commonalities across indigenous peoples and local communities' conceptualizations of sustainable use are either absent or poorly represented in the key elements of global and regional standards. These include the foundational concept of reciprocal relationships among people and nature, and the conceptualizations of sharing across social networks, cultural continuity and community health and wellbeing as fundamental, interconnected aspects of sustainable use (sections 2.2.4, 2.2.8).

At the global level there was very high uptake of all key elements in the overarching policy and guidance documents of a range of intergovernmental organizations and bodies with both business and conservationist orientations. As with the key elements themselves, uptake was slightly less complete for elements about working conditions, full recognition and empowerment of indigenous peoples and local communities in governance, and rehabilitating degraded ecosystems and species. However, there were no differences among the different types of global policy bodies with regard to degrees of uptake of aspects of key elements of sustainable use, nor among types of agencies. Nevertheless, the commitments in policy and the guidance in the relevant guidance documents were in generally high level and general language with broad scope for interpretation.

At the regional level, comparisons among regional bodies were possible for fishing, hunting and logging, but multiple regional agencies with fully comparable broad policy and guidance documents were not located for gathering or non-extractive uses. At the regional level uptake of the key elements was again very high; comparable to uptake by global agencies and generally with the same key elements showing less complete an uptake. The important feature at the regional scale was the larger number of bodies and organizations who were considered to have only partial or implied uptake of the key elements, compared to complete uptake globally. This did not appear as more apparently weaker commitments being made, but as much more carefully crafted language particularly in guidance documents and families of regulations for implementation of the policy commitments. This reflected the effort in those documents to walk a very fine line of both interpreting the generally abstract commitments in the global policy documents more concretely in the context of the resources, cultures and economies of the various regions, while respecting the sovereignty and diverse legal and statutory bases of governance of the individual States within the region.

This pattern appeared even more strongly at the national policy level with the analyses of national biodiversity strategies and action plans. It was at the national scale where some of the key elements were found not be taken up in a minority, but still a noteworthy number, of national policy frameworks. The key elements most likely to be missing in the national policy frameworks were explicit commitments regarding empowering indigenous peoples and local communities in governance, integrating diverse knowledge systems, and considering non-monetized values of the uses of biodiversity in policy, including spiritual and/or relational values. This is consistent with a pattern seen elsewhere in the chapter and assessment as a whole – that the ecological aspects of sustainable use (with the important exception of minimizing waste) are quite fully embraced in policy commitments at all level, with almost comparable uptake of macro-economic, employment, and general quality of livelihoods. Uptake in policy does not ensure success at or even adequate resourcing for implementation, but it provides a strong foundation for unified and integrated efforts at achieving and maintaining sustainability. The foundations in national policies for efforts at the more socio-cultural aspects of sustainable use are weaker and less unified, even if the aspirational commitments to the relevant key elements have been made globally.

2.3 HOW IS SUSTAINABLE USE OF WILD SPECIES MEASURED AND MONITORED?

Criteria and indicators translate concepts and ideas about sustainability into factors that can then be measured and monitored (Linser *et al.*, 2018). Therefore, the types of indicators used can reflect conceptualizations of sustainable use and of the relative importance placed on different aspects or elements of sustainable use. As ideas, understanding, and societal risk tolerances change about the elements of sustainable use, criteria and indicators are continually updated. For example, criteria and indicators in sustainable forest use standards have changed as perceptions of forests change, with more emphasis on economic and social values in recent versions (Linser *et al.*, 2018). Because indicator sets may influence the development of policies on sustainable use of wild resources, differences in the conception, measuring and monitoring of indicators may translate into differences in policies with potentially different outcomes for nature and people (Linser *et al.*, 2018; Sterling, Filardi, *et al.*, 2017; Sterling *et al.*, 2020). The use of criteria and indicators can be expressed in policies for sustainable use in multiple ways, including as reporting tools for description and diagnosis; as a means of providing a framework for policy making or to identify enabling conditions, including financial and technical resources, to implement management; as a reference framework for the development of policies; and as assessment tools for evaluating the effectiveness of programs and measures (Linser *et al.*, 2018).

This section examines how sustainable use is measured and monitored, with a focus on indicators used across practices and scales, from global to local. First, a review of indicator choice is presented. Then, given the relevance of the Sustainable Development Goals commitments to the future dialogue on policy and progress for sustainable use of wild species, this is followed by an evaluation of the relevance of each indicator to the sustainable use of wild species. To identify how conceptualizations of sustainable use of wild species are reflected in approaches to measure and monitor use, a review of global indicator sets and indicators in indigenous peoples and local communities are presented. Finally, a crosswalk of the academic literature, global principles and policies, and indigenous peoples and local communities' conceptualizations was carried out with the indicators, to identify which ideas about sustainable use are captured in commonly used metrics of sustainable use and which are poorly represented.

2.3.1 Indicator choice and interpretation for assessing sustainable use of wild species

2.3.1.1 Context and literature review of criteria used in indicator selection

Indicators are important to contemporary governance processes. They can serve functions as diverse but vital as expert assessments of status and trends of components of the natural world, their uses, and well-being of people; informing decision-making processes with regard to needs for actions and effectiveness of measures or programs in place, and facilitating communication among experts, decision-makers, stakeholders, rights-holders, civil society and media (Lakhani *et al.*, 2005; Lyytimäki *et al.*, 2013). All of these functions can be important to sustainable use of wild species, individually or in combination.

Even for single aspects of biodiversity or human well-being, a single indicator rarely serves all of these functions robustly, so use of suites of multiple indicators is common, with different members of the suite having different strengths and vulnerabilities. Correspondingly, reviews have found thousands of indicators have been proposed, and the number has more than doubled between reviews by Gudmundsson *et al.* (2010) and by Pires *et al.* (2020). This has resulted in a proliferation of not only indicators, but even criteria and processes for selecting appropriate suites of indicators.

The recent review of Pires *et al.* (2020) found that approximately 350 criteria have been advocated in various expert applications, and even after overlaps and redundancies among criteria were taken into account and removed, 60 different criteria for selecting indicators were identified. This demonstrates that choices are necessary in selecting even the criteria and standards for choosing indicators. Using more selection criteria may increase the quality of the assessment by allowing multiple perspectives on sustainability to be accommodated (Niemeijer & Groot, 2008). Nevertheless, as the number of selection criteria increases the complexity and cost of even choosing the indicators, let alone using them in an assessment, also increases.

The findings of the Pires *et al.* (2020) review, and earlier ones approaching the problem of indicator selection for sustainable practices from various perspectives (e.g., Cloquell-Ballester *et al.*, 2006; James *et al.*, 2012) are important for the the IPBES assessment of the sustainable use of wild species, where indicators have several roles (see Chapter 1). Interpretation throughout the assessment of both findings from its own summaries of information and findings taken from publications and other sources often are in the form of indicator values and trends, and the indicators need to interpreted with appropriate caution and confidence.

Reviews considered typically were consistent with the approach of Pires *et al.* (2020), even if they used different terminology in presenting their findings. In fact, as Pires *et al.* (2020) note, there is no consensus among experts on the terms to be used for specific properties of indicators or their criteria, so substantial inference is needed to identify similarities of concepts presented in different words. There is also no consensus on the best processes for selecting suites of indicators, among options as diverse as modeling, expert opinion, participatory processes with users and stakeholders, empirical validation with reference data sets, and efforts at mathematical optimization of indicator coverage. Moreover, indicator selection processes can be conducted as top-down or bottom-up exercises, and in highly structured ways, such as formal Delphi methods for consultation, or very informally, seeking broad buy-in of experts, stakeholders, rights-holders, and decision-makers to a final suite of indicators, even though no single perspective may have confidence in all members of the set.

In their recent and very thorough review of articles specific about criteria for selecting indicators, Pires *et al.* (2020) identify two different sets of criteria. One set of criteria is based on prioritizing scientific and expert perspectives on valuable criteria for indicator selection, the other based on prioritizing criteria associated with the end uses of the indicators. The criteria mentioned of each type, mentioned in at least five different review papers meta-reviewed by Pires *et al.* (2020) are presented in **Table 2.5** ranked by frequency of explicit mention.

These criteria still need to be applied in a systematic process. Again, many such processes have been proposed. Although the exact language varies among the sources (e.g., (Becker, 2010; GAO, 2004; Reed *et al.*, 2005; Spangenberg, 2008), most can be fit into the steps outlined in J. C. Rice & Rochet (2005).

2.3.1.2 Review of recent literature on criteria for selecting indicators directly relevant to the IPBES assessment of the sustainable use of wild species

A literature review was performed based on the findings of Pires *et al.* (2020). The data management report is available at: https://doi.org/10.5281/zenodo.6452576. The review presented few surprises. The coverage of multiple aspects

Table 2 5 **Categories of criteria identified in Pires *et al.* (2020) for use in selection indicators for biodiversity, its uses, and human well-being.**

Scientific perspective	End-usage perspective
Strong scientific foundations for the indicator reflecting the underlying property	Data availability for calculating the indicator values
Reliability of the indicator values across different users	Relevance of the indicator to the decisions or dialogue on the underlying property
Measurability of the property represented by the indicator	Comprehensibility of the indicator in the same way by diverse perspectives
Sensitivity of the indicator to changes of the property of the ecosystem or its use	Usefulness of the indicator to the user audiences
Accuracy with which the property can be measured	Target-oriented where thresholds have been or could be set for the indicator
Specificity of the indicator value to the specific property of concern	Operational simplicity in providing indicator values
Timeliness of indicator response relative to changes in the ecosystem or usage property	Compatibility with Indictors used by other jurisdictions for similar properties
Representativeness relative to larger property which the indicator is supposed to reflect	Linkage of an indicator to specified management actions
Data quality of the available information sources	Retrospectivity of the indicator in capturing past trends in the property
Space-bound in having a clearly defined spatial scope	Resource demands to collect the information needed for the indicator
Anticipatory in giving early warning of changes in the property	Sustainability of the commitment to the indicator, given the governance of the system
Spatial and temporal scales appropriate for the desired interpretations of the underlying property	

of sustainable use was clearly an important feature when choosing indicators for sustainable use of biodiversity. It was mentioned explicitly in more than half the papers reviewed for both proposing criteria for selection and specifying desired performance features of indicators and suites of indicators. The literature clearly supported mathematical algorithms for choosing suites of indicators, but this could be biased by the dominance of academic and government institutional bases for the authors of the papers that were reviewed, such that they might have been more comfortable with such algorithmic approaches than if more stakeholder and civil society sources of selection criteria could have been included.

Many of the types of properties proposed for use in selecting suites of indicators were properties which would have increased the likelihood of good performance as perceived by user communities – uptake by decision-makers, civil society, etc. It was initially a concern that uptake by various audiences was very rarely mentioned explicitly as desirable properties when selecting indicators, and in **Table 2.6** uptake is represented by a star (*) rather than a count of papers mentioning the properties explicitly in some way (which would have consistently been a misleadingly low number). However, it is likely that the papers specifying desirable properties for indicators considered factors like uptake by various audiences to be the outcome produced by good choices of indicators, rather than as a property of the indicators themselves.

Given the lack of standardization in terminology when discussing desirable properties of indicators, it was not possible to provide finer breakdowns of priority given to operational features such as sensitivity, specificity, and responsiveness, nor to apply the scaling factors identified by Pires *et al.* (2020) as important considerations. Nevertheless, the high compatibility between the findings of that the Pires *et al.* study, which encompassed a very broad literature on environmental properties and human well-being, and this review that focused specifically on literature about sustainable use of wild species, suggests that the broader considerations are applicable in the the IPBES assessment of the sustainable use of wild species. This means when indicators are presented or reported through

Table 2 6 **Tabulation of results of review of 2010–2010 literature on approaches to selection of indicators for sustainable use of wild species.**

Property of the indicator or Suite	Performance	Criteria
Relevance to multiple sustainable use dimensions	22	26
Output by analytical optimization algorithms	11	8
Ability in statistical trend detection	16	7
User satisfaction	8	3
Confirmation with independent data	9	6
Data availability and cost	5	9
Uptake in Decision-making	*	14
Consistency with Legal frameworks and Objectives	*	15
Uptake in public awareness	*	16
Respect for indigenous knowledge and values	*	2
Breadth of use already established	*	2
Respect for multiple values	*	14
Ability to use in projection models	*	4
Confidence of experts	*	11**

** The confidence of experts was implicit in many more of the articles than the ones which mentioned it explicitly.

* The language used in articles on the performance of various criteria for selecting of indicators did not use these types of terms. However, in many cases, such as with uptake in decision-making, consistency with legal frameworks and objectives, and uptake in public awareness, these were the desired performance outcomes, so their inclusion as properties of good indicators would have been circular. Hence the table presents the values as a star (*) rather than 0 hits.

the assessment, it will be important to consider both their scientific/expert soundness and end-usage appropriateness when interpreting their messages. Weaknesses in scientific features like sensitivity, specificity, and responsiveness or their space or time scales, or in their actual relevance in the necessary dialogue and linkage to appropriate policy or management responses, all can weaken conclusions about their messages on sustainable use of wild species.

2.3.2 Indicators and approaches used at international level

2.3.2.1 Sensitivity and specificity of the Sustainable Development Goals indicators for sustainable use of wild species

2.3.2.1.1 Introduction – the Sustainable Development Goals Global Indicator Framework

United Nations Resolution A/RES/71/313 has endorsed a Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development (https://undocs.org/ru/A/RES/71/313; see also Chapter 1, section 1.6). This indicator framework was evaluated as part of the overview of indicators as they relate to the conceptualization of sustainable use. This is not straightforward because the Sustainable Development Goals are not designed around specific practices. Almost all of the Goals are aspirational outcomes to which any or all of the practices many make important contributions under some circumstances, whereas under other circumstances they might have little relevance. Nevertheless, given the potential importance of the Sustainable Development Goals to policy development, it is important to improve understanding of how effectively the Sustainable Development Goals Global Indicator Framework will reflect improvements in sustainability of each of the practices, and how improvements in the sustainability of the practices contribute to improved performance as measured by the Global Indicator Framework.

Because the majority of the indicators in the Sustainable Development Goals Global Indicator Framework are not yet in near-global application, there is no database of past performance on which they can be evaluated. Moreover, cell scores in a matrix of the five practices and the individual Sustainable Development Goals indicators would be context specific, and scale-dependent. However, a high-level scoping of the relevance of each practice for each indicator might be "conceptualizing" what interpretations could be applied to the individual members of the Global Indicator Framework. Consequently, this evaluation consists of an evaluation of the relevance of each indicator in the framework, evaluating the potential sensitivity and specificity (section 2.3.1) of each indicator for each practice. The scorings are qualitative and often subjective, but major overall patterns in the results are expected to be robust to the subjectivity of the scores. The data management report is available at https://doi.org/10.5281/zenodo.6452576.

2.3.2.1.2 Results

The scores of the sensitivity and specificity of each possibly relevant indicator in the Sustainable Development Goals Global Indicator Framework for each practice are summarized in **Table 2.7**.

The results suggest that the majority of Sustainable Development Goals indicators are not strongly or even moderately sensitive to any of the practices. Logging is the practice to have modest or high influence on the largest proportion of the Sustainable Development Goals indicators (30%), but only 10% of the indicators are

Table 2 7 **Number of indicators in the Sustainable Development Goals Global Indicator Framework scored as having little or no (0), small (1), modest (2), or strong (3) sensitivity and specificity relative to fishing (F), logging (L), hunting (H) and gathering (G). Note that 93 of the Global Indicator Framework indicators were not scored because they were considered not be related to the uses of wild species.**

Score	Sensitivity				Specificity			
	F	L	H	G	F	L	H	G
0	57	49	75	110	88	70	87	126
1	55	44	51	38	42	42	53	36
2	37	55	34	25	30	44	24	11
3	24	25	13	0	13	17	9	0

thought to be highly sensitive to sustainability of logging. Fishing is the practice showing modest to high influence on the next largest proportion of Sustainable Development Goals indicators (23%), with a comparable 10% of the Sustainable Development Goals indicators highly sensitive to sustainability of fishing. An even lower proportion of Sustainable Development Goals indicators are modestly or highly sensitive to sustainability of hunting (23%), with a much lower proportion of Sustainable Development Goals indicators (5%) highly sensitive. Gathering has the fewest indicators modesty or highly sensitive to its sustainability (9%) and none are highly sensitive to gathering.

Although only a third or fewer of the 173 Sustainable Development Goals indicators were considered modestly or highly sensitive to the four practices considered, those that were had a strong tendency to be sensitive across all or most of the practices. In fact, 53 of the indicators had non-zero scores for at least three of the four practices, and scores of 2 or 3 on at least two of them, with gathering the least likely to be included in the list of practices for which the indicator was considered sensitive. This has a likelihood less than 1 x 10-6 (binomial test) if the sensitivity of the respective indicators was wholly independent among practices.

Looking from the perspective of specificity, where changes in an indicator value were considered to be reasonably attributed at least in part to changes in sustainability of a specific practice, scorings were generally lower, with significantly more zero scores for specificity than sensitivity for all practices (fishing $P < 1 \times 10^{-5}$; logging $P < 0.0004$; hunting $P < 0.038$; gathering $P < 0.026$; binomial tests). However, patterns were generally similar between sensitivity and specificity. Logging had the most moderate or high scores for specificity (36%), followed by fishing (25%), suggesting more of the Sustainable Development Goals indicators are informative about changes in the sustainability of these practices than for the others.

Substantially fewer indicators showed modest or high specificity for hunting (20%) with again many fewer indicators having such levels of specificity for gathering (6%). Likewise, however, the indicators scored as having modest or high specificity for one of the practices were significantly likely to have a similar level of specificity for other practices. Gathering was outside this group, but 24 of the indicators had non-zero scores for specificity with regard to fishing, timber-harvesting and hunting, and scores of 2 or 3 on two or all three of them ($P < 1 \times 10^{-6}$).

2.3.2.1.3 Interpretation

The major emergent finding from this analysis is the Global Indicator Framework for the Sustainable Development Goals is not focused specifically on the sustainability of how people use nature, or even on how they use parts of biodiversity and then distribute the benefits from those uses. It certainly does not ignore the sustainable use of wild species, but these considerations are present in less than half of the total indicator framework, and expressed strongly in at most a third of the framework. As is common with indicators (see section 2.3.1), the relevant indicators in the Sustainable Development Goals Global Indicator Framework are consistently more sensitive than they are specific. The greater sensitivity means changes in the indicator values may reflect changes in the sustainability of any or all of the practices in an area. However, the low specificity means that changes in the indicator values cannot be interpreted as reflecting comparable changes in the sustainability of any specific practice. In this context, it may seem counter-intuitive that this assessment's evaluation found that experts can consider a single indicator to be modestly to highly informative about the sustainability of multiple practices at once. However, this could be both a credit to the Sustainable Development Goals Global Indicator Framework, and a strong warning about how it can be interpreted when in use. There could be a benefit in having indicators that actually are integrative of all the practices in a place – an attribute of assessments and policies that has been widely advocated (see Chapter 1, sections 1.3.1, 1.3.5). The warnings are also important however. When the values of the indicators in the Sustainable Development Goals Global Indicator Framework are being interpreted, the interpretation can only be meaningful if accompanied by a well-informed understanding of the context in which the Framework is being applied each time. Only then can changes in the indicator values be attributed to the proper causes, and appropriate policies and programs to build on progress and address shortcomings be developed. Also, more generally, at best only a minority of the Sustainable Development Goals Global Indicator Framework is going to be informative about specific or even general trends in sustainable use of wild species. If the Sustainable Development Goals are going to be central to the policy and program efforts of all United Nations and regional agencies, and to States, then the indicators that are informative about the sustainable use of wild species need to be highlighted and strongly supported in reporting, for the well-being of both nature and people to develop in harmony.

2.3.2.2 Global indicators of sustainable use of wild species across practices

Over the past three decades, numerous international and regional standards for sustainable use and certification schemes (see section 2.2.6 on key elements) have developed criteria and indicators to measure and monitor the sustainable use of wild species. Many indicators are explicitly associated with lists of key elements, and/or specified in specific policies. FAO defines criteria as "the essential elements against which sustainability is assessed. Each criterion relates to a key element of sustainability, and may be described by one or more indicators" (http://www.fao.org/forestry/ci/en/ accessed June 11 2019). The fulfillment of a criterion is evaluated by using indicators, which may be quantitative, qualitative or descriptive. An indicator that is measured and monitored periodically is used to indicate the direction of change relative to a criterion, and if quantitative or rank-quantitative, the magnitude of change as well.

2.3.2.2.1 Approach

To identify how conceptualizations of sustainable use are reflected in indicators used at the international level, global and regional indicators sets for different practices were compiled. Previous reviews of forestry standards (Holvoet & Muys, 2004; Linser *et al.*, 2018) have compared the number and types of indicators associated with different criteria. This assessment builds on their approach here but groups indicators into the broad themes of sustainable use observed in the key elements analysis (see section 2.2.6) and subsequently analyzed in the policy analysis (see section 2.2.7). This analysis is intended to be illustrative rather than exhaustive. As such, the assessment draws on two widely used international indicator sets per practice as examples, recognizing that there are other global and regional indicator sets that may differ. The data management report for this analysis is available at: https://doi.org/10.5281/zenodo.6452576.

2.3.2.2.2 Results

Figure 2.7 illustrates clearly that the four broad categories of sustainable use that are present in the key elements: ecological, socio-economic, governance and management & monitoring, are also clearly represented in the indicator sets. Thus, these conceptualizations of sustainable use are clearly captured in international level indicators across practices. The category "education", which encompasses the idea that public awareness of sustainability is a part of sustainable use, was only represented once, and as a secondary category, and was also not frequently found in the key elements. Variation in the number and proportion of indicators within any category can reflect multiple issues, including variation in the size of the indicator set, differences in scale and in purpose of the indicators as well in how broad or multidimensional each category is. As such, specific comparisons are not meaningful here.

A small minority of indicators (for example, an average of <10% per indicator set, median <5%) were scored as representing both an ecological category and a social category (governance, socio-economic benefits) category. A handful of indicators were scored as both ecological and governance. This included indicators such as, "number of countries with policies to secure that [fish] mortalities are accounted for and kept within safe biological limits" or "number of countries with regulations requiring recovered of depleted species". Only a couple of indicators were scored as both ecological and socio-economic. These included "Marine Stewardship Council Certified catch" and "Share of main groups of species in fish trade in terms of value". These cross-cutting indicators were found mostly in the fishing indicator sets.

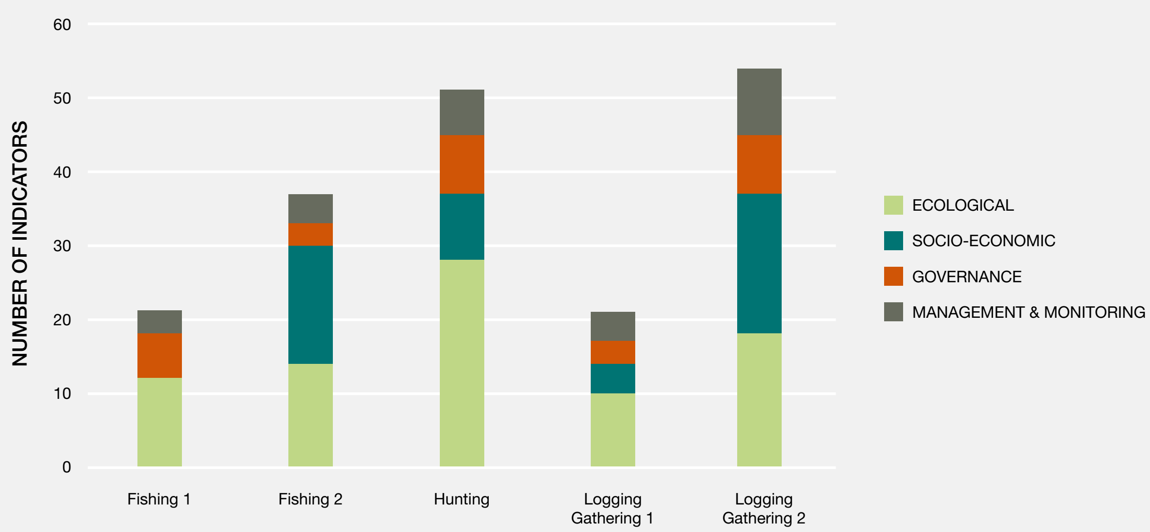


Figure 2 7 **Number of indicators in global and regional indicator sets in five broad categories of sustainable use.**

See data management report at https://doi.org/10.5281/zenodo.6452576.

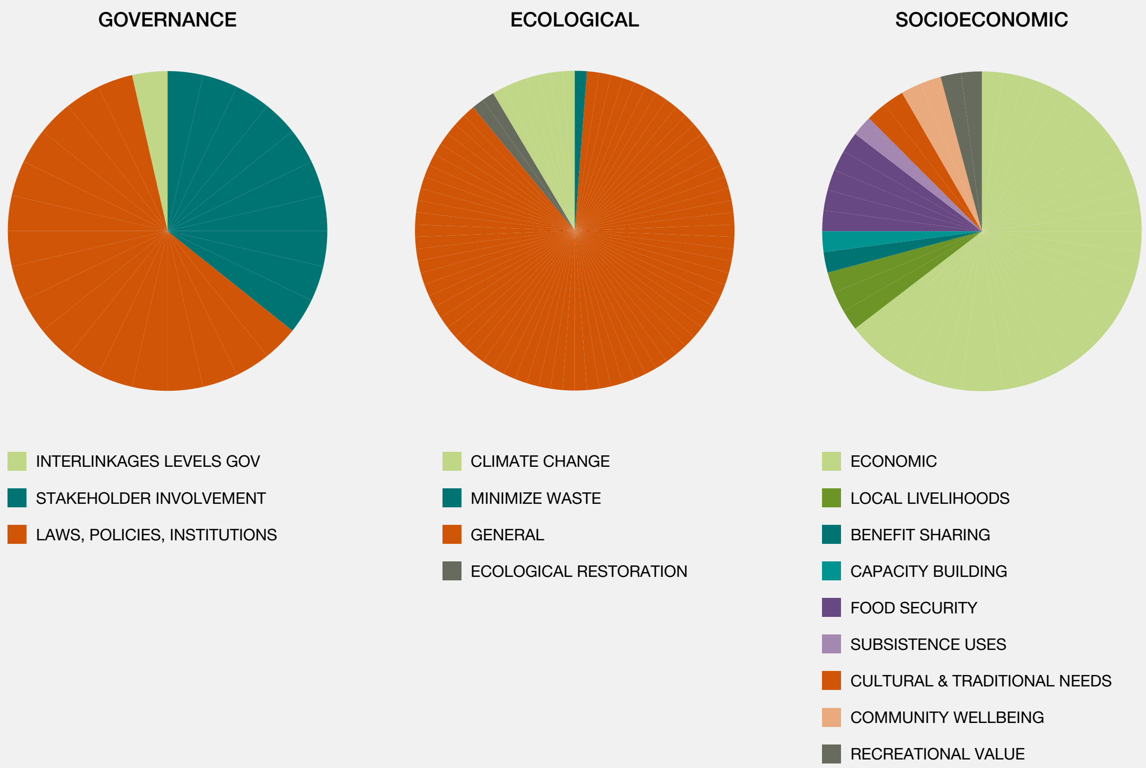


Figure 2 8 **Subcategories of ecological, governance and socio-economic indicators in global indicators sets for the sustainable use of wild species.**

See data management report at https://doi.org/10.5281/zenodo.6452576.

Figure 2.8 illustrates the subcategories of indicators. Most of the ecological indicators fell within the broad areas of minimizing ecological impacts and conserving biodiversity (classified as "general" here). Only one set included indicators related to the measurement of ecological restoration. Similarly, of all the indicators, there was only one that pertained to minimizing waste. These aspects of sustainable use were present but not prevalent in the analysis of key elements. However, there were indicators in nearly each set intended to measure issues related to climate change (whether emissions or mitigation).

In terms of governance, indicators related to respecting laws, policies and institutions, and to measuring local stakeholder involvement in the governance process were both very well represented. These concepts were also well represented in the key elements analyses. Indicators related to community rights and access, and to monitoring that involved the integration of indigenous and local knowledge and science were absent, although these themes were consistent with many key elements. Most of the socio-economic indicators were economic, focusing on measuring financial resources, revenues, or employment. A few indicators measured local livelihoods in particular and two indicator sets had indicators related to food security. Indicators relating to socio-cultural aspects of sustainable use were the least represented, with community wellbeing, cultural and traditional uses, subsistence value and recreational value found in only one indicator set.

In past decades, when social indicators were included in the conservation arena, they tended to focus on measuring the "value" of people being in nature as "instrumental values" (how responders "felt" about their experience with nature), for example pleasure or satisfaction from being in nature, via the recreational or educational value of nature to the individual. As reflected in the review of the academic literature (see sections 2.2.2, 2.2.3), in the 2010s, values reflecting relationships between people and nature (e.g., "relational values"), have been increasingly conceptualized as critical to consider for sustainable use (Chan *et al.*, 2016) The latter include cultural identity, kinship, connection to place, social ties, and stewardship, among other relationships. In the review, only one indicator set included indicators that may capture these kinds of relational values **(Table 2.8)**. Similarly, the same indicator set was the only one that included subsistence use (which might also be a relational value depending on the context) and community

Table 2 8 **Examples of socio-cultural indicators in global indicator sets.**

Indicator	Value
The importance of forests to people	Can measure instrumental value
Area and percent of forests managed primarily to protect the range of cultural, social and spiritual needs and values; Recognition and value of forest-management knowledge and skills of local people	Can measure relational value
Area and percent of forests used for subsistence purposes	Can measure subsistence value (can also be a relational value)
Resilience of forest-dependent communities	Can measure community well being

resilience. The latter indicator is intended to provide "information on the extent to which communities dependent on forests for their wellbeing, livelihoods, subsistence, quality of life or cultural identity are able to respond and adapt to social and economic change" (USDA, 2011).

2.3.2.3 Status of wildlife watching indicators

Analysis of global sustainability indicators in the context of wildlife watching is challenging due to absence of a global or even regional governance authorities focused on this practice. At the same time, there is proliferation of small and micro level measures, focused on specific species, practice and/or geographic area, aimed to increase sustainability of wildlife watching. These are first and foremost, wildlife watching focused codes of conduct, ecolabelling and certification, briefly discussed below.

Although codes of conduct in wildlife watching are too numerous for a comprehensive overview, some common patterns can nevertheless be identified. Reis (2020) identified 22 codes of conduct pertaining to marine wildlife tourism management, Fennell & Yazdanpanah (2020) identified 32 codes for wildlife photography, Garrod & Fennell (2004) talk about 58 codes for whale watching tourism, and Öqvist *et al.* (2018) mention 35 seal watching codes. It is emphasized, however, that codes of conduct at least need to be accompanied with educational and training activities to have any tangible impact (de Lima & Green, 2017; Garrod & Fennell, 2004; Reis, 2020). In addition, even if voluntary, clear links between codes of conduct and wild species legislation and monitoring organizations need to be established, otherwise "the recommendations will sit on a shelf, along with all the others" (Reis, 2020, p.6). Overall, codes of conduct still continue to multiply without any consolidation on regional or global levels, despite calls for internationally recognized codes of conduct and regulatory bodies have been visible in the research literature for decades (Buckley & Pegas, 2013; Fennell & Yazdanpanah, 2020; Garrod & Fennell, 2004; Öqvist *et al.*, 2018; Reis, 2020).

Patterns observable with codes of conduct in wildlife watching are also present in ecolabelling and certification. First, there are similarly proliferation of ecolabels and certification schemes with relatively low efficiency and international recognition. According to Ecolabel Index there are currently more than 400 ecolabels globally (www.ecolabelindex.com) of which at least 50 focus on tourism (Dziuba, 2016) and their number keeps growing. In fact, only within the first decade of the 21st century 70 new ecolabels were launched within tourism market (Bučar *et al.*, 2019). Although the exact number is unclear, this situation has been referred to as an "ecolabel jungle", given the high numbers, diversity and lack of quality regulation of these labels (Bučar *et al.*, 2019).

A major challenge hindering efficiency of ecolabelling and certification schemes in tourism in general and wildlife watching in particular remains the nature of overwhelming majority of these businesses. As mentioned above, wildlife watching tourism firms are usually not small and medium entrepreneurs but rather micro entrepreneurs. Micro-enterprises often lack resources, knowledge, skills and willingness to engage in formalized sustainability schemes (Margaryan & Stensland, 2017; Tippett *et al.*, 2020). This however, does not mean that these businesses are not interested in managing their impacts and pursuing sustainability goals. Quite often the contrary is the case, as many nature-based tourism entrepreneurs are so-called lifestyle entrepreneurs, for whom achieving certain lifestyle goals is prioritized over economic goals and business growth (Jenkins, 2004; Margaryan *et al.*, 2020; Margaryan & Stensland, 2017). Motivations such as "contributing to sustainability", "educating people about nature" or "using local natural resources" are ranking very high among the motivations to run nature-based tourism business in Sweden and Norway, although adoption of ecolabels remains very low. There is a strong perception that small and micro firms do not need to formalize or legitimize their sustainability efforts, and that ecolabelling and certification schemes favor big players and are a redundant bureaucratic effort overall (Margaryan & Stensland, 2017; Tippett *et al.*, 2020).

Further, similarly to the codes of conduct, the majority of tourist ecolabels focus on local tourism impacts of businesses, leaving the surrounding impacts out of scope, e.g., transportation of tourists, products and other resources to and from the destination. In this context, greenwashing remains a major issue, when an ecolabel is used purely for marketing purposes, without transforming business practices towards sustainability (Buckley & Pegas, 2013; Tippett *et al.*, 2020). (Buckley, 2013) claims that ecocertification schemes can be largely understood as a political game between business and civic interests, because contrary to economic logic, the "market" of ecolabels has become neither more mature nor more solidified around the most successful and high-quality labels over time. Consequently, he argues that ecolabels in tourism have not become more useful to consumers, businesses and regulating authorities, although they have currently more relevance and transparency than they had three decades ago (Buckley, 2013).

The quantity of codes of conduct, ecolabels and certification schemes in tourism continues to increase, although the same cannot be said about their quality and efficiency. The theory and practice of ecolabelling and certification in tourism have not yet converged (Bučar *et al.*, 2019). Calls for two-tiered approaches, i.e., combining abstract and general principles with factors specific to certain species and geographical contexts (e.g., Fennell & Yazdanpanah, 2020) as well as strengthening global wild species governance in general (Decker *et al.*, 2017) have begun to appear in the literature.

2.3.3 Indicators of sustainable use of wild species among indigenous peoples and local communities

The above sections focus on indicators of sustainable use of wild species used at global and regional scales. There is also a diversity of indicators of sustainable use of wild species used at national and local scales. Indigenous peoples and local communities in particular have long used indicators to effectively measure and monitor the status of wild species (e.g., Berkes, 2017; Lyver *et al.*, 2017; Parlee *et al.*, 2005; Sterling, Filardi, *et al.*, 2017; Sterling *et al.*, 2020; Thompson *et al.*, 2019). Consistent with the broad commonalities across many indigenous peoples and local communities' worldviews (see sections 2.2.4 and 2.2.8), the sustained use and health of wild-species and their habitats is often conceptualized as fundamentally interconnected to community well-being and cultural continuity. Monitoring, which is often carried out through the act of harvesting and harvest-related activities (e.g., "monitoring through harvesting"), includes interlinked indicators that capture social, ecological, and social-ecological (linkages and feedbacks among social and ecological components) aspects of sustainable use (Berkes, 2017; Lyver *et al.*, 2017; Parlee *et al.*, 2005; Sterling, Filardi, *et al.*, 2017; Sterling *et al.*, 2020; Thompson *et al.*, 2019). Indicators in indigenous peoples and local communities may also take many forms, from evaluations of the quantity and quality of species, habitats and interactions, to those embedded in stories, songs, ceremonies, oral histories and what *ex situ* actors might view as "art" (Sterling, Filardi, *et al.*, 2017; Sterling, Ticktin, *et al.*, 2017). **Box 2.7** provides an example of monitoring and indicators for wild species used by the Gitga'at, on the northwest coast of North America.

Box 2 7 **"We monitor by living here": social-ecological approaches to monitoring and indicators by Gitga'at resource users.**

The Gitga'at are a Tsimshian (Ts'msyen) tribal group whose people have occupied and stewarded their lands and waters on the northwest coast of North America since time immemorial. As has been the case for millennia, hereditary leaders continue oversee the stewardship, allocation and management of resources based on an intimate knowledge of their territories, adaawx (oral history), and ayaalx (Tsimshian law). Gitga'at territorial management activities now also draws on the methods and technology offered by science (e.g., Keen *et al.*, 2017; Ritts *et al.*, 2016), with advice and technical administration provided by the Gitga'at Oceans and Lands Department, including the Gitga'at Guardians (Gitga'at First Nation, 2011). Despite colonial policies of cultural assimilation and land dispossession, many Gitga'at cultural identity persists and continues to be underpinned by the harvest, consumption, trading, and celebrating of traditional foods on a daily-basis (Fediuk & Reid, 2014).

In 2016, the Gitga'at Oceans and Lands Department invited university researchers to assist in designing and piloting a monitoring program that would focus documenting the observations of Gitga'at harvesters and knowledge holders (Thompson *et al.*, 2019). The monitoring objectives of the program (now known as "We monitor by living here") were established by harvesters and knowledge holders, and include: tracking changes in Gitga'at territory, including traditional food species, to inform stewardship decisions and adaptation measures; encouraging youth to learn about traditional foods and how the territory is changing; strengthening the case for Gitga'at rights and title; and informing health and wellness programming.

Over the course of two pilot data collection seasons a monitoring framework was co-developed (Thompson, Lantz, *et al.*, 2020). The framework includes the elements and indicators that Gitga'at people monitor through the harvesting and harvest related activities including processing, preserving, cooking and sharing. It made explicit the numerous interlinked social, ecological, and social-ecological elements that are monitored by Gitga'at land- and sea-users including the quality and abundance of food and medicine species, habitat quality, harvest intensity, sharing and trading institutions, accessibility of resources, weather patterns, cultural continuity, and abnormal occurrences in the territory (**Table 2.9**, **Figure 2.8**). It is important to note that the distinction between social and ecological elements of the monitoring framework was not made by Gitga'at participants, as occurrences in the spiritual and social-political world and the natural world are understood as inseparable.

Table 2 9 **Non-comprehensive list of concepts and indicators that Gitga'at people described monitoring during harvesting activities (from Thompson, Hill, *et al.*, 2020).**

Concepts monitored by Gitga'at people through harvesting activities	Indicators
Abundance of food species	Catch per unit effort Spatial distribution of species Associated species Cyclical patterns of abundance
Quality of food species	Texture Size Smell Color Taste Ease of harvest Signs of illness
Habitat quality	Water clarity Smell Species diversity and abundance Sediment texture General feeling Presence of supernatural beings
Food harvest intensity	Prevalence of traditional management practices Spatial harvest intensity Amount harvested
Sharing and trading institutions	Number of people giving and receiving foods Age of people giving and receiving foods Geographic spread of shared or traded foods
Accessibility	Physical barriers to harvesting Physical barriers to travelling Cost of fuel Availability of time
Weather	Wind strength Wind direction Relative number of sunny days Relative number of rain or snow days Air temperature Water temperature
Cultural continuity	Knowledge of territory Use of Sm'algyax (traditional language of Tsimshian peoples) Knowledge of harvest protocols Number of young people on the land Prevalence of ceremony
Abnormal species and landscape features	Invasive species Strange animal behavior Unusual phenology Landslides

The example of Gitga'at monitoring through land- and sea-based practices is similar to reports from other indigenous communities. For example, Māori communities monitor forest health and community well-being using indicators that include prevalence of certain species, sounds associated with the forest, intensity of weather, and the strength of people's connection to the forest (Lyver *et al.*, 2017). Denésǫ̂łiné hunters monitor barren ground caribou migrations using physical indicators such as body condition and population size as well as spiritual indicators to explain variability in migration patterns (Parlee *et al.*, 2005).

A recent global review of participation of indigenous peoples and their knowledge in environmental monitoring highlights that in collaborative monitoring efforts, the degree of power and participation of indigenous peoples and local communities influences which monitoring indicators are used (Thompson, Hill, *et al.*, 2020). Initiatives with strong indigenous leadership throughout all phases of monitoring, including initiating and setting monitoring objectives, designing methods and indicators, and ultimately making management decisions, were most likely to monitor a diversity of indicators, including social-ecological, social, and ecological indicators within the same initiative. For example, Inuit people monitoring environmental change paid attention to ecological indicators, such as the body condition of caribou, social-ecological indicators such as hunting success, and social indicators such as the prevalence of knowledge about seasonal cycles in their communities (Berkes *et al.*, 2007). Collaborative initiatives with indigenous participation were most likely to monitor a combination of ecological and social ecological indicators. For example, Kaxinawá people in collaboration with non-profit organizations monitored wild species in their territory using ecological indicators, such as the mean body mass and abundance of preferred harvest species, as well as social-ecological indicators such as the catch-per-unit effort of harvest species (Constantino *et al.*, 2008). Meanwhile, initiatives with less strong indigenous involvement in phases of design and management were most likely to focus solely on monitoring ecological indicators. Indeed, monitoring initiatives driven by external agencies tended to

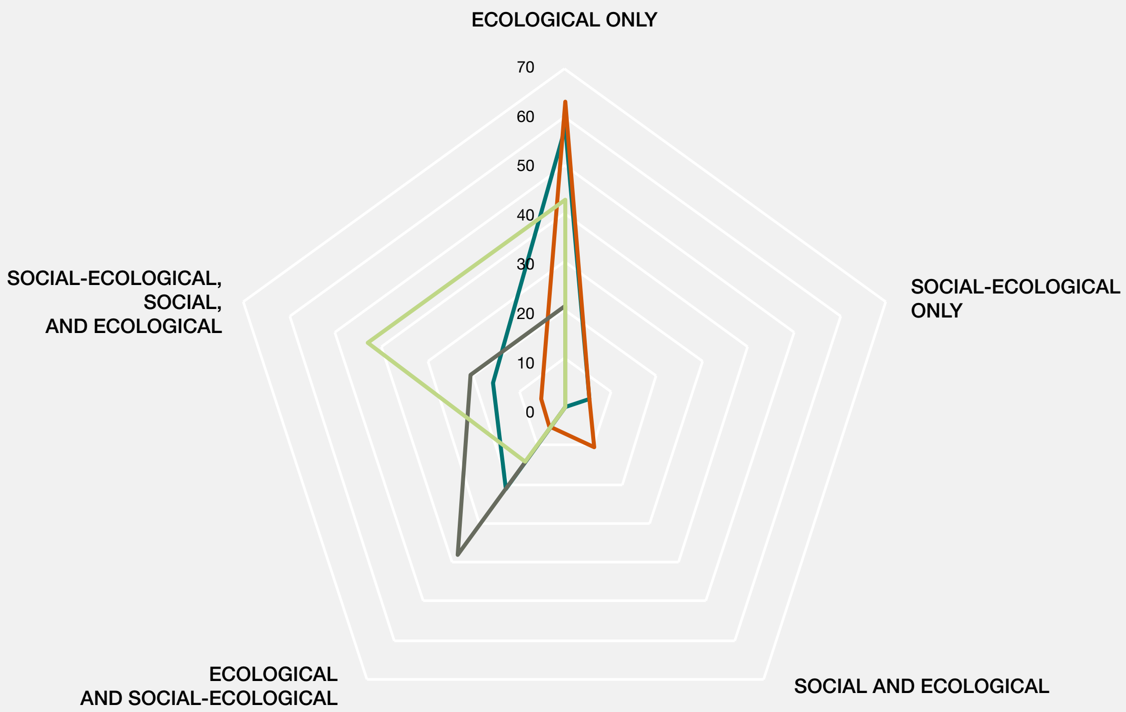


Figure 2 9 **Percent of monitoring initiatives displayed according to the type of indicators used.**

Initiatives are classified according to the degree of participation of indigenous people: the blue dashed line indicates externally driven initiatives with indigenous people as data collectors; orange dotted line indicates collaborative initiatives with indigenous people playing some role in design and execution; grey solid line indicates collaborative initiatives with indigenous people playing a strong role in design, execution and management; and the yellow dashed line indicates autonomous monitoring by indigenous people with some external support. Modified from (Thompson, Lantz, et al., 2020), under CC BY-NC 4.0. See data management report at https://doi.org/10.5281/zenodo.6452576.

focus primarily on ecological indicators, while those led by indigenous peoples tended to include a more holistic suite of indicators including social (i.e., human processes such as spirituality, language), ecological (i.e., biological, physical, or chemical), and social-ecological indicators (i.e., interactions between humans and the natural world such as hunting activities) **(Figure 2.9)**.

2.3.4 Summary of global and local indicators of sustainable use of wild species

How sustainable use of wild species is measured and monitored is shaped by the ways in which it is conceptualized. At the global level, as conceptualizations of sustainable use have changed over time (see section 2.2.2, 2.2.3), indicators for sustainability have also shifted, for example from a fairly narrow focus on ecological aspects towards inclusion of social, especially economic and governance aspects (Linser *et al.*, 2018; see section 2.3.2). Today, global indicator sets clearly capture many of ecological, economic and social components of sustainable use that are broadly agreed upon in the global conservation arena (see section 2.2.6). They also overlap with some of the indicators used in indigenous peoples and local communities, for example ecological indicators of abundance and distributions in harvested species (see section 2.3.3).

Nonetheless, there are also some widely agreed upon aspects of sustainable use that are poorly represented in global indicator sets. In particular, in the academic literature today, there is widespread agreement that the harvest of wild species is best understood as a social-ecological system, where sustainable use requires understanding and maintaining linkages and feedbacks among and between social and ecological elements (see section 2.2.3). There is also growing recognition of the importance of socio-cultural dimensions of sustainability, including relational values (see section 2.2.3). Similarly, in indigenous peoples and local communities, the sustained use and health of wild-species and their habitats is often conceptualized as fundamentally interconnected to community well-being and cultural continuity (see sections 2.2.4, 2.2.8, 2.3.3). However, indicators that capture these concepts of sustainable use, i.e., social-ecological indicators and socio-cultural indicators, including those that capture relational values, are sparse in global indicator sets (see section 2.3.2). Similarly, despite their representation in key elements of sustainable use of wild species (see section 2.2.6.), indicators that relate to indigenous peoples and local communities' community rights and access, and to monitoring that involves both indigenous and local knowledge and scientific knowledge are poorly represented.

The underrepresentation of these kinds of indicators can have multiple consequences for the sustainable use of wild species. First, regardless of the scale in which they are applied, missing key elements of sustainable use can increase the potential for misdiagnosis and poor design of interventions (Sterling *et al.*, 2020). For example, indicator sets that lack social-ecological linkages may miss important connections and feedback loops that are critical to ensuring sustainable use. This potential for misdiagnosis and subsequent poor design of interventions is aggravated by the strong tendency for indicators of all aspects of sustainability to be more sensitive than specific, calling attention to the need to address a shortcoming in performance without guidance on what practices are actually responsible for the shortcomings

Second, if indicators fail to measure aspects of sustainable use perceived locally to be critical, they will hold little meaning locally, may fail to inspire appropriate action, and in addition, have the potential to cause both environmental and social harm (Sterling *et al.*, 2020; Sterling, Ticktin, *et al.*, 2017). Ultimately the impacts of global goals and indicators are felt at the local level through the direction of financial resources and implementation of programs intended to achieve progress towards these metrics (Sterling *et al.*, 2020).

Designing global indicators is complex (see section 2.3.1) and designing those that capture social-ecological linkages and socio-cultural components poses even more challenges since global processes rely on indicators that are easy to quantify, compare, aggregate and communicate across scales. Nonetheless, there are examples of existing global indicators that encompass these aspects of sustainable use (see section 2.3.2.2), for example, numerous social-ecological indicators in the fishing indicator sets reviewed, and socio-cultural indicators, including relational indicators, in one of the forestry indicator sets reviewed. These and other indicators could be appropriately adapted to other practices and/or contexts.

Moreover, increased and improved collaboration with indigenous peoples and local communities represents a critical opportunity for better measuring and monitoring of sustainable use at both local and global scales **(Figure 2.9)**. Indicators of sustainable use that have long-been used in indigenous peoples and local communities to monitor the linkages among social and ecological elements, and that link to community wellbeing and cultural continuity, can inform the development of appropriate global indicators. Conversely, collaborations with indigenous peoples and local community knowledge holders and knowledge experts can lead to the co-creation of local indicators that can help localize global, regional or national indicators to local realities (Dacks *et al.*, 2019; Sterling *et al.*, 2020; Sterling, Filardi, *et al.*, 2017; Sterling, Ticktin, *et al.*, 2017; Thompson, Hill, *et al.*, 2020). The Tracking Change project conducted with communities across the Mackenzie, Mekong, and

Amazon River basins, as well as community-based observation networks across coastal Arctic communities, are demonstrating this potential by building local monitoring indicators, and networking knowledge gained (Michell *et al.*, 2018; Parlee & Mahoney, 2017). These collaborations are effective when colonial governments recognize the authority of indigenous peoples as managers of their territories and when power is shared between indigenous experts and outside scientists.

In sum, while there are some broad commonalities, conceptualizations of sustainable use of wild species are highly dynamic and variable across practices, and economic, cultural and social contexts. Ultimately, the diversity of ways in which sustainability is conceptualized means that there is no “one size fits all” approach to appropriately and effectively measure and monitor sustainable use.

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Chapter **3**

STATUS OF AND TRENDS IN THE USE OF WILD SPECIES AND ITS IMPLICATIONS FOR WILD SPECIES, THE ENVIRONMENT AND PEOPLE[1]

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Chapter 3

Chapter **3**

STATUS OF AND TRENDS IN THE USE OF WILD SPECIES AND ITS IMPLICATIONS FOR WILD SPECIES, THE ENVIRONMENT AND PEOPLE

EXECUTIVE SUMMARY

1 **Monitoring of the ecological and social, including economic aspects of uses of wild species is critical for sustainable use *(well established)* {3.2.4, 3.3.3.3.4}. Progress towards achieving the Sustainable Development Goals and the Aichi Biodiversity Targets is assessed using global indicators, however to date, there is not a comprehensive set of global indicators able to monitor status and trends of wild species use *(well established)* {3.2.1}.** Scientific monitoring is limited or lacking for many extractive and non-extractive practices *(well established)* {3.3.1, 3.3.3, 3.3.5} and is identified as a critical knowledge gap for sustainable use {3.5}. The indicators available provide a fragmented view of wild species use in different social-ecological systems across the globe and within each practice. Global indicators on biodiversity status and trends emphasize major fisheries and terrestrial animal harvesting of large mammals, while gathering and non-extractive practices lag behind significantly in global indicator initiatives *(established but incomplete)* {3.2.1.2, 3.2.1.3, 3.2.1.5}. Monitoring is resource intensive and will require more support and investment in all countries to overcome the capacity, financial, technical and institutional challenges that generate strong limitations to monitoring of wild species, which are more pronounced in developing countries. Monitoring efforts that are inclusive of indigenous peoples and local communities, scientific approaches and equitable participation of all key actors can better inform decision-making *(well established)* {3.2.4, 3.3.3, 3.3.5}.

2 **A conservative estimate of approximately 50,000 wild species are used for food, energy, medicine, material, income generation and other purposes through fishing, gathering, logging and terrestrial animal harvesting globally *(well established)* {3.2.1, 3.3.1, 3.3.2, 3.3.3, 3.3.4}.** People all over the world directly use about 7,500 species of wild fish and aquatic invertebrates, 31,100 wild plants (7,400 of which are tree species) 1,500 species of fungi, 1,700 species of wild terrestrial invertebrates and 7,500 species of wild amphibians, reptiles, birds and mammals *(well established)* {3.2.1.3, 3.3, 3.3.2.3.4}. Among the wild species that are used, more than 20% (over 10,000 species) are used for human food, making the sustainable use of wild species critical for achieving food security and improving nutrition, in rural and urban areas worldwide *(well established)* {3.3} Knowledge and skills developed over generations make single species likely to deliver multiple uses. The contribution of wild species to livelihoods is context and situationally specific, ranging from 10% to 80% of household income globally *(well established)* {3.2.2}. An estimated 70% of the world's poor depend directly on biodiversity and businesses it fosters *(well established)* {3.2.1}. Therefore, sustainable use supports subsistence livelihoods, trade, and human well-being, including for indigenous peoples and local communities, and provides options for further economic development linked directly to successful conservation *(well established)* {3.2.1, 3.3.1, 3.3.2, 3.3.3.2.3, 3.3.3.2.4, 3.3.4.3.1, 3.3.4.3.2, 3.3.4.4.2}. While trade in local markets is important, some wild species products are part of long commodity chains and are global commodities {3.3.1, 3.3.2}. In many cases, wild species are considered superior to cultivated alternatives *(well established)* {3.3.1.5.1, 3.3.2.3.4, 3.3.3.2.3, 3.3.3.3.2, 3.3.5.2}. Fishing, terrestrial animal harvesting, logging, and nature-based tourism are vital to regional and local employment and economies in many developing and developed countries and further contribute to public infrastructure, development and provisioning of related goods and services *(well established)* {3.3}. The use of wild species also provides nonmaterial contributions by enriching people's physical and psychological experiences, including their religious and ceremonial lives *(well established)* {3.3.5.2.1}.

3 **Fisheries constitute a major source of food from wild species, with a total annual harvest of 90 million tons over recent decades of which about 60 million tons go to direct human consumption and the rest as feed for aquaculture and livestock *(well established)* {3.2.1.1}. Recent global estimates indicate that approximately 66% are fished within biological sustainable levels and 34% of marine wild fish stocks**

are overfished, but this global picture displays strong heterogeneities *(well established)* {3.2.1.1}. In countries or regions with strong fisheries management, which account for approximately half of the fisheries landings reported by the Food and Agriculture Organization of the United Nations, on average stocks are increasing in abundance and above target levels *(well established)* {3.3.1}. For countries and regions with low intensity fisheries management of large- and small-scale fisheries, the status of stocks is less well known *(well established)* {3.3.1.2}, but generally believed to be below the abundance that would maximize sustainable food production *(established but incomplete)* {3.3.1}. At the same time, small scale fisheries contribute two-thirds of the global fish catch destined for direct human consumption *(well established)* {3.3.1}. In most fisheries, there are large gaps in understanding of life histories for many marine species. For small-scale fisheries that have been assessed around the world, many have been considered to be unsustainable or only partially sustainable, especially in Africa for both inland and marine fisheries and in Asia, Latin America and Europe for coastal marine fisheries *(established but incomplete)* {3.3.1.4.1}. Small-scale fisheries are strongly anchored in local communities' ways of life on all continents and it is known that small-scale fisheries support over 90% of the 120 million people engaged in capture fisheries globally. About half of the people involved in small-scale fisheries (e.g., production, marketing) are women *(well established)* {3.4.3.1}.

4 Unintentional bycatch fishing mortality of vulnerable, endangered, threatened and/or protected marine species, which is beginning to be assessed and managed, is unsustainable for many populations of marine turtles, sea snakes, seabirds, sharks, rays, chimaeras, marine mammals and some bony fishes *(well established)* {3.3.1.1}. Reducing unintentional bycatch and discards is progressing, but still insufficient *(well established)* {3.3.1.1}. Some of these species may be unintentionally targeted, but are retained for food as incidental catch (including retention of shark fins and manta and devil ray gill plates and discarding of the remaining carcass), or discarded *(well established)* {3.3.1.3}. Among the 1,250 shark and ray species identified today, 1,199 have been recently assessed and 449 (37.5%) have been assessed as threatened *(well established)* {3.3.1.3}. While fishing of target species may be sustainable, the conservation status of bycatch species and other associated and dependent species is often poorly known. Bycatch is a well-known issue for several large-scale fisheries, such as the shrimp or bottom trawl fisheries, but it is also a concern for several small-scale fisheries *(well established)* {3.3.1.1, 3.3.1.5}. There have been recent advances in monitoring and managing fishing mortality of marketable incidental species and discarded bycatch species, however global uptake of effective bycatch management measures is severely lagging in a majority of marine capture fisheries *(well established)* {3.3.1.5}. For example, nearly all (99%) shark and ray species are officially declared to be taken unintentionally, but are valuable and are retained for food. Consequently, shark species have been declining steeply since the 1970s, especially in tropical and subtropical coastal shelf waters *(well established)* {3.3.1.3}.

5 Increases in recreational fishing show it is becoming a significant component of marine capture fisheries *(well established)* {3.3.1.5.3} and a potentially significant contributor to fish declines *(established but incomplete)* {3.3.1.5.3} in combination with the commercial fleet. There have been recent advances in monitoring and managing fishing mortality of marketable incidental species and discarded bycatch species, however global uptake of effective bycatch management measures is severely lagging in a majority of marine capture fisheries. Therefore, stock assessments which do not incorporate recreational fishing do not provide accurate assessments of global uptake and fish mortality. Recreational catch and release fishing can have negative impacts, but can be done sustainably if responsibly practiced *(well established)* {3.3.1.5.3}.

6 Indigenous peoples and local communities contribute vital knowledge to the sustainable use of wild animals {3.3.3}, wild plants and fungi {3.3.2}, wild timber species {3.3.4.3.1} and small-scale fisheries {3.3.1.4} *(well established)*. Subsistence uses of wild species are important sources of food, medicine, fuel and other livelihood resources for indigenous peoples and local communities in both developed and developing countries. A key to sustainable gathering, terrestrial animal harvesting, fishing, and logging practices is to work with indigenous peoples and local communities in data collection and knowledge production, which is deemed essential to evaluate and reconstruct temporal trends on resource use, establish participatory monitoring programs and develop locally based co-management systems *(well established)*. Many wild foods have nutritional benefits over processed foods and there may be no culturally acceptable alternative for ceremonial and ritual materials *(well established)* {3.3.1.7.1, 3.3.2.3.4, 3.3.3.3.3, 3.3.3.4.2, 3.3.5.2.1}. Wild species also provide a basis for culturally meaningful employment {3.3.3.2.1, 3.3.5.2.3}. In light of ongoing growth and demand for health and food security, collaboration with indigenous peoples and local communities on wild plants and fungi, genetic resources of crop wild relatives, and small-scale fisheries is an especially urgent need *(well established)* {3.3.1.4, 3.3.2.3.7}.

7 The gathering and trade of wild fungi, plants and algae for food, medicine and ornamental use is increasing because of public demand *(well established)* {3.3.2}, and continues to be an

economically and culturally important activity worldwide. An estimated one-fifth of the world's population participates in gathering practices, often irrespective of economic status *(established but incomplete)* {3.3.2}. People in economically disadvantaged urban and rural areas rely on wild plants, algae and fungi as a source of of essential calories, micronutrients and medicine *(well established)* {3.3.2, 3.3.2.2.2}. Gathering is often assumed to be an activity more prevalent in the Global South. However, estimates of individuals and households participating in gathering in Europe and North America range from 4% to 68%, with the highest rates of gathering by households in Eastern Europe *(established but incomplete)* {3.3.2.2.1}, often irrespective of economic status *(established but incomplete)* {3.3.2.2.3}. Nor is gathering is confined to rural areas, with dozens to hundreds of wild plant and fungi species gathered for food, medicine, firewood, decoration, and cultural practices in urban ecosystems worldwide *(well established)* {3.3.2.2.2}. Gathering is often a gendered activity in many parts of the world, with roles depending on cultural rules, on the type of harvested wild plants, algae or fungi and the places where they are harvested. In many countries, women perform the bulk of gathering and processing of wild plants for food, medicine, fuel and handicrafts for subsistence purposes and sale in local markets *(well established)* {3.3.2.2.3}.

Trade of wild plants, algae and fungi is a billion-dollar industry and establishment of supply chains can fuel economic development and diversification *(well established)* {3.3.2.1}. Trade in ornamental plants has increased rapidly over the past 40 years. Although much of the trade is in cultivated plants, poaching of ornamental species from the wild continues to occur, and can threaten the survival of species *(well established)* {3.3.2.3.2}. There is a growing demand for wild foods in the food and aromatics industries including among fine dining and *haute cuisine* establishments, and among urban populations *(well established)* {3.3.2.2.2, 3.3.2.3.4}. There is also a growing demand for products produced at least in part from harvested wild plants and fungi, for example to complement chemical medicines in many developed and developing countries *(well established)* {3.3.2.3.5}.

Unsustainable gathering is one of the main threats for several plant groups, notably cacti, cycads, and orchids *(well established)* as well as other plants and fungi harvested for medicinal purposes {3.2.2, 3.3.2.3.2}. Harvests that have been sustainable in the past due to smaller markets and sustainable harvesting practices may become unsustainable if, for example, harvesting is undertaken without following established techniques and protocols *(well established)* {3.3.2.3.4}, or new technologies are employed which increase the volume of harvest or result in damage to or death of the organism, for example when entire trees are felled rather than climbed to harvest ripe fruits *(established but incomplete)* {3.3.2}. Wild plants, algae, fungi and trees are at risk from land use change, environmental degradation, deforestation, climate change and overharvesting *(well established)* {3.3.2.3.2}, but long-term systematic research on the relative importance and interplay of these factors is lacking *(well established)* (3.6.2). Traditional management practices and cultivation / silviculture are promising approaches to increase the sustainable use of wild species *(established but incomplete)* {3.3.4.3}.

8 Terrestrial animal harvesting takes place in a variety of governance, management, ecological and socio-cultural contexts, which affect the outcomes for sustainable use. Globally, populations of many terrestrial animals are declining due to unsustainable use, but the impacts of use on wild species and society can be neutral or positive in some places *(well established)* {3.3.3}. Terrestrial animal harvesting contributes to the food security of many people living in rural and urban areas worldwide, especially in developing countries *(well established)* {3.3.3.2.3}. The most targeted species for subsistence and commercial hunting (a sub-category of terrestrial animal harvesting) are the largest-bodied (> 30 kg), as these animals provide more meat for consumption and sale and generate more economic benefits for hunters' households *(well established)* {3.3.3.2.3}. Wild meat is an important source of protein, fat and other micronutrients such as calcium, iron, zinc and fatty acids *(well established)* {3.3.3.3.3}.

Large mammals alone comprised 55-75% of total wild meat biomass extracted annually in different regions of the world, although in some traditional small band societies (e.g the San, the Hadza, the Ache, Native American groups) small game as well as wild plant resources are gathered as primary sources of protein and daily nutrition *(well established)* {3.3.3.2.3}. Estimates of wild meat consumption differ greatly – from more than 5 million tons a year globally to around 4.6 million tons in the Congo Basin and 1.3 million tons a year in the Amazon respectively. In tropical forests, exploitation of wild meat increased drastically during recent decades due to large numbers of urban consumers, individual food preferences, change in hunting technologies, and scarcity of alternative sources of protein *(established but incomplete)* {3.2.1, 3.3.3.2.3}. Sustainability of hunting for food, especially in tropical areas, has been negatively affected by profound socio-economic changes, which have resulted in shifts from local-level subsistence towards more intensive wild meat trade *(well established)* {3.3.3.2.3}. The sustainability of wild meat hunting is increasingly driven by socio-economic changes, recreation, entertainment, trade, or trafficking, rather than solely hunting for subsistence *(well established)* {3.3.3}.

9 Many game species with high intrinsic rates of population increase or high ecological adaptability have been used sustainably and tolerate even high

utilization levels *(well established)* {3.3.3.2.4}. The impacts of hunting on the abundance of wild species vary worldwide depending on the biological characteristics of the animals as well as the management systems but are generally lower for species with high population growth rates, or high ecological adaptability, and where hunting is well managed *(well established)* {3.3.3.2.4}. Research suggests that hunting can support sustainable use because it increases the economic value of wild species and the habitats they depend on for local people and communities, providing critical benefit flows that can motivate and enable sustainable management approaches *(established but incomplete)* {3.3.3.3.4}.

Hunting can also create major costs for biodiversity, ecosystem functioning, and animal welfare *(well established)* {3.3.3.2.4}. Selective hunting of particular species or of individuals or of populations which have particular attributes (e.g., large-sized or large horns) can impact ecosystem structure and processes through modifying vegetation composition and structure, including forest succession and regeneration patterns, shifts in ecosystem functions, such as nutrient cycling and carbon capture, declines in carnivore densities, changes of the genetic structure of affected populations {3.3.3.2.4}, changes in predator-prey relationships and shifts in distribution of species and biomass across multiple trophic levels *(well established)* {3.3.3.4, 3.3.3.2.4}. Unsustainable hunting has been identified as a threat for 1,341 wild mammal species, including 669 species that were assessed as threatened, and declines in largebodied species with low intrinsic rates of population increase have been linked to hunting pressure *(well established)* {3.3.3}. Negative impacts of hunting have also been reported on bird species *(well established)* {3.3.3.2.5, 3.3.3.2.6, 3.3.3.3.4}.A long-term holistic approach with consideration of all ecological, evolutionary, economic, and social consequences is required to fully evaluate hunting wild species as a conservation tool and provide appropriate management policies {3.3.3.3.4}.

10 Recreational hunting is highly controversial and has been written about extensively in the scientific literature, however only a limited number of these studies contain well-argued, data-driven evidence and even fewer address recreational hunting with regards to sustainable use and its trade-offs *(well established)* {3.3.3.2.4}. There is considerable variation in the way recreational hunting is governed and administered in different regions, which makes any generalization about its sustainability or unsustainability difficult {3.3.3.2.4}. Some species are recovering from small population sizes under management systems that allow regulated recreational hunting, usually as a way to generate revenue and increase the land area for population expansion *(established but incomplete)* {3.3.3.2.4}. Sustainable use needs to consider the social (including institutional and economic) and ecological factors and is therefore highly context specific. Operationally, sound biological management is contingent on appropriate institutional, social and economic conditions, which include proper regulation of the hunting system by scientific and/or local control and knowledge. Weak tenure, the centralization of revenues derived from hunting and breakdown of community governance without any effective replacement by state officials can result in unsustainable recreational hunting *(well established)* {3.3.3.2.4}.

Large areas of land that are managed for recreational hunting (e.g., ~1.4 million km² in Africa) could contribute to conservation objectives and spatial conservation targets, but their unique biodiversity values as well as their ecological and social durability have mostly not been evaluated *(established but incomplete)* {3.3.3.2.4}. Economically, recreational hunting has been considered an important activity and is credited with generating revenues and creating jobs, as well as providing income and other important economic and social benefits to indigenous and local people in rural, remote and/or otherwise marginal areas. Some recreational hunting activities can generate hundreds to hundreds of thousands of United States dollars, and globally create a substantial revenue flow from developed to developing countries, as well as from urban to rural areas within countries *(well established)* {3.3.3.2.4}.

11 Logging for energy is prevalent globally but reliance on wood for heating and cooking is highest in developing countries *(well established)* {3.3.4}. Logging is also an important source of subsistence resources and income for millions of people worldwide *(well established)* {3.3.4.3}. Logging for energy accounts for 50% of all wood consumed globally, and accounts for 90% of timber harvested in Africa. Fuel wood use is declining in most regions but is increasing in sub-Saharan Africa *(established but incomplete)* {3.3.4.4.2}. Fuel wood demand can be met at global and national scales when comparing supply-demand balances, but localized fuel wood shortages and the associated forest and woodland degradation occur in areas where people have few alternatives for cooking and heating *(established but incomplete)* {3.3.4.4.2}.

Worldwide, 2.4 billion people rely fuel wood for cooking and an estimated 880 million people globally log firewood or produce charcoal, particularly in developing countries *(established but incomplete)* {3.3.4.4.2}. Sustainable fuel wood logging remains a renewable energy opportunity that provides income, heating and cooking in developing countries where 1.1 billion people do not have access to electricity or alternative energy sources *(established but incomplete)* {3.3.4.4.2}, provided air pollution (indoor and outdoor) and climate change emissions are mitigated.

Logging is carried out by smallholders, communities and industrial entities *(established but incomplete)* {3.3.4.3}. For example, logging by smallholders provides thousands of jobs in Central African countries *(well established)* {3.3.4.3.1}. An estimated 15% of global forests are managed as community resources by indigenous peoples and local communities, often with a strong focus on multiple use management *(established but incomplete)* {3.3.4.3.2}, while industrial logging occurs in over one quarter of the world's forests *(well established)* {3.3.4.3.3}.

12 Wild tree species are currently the major sources for wood and wood products and will continue to be in the coming decades *(well established)* {3.3.4.1}. Globally, wild tree species provide two thirds of industrial roundwood {3.3.4.3.3}. However, destructive logging practices and illegal logging threaten sustainable use of natural forests *(established but incomplete)* {3.3.4} and an estimated 12% of wild tree species are threatened by unsustainable logging {3.2.1.4}. The outcomes of logging affect forest ecology, as well as other forest-based uses of wild species, such as gathering, terrestrial animal harvesting and observing wild species *(well established)* {3.3.4}.Although there is an expected increase in production of plantation wood, there is also a projected increase in timber demand, which will not be matched by plantation wood *(well established)* {3.3.4.1, 3.3.4.2}. Inventory-based management plans and selective logging could reduce the impacts of logging, but its sustainability depends on the planning, techniques and implementation used to minimize damage to the residual forest stand, as well as forest soils, flora and fauna *(well established)* {3.3.4.2}. About 20% of the world's tropical forests (3.9 million km²) are currently subject to selective logging *(well established)* {3.2.1.4, 3.3.4.2}.

13 A geographic shift is observed in illegal logging and related timber trade *(established but incomplete)* (3.3.4.2). Illegal logging has declined in parts of the tropical Americas, as well as parts of the tropical and mountain regions of Asia due to improved monitoring and collaborative transboundary collaborations. However, illegal logging and trade has increased in other regions, including Southeast Asia, Northeast Asia and parts of Africa *(established but incomplete)* {3.3.4.2, 3.3.4.3.1}.

14 Non-extractive practices using wild species occur widely in all areas by all cultures, although the nature of the practice differs across cultures and locations *(well established)* {3.3.5}. The benefits of wild species for improving human mental and physical health have been widely documented in both urban and natural settings *(well established)* {3.3.5.2.2}. Non-extractive practices are core to human identity, support mental and physical well-being, raises awareness and facilitate connection to nature and society *(well established)* {3.3.5.2.2}. Despite the crucial importance of non-extractive practices for human-nature connections, with the exception of recreational tourism, there is extremely limited knowledge on the use, trends or sustainability of these practices *(well established)* {3.3.5, 3.5}.

15 Nature-based tourism is the most prominent non-extractive practice and demand for wild species media (i.e., documentaries) and *in situ* observing (e.g., wildlife watching tourism) was growing steadily until 2020 and the global COVID-19 pandemic *(well established)* {3.3.5.2.3}. Wildlife watching generates substantial revenue, contributing US$120 billion in 2018 to global gross domestic product (five times the estimated value of the illegal wild species trade) and sustaining 21.8 million jobs {3.3.4.2.3}. Prior to the COVID-19 pandemic, protected areas, globally, received approximately 8 billion visitors per year, generating 600 billion United States dollars per year, with wild-species rich countries experiencing bigger increases in tourism visitation *(well established)* {3.3.5.2.3}.

Wildlife watching is crucial for local livelihoods, provides employment and promotes development of tourism-related infrastructure, particularly in some remote locations *(well established)* {3.3.5.2.3, 3.4.4.2}. These and additional benefits make positive contributions to conservation, community development, and livelihoods in underdeveloped and remote regions when well-managed, but may also create vulnerability to shocks such as global recessions or pandemics *(well established)* {3.3.5.2.3, 3.3.5.3}. Although non-extractive practices are frequently less directly harmful to wild species and ecosystems than extractive ones, wildlife watching may have unintended detrimental impacts through changes to species behavior, physiology, or damage to habitats *(well established)* {3.3.5.2.3}. Many of the unsustainable impacts of the tourism industry could be mitigated through context-based understanding, implementation of best practice guidelines for observing, communication, education and public awareness of tourists and tour operators, collaborative engagement with all stakeholders and sector-specific regulation *(well established)* {3.3.5.2.3, 3.3.5.2.4}.

16 Effective management systems that promote the sustainable use of wild species can contribute to broader conservation objectives *(established but incomplete)* {3.3.3.3.4, 3.3.3.4.1, 3.3.4.3.2, 3.3.5.2.3}. Based on assessment of 10,098 species from 10 taxonomic groups documented for the International Union for Conservation of Nature Red List of Threatened Species, at least 34% of the wild species assessed are used sustainably *(established but incomplete)* {3.2.1, 3.2.2, 4.2.4.3.1}. This includes 172 threatened or near-threatened species. Overall, unsustainable harvest contributes towards elevated extinction risk for 28-29% of near-threatened and threatened species from 10 taxonomic groups assessed on the International Union for Conservation of Nature Red List of Threatened Species {3.2.1, 3.2.2}.

17 **Trade-offs and synergies among fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices are inherently linked but often treated exclusively or in isolation from each other *(well established)* {3.4}.** This exclusivity is reflected in the dominant approach of practice specific policies, which leads to significant compartmentalization of rules and regulations. The bifurcation of existing uses alongside the emergence of new uses within a practice area must also be considered; for example, the positioning of capture fisheries vs. aquaculture within fishing practices; or ceremony and cultural expression vs. recreation and nature-based tourism within gathering practices. Considering these uses exclusively has led to an intense reconfiguration of intra-practice trade-offs and synergies with similar effects *(well established)* {3.4.5}. Intensification of existing uses and/or emergence of new uses for wild species have often led to rapid and substantial reconfiguration of trade-offs and synergies within and among practices with negative impacts on sustainable use *(well established)* {3.4}.

3.1 INTRODUCTION

People directly benefit from nature by interacting with and using wild species (see 1.3.2) for definition of wild species), which provide provisioning and material contributions, and cultural and spiritual uses for human well-being (Millennium Ecosystem Assessment, 2005). Furthermore, as discussed in greater depth in Chapter 1, the ability to use wild species is crucial for social and economic justice, and to maintain the livelihoods, well-being and cultural diversity of indigenous peoples and local communities. The use of wild species involves three interconnected dimensions: (i) the wild species itself, (ii) the practices undertaken by people to obtain parts of or the whole organism, and (iii) the uses (both extractive and non-extractive) of the organism (Figure 1.1). Identifying and documenting the status of these dimensions, and their interactions and trends, is the subject of this chapter.

It is important to note that the scoping document for this assessment calls for "an understanding of sustainable use of wild species that are important elements in the present and future functioning of ecosystem and their contributions to people," (p.3 of the sustainbale use of wild species scoping document). Thus, the systematic literature reviews on which much of the current chapter are based specifically focused on those uses considered to be sustainable, rather than reporting on all uses and determining their sustainability. This has clear implications for the status and trends reported in the following pages in terms of which literatures were reviewed and how status and trends are reported.

The scale and scope of the overall use of wild species is needed in order to understand the status and trends of specific uses at a finer scale. This overview is provided in section 3.2, based on an analysis of a subset of global indicators previously used by IPBES and from the Biodiversity Indicators Partnership. Subsistence use includes the use of wild species by individuals or their direct social network, for nutritional, cultural, spiritual and social survival (Emery & Pierce, 2005). Wild species use also includes trade in informal and formal markets. Informal trade is defined as unrecorded trade which may be paid for in currency or in goods and services. Formal trade refers to recorded transactions in legal and illegal markets. These aspects are considered part of sustainable use. This section also provides a global level overview of human-used wild species distributions, practices and purposes.

As discussed in detail in Chapter 1, the IPBES conceptual framework recognizes different types of evidence, including but not limited to scientific knowledge. It aims to include different worldviews and associated knowledge systems equally, as much as possible, in the assessment. Therefore, throughout the chapter every effort was made to augment the systematic review of the scientific literature with knowledge from additional sources. This included drawing from experts' own experiences working with indigenous people and local communities, attending the indigenous people and local communities Workshops organized as part of this assessment, and drawing from non-scientific reputable sources when appropriate.

Reports on the status and trends separated out by practice and uses (as defined in chapter 1) are provided in section 3.3 ((fishing (3.3.1), gathering (3.3.2), terrestrial animal harvesting (3.3.3), logging (3.3.4), and non-extractive practices (3.3.5)). These analyses were conducted following a common standard, but somewhat independently in order to be consistent with the standard approach in the relevant scientific and policy literature. Throughout section 3.3 all authors made every effort to draw from multiple knowledge systems in tandem. Within each sub-section the information is organized, as much as possible, according to the relevant uses: ceremony and cultural expression, decorative and aesthetic, energy, food and feed, medicine and hygiene, recreation, science and education, and materials and shelter. In order to save space, only those uses relevant for the practice, and being undertaken at significant enough levels as to be appropriate for inclusion in a global assessment, are included in the various sub-sections. Within the fishing and terrestrial animal harvesting sections there are separate sections for non-lethal uses. Each practice sub-section concludes with a brief review of emerging issues to highlight complex and novel topics. These vary by practice but all sections include information on the emerging effects of the COVID-19 pandemic.

Nature's contributions to people are discussed throughout the chapter, as it was felt most effective to include the information in the relevant sections rather than sequestered into its own section. Throughout section 3.3 it becomes abundantly clear that the ability to sustainably use wild species is important for people all over the world, in all countries where people eat meat or fish, eat berries or wild vegetables, use paper, and enjoy nature; and it is absolutely critical to indigenous peoples and local communities worldwide who fundamentally rely on wild species for their own subsistence and livelihoods in terms of food and medicinal provisioning, informal and formal trade, and often also cultural and spiritual practices. Furthermore, several sections in 3.3 point out that certain kinds of uses may create new opportunities for upward social and economic mobility for some but simultaneously exclude others, resulting in differential qualities of life and well-being for groups of people, often exaggerating existing inequalities.

A growing trend in the scientific literature is increasing awareness of the trade-offs and synergies among the practices and uses, which is addressed in section 3.4. This includes a discussion of multifunctionality in different sectors. Trade-offs and synergies reflect a host of interactions, connections, relationships and linkages within, between and among practices and uses. This being the case, achieving and maintaining the goal of sustainable use of wild species hinges on the level of understanding of the key trade-offs and possible areas of synergy within and across practice areas. A simple three-pronged approach is used to consider the various trade-offs and synergies by focusing on (i) Trade-offs and synergies at intra-practice and intra-use level; (ii) Trade-offs and synergies between practices and uses; and (iii) Trade-offs and synergies involving the social, economic and environmental aspects of sustainable use.

3.2 SCALE AND SCOPE: A GLOBAL OVERVIEW

Use of wild species varies across space and over time. While use of wild species is often addressed based on local case studies, a global overview on status and trends of wild species use is lacking. In order to provide this global overview, a search was conducted across different global organization websites to select available datasets and global estimates on wild species use (3.2.1) (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Indicators for sustainable use of wild species were selected based on criteria in the scoping document and Chapter 1; this process is outlined in section 3.2.2. From a high diversity of indicators available (see chapter 2), this section focuses on (i) indicators selected by IPBES experts in the context of the global and regional assessments, (ii) Sustainable Development Goals indicators by the United Nations and (iii) the Aichi Biodiversity Target indicators by the Convention on Biological Diversity, particularly focusing on indicators within the theme "sustainable use" and "species". In addition to searching data and indicators across different institution websites, a literature search was completed in "Google" and "Science Direct" using the following keywords: "wild species" AND "use" AND "indicators" OR "indices" OR "indexes" (accessed in June 2020). Data sources and indicators suggested by reviewers during internal and external reviews were also reviewed and considered. Following the section indicators which focuses on spatial scales and distribution, we include a special section on the importance of the temporal scale in relation to use of wild species (3.2.3). Finally, this we explore the relative importance of different contexts in which wild species are used both for subsistence and trade (3.2.4).

3.2.1 Datasets available and global estimates of wild species used

Estimates on the number of wild species used by humans across the different regions of the globe are scarce and scattered amongst different datasets and organizations. The review of datasets presented below show that there is an uneven distribution of data available across the world documenting the number of wild species and their direct uses by humans. Most of the global datasets reviewed predominantly register and document use of wild species in the Northern Hemisphere (**Figures 3.1** to **3.3**). However, evidence suggests that the greater part of global biodiversity occurs in the tropical and subtropical regions, and in many of these countries local communities depend heavily on direct use of natural resources.

Uses are dynamic and change over time. Traditional knowledge and skills as well as science and technology continue to develop novel techniques and adapt to changing uses (Kersey *et al.*, 2020). The evolving relationships between wild species use and associated knowledge/skills, together with the development of science and technology, drives the creation of novel economies surrounding to and associated with the use of wild species. Unfortunately, the review shows that although traditional and scientific knowledge often highlight that one wild species can have many uses (e.g., food, raw material, cultural expression, etc.), and provide a range of nature's contributions to people (NCP) benefits, the datasets reviewed generally focus on a single use category for a single species.

Table 3.1 summarizes key estimates in order to provide an overview of the total number of wild species and their uses across different taxa and practices of use. About 50,000 wild species are used for food, energy, medicine, material and other purposes through fishing, gathering, logging and terrestrial animal harvesting globally. People all over the world directly use about 7,500 species of wild fish and aquatic invertebrates, 31,100 wild plants, of which 7,400 ON 5 species are trees, 1,500 species of fungi, 1,700 species of wild terrestrial invertebrates and 7,500 species of wild amphibians, reptiles, birds and mammals. Among the wild species that are used, more than 20% (over 10,000 species) are used for human food. The practices are further analyzed in the following sections (3.3.1 to 3.3.5).

The International Union for Conservation of Nature (IUCN) Red List of Threatened Species (https://www.iucnredlist.org/) is one of the most widely used datasets to determine status and trends of wild species use. The list includes assessments of 128,918 species of vertebrates, invertebrates, wild plants, fungi and protists; its major focus is to report their threat categories. In the November (IUCN, 2020b:4) update of the list, the total number of species assessed was: animal: 78,126, wild plants: 50,369, fungi: 408 and Chromista: 15.

The use of wild species is captured by the International Union for Conservation of Nature Red List in two ways: as a threat (under the threats classification scheme) and as a form of use or trade (under the use and trade classification scheme). While the coding of major threats is required (except for species of least concern), the coding of use and trade is only recommended, and is therefore less consistently coded across listed species, including the comprehensively assessed groups. To qualify as a comprehensively assessed group, the taxonomic group must include at least 150 species, of which more than 80% have been assessed (Marsh *et al.*, 2021). The 2020 July (IUCN, 2020b:3) report shows that around 35,765 species (28%) are considered threatened to minor or major degrees. Of these, 20,935 species of animals (26.8% of the total assessed animals), 13,142 species of wild plants (26.1%) and 162 species of fungi (39.7%) were reported as threatened.

Table 3 1 **Number of species and their uses by practice.**

The table shows estimates from different sources. Only estimates corroborated by two or more sources are included. Sources: Flora of China (FOC), The Plant List (TPL), World Flora Online (World Flora Online), State of the World's Plants 2016 (SOTWP-2016), State of the World's Plants and Fungi 2020 (SOTWPF-2020), State of the World's Fungi 2018 (Willis, 2018), Food and Agriculture Organization (FAO), Butchart, (2008), Global Tree Assessment (BGCI, 2021; Global Tree Assessment, 2020, 2021), (Balmford *et al.*, 2015; WTTC, 2019a).

Number of wild species & uses/ practices	Fishing (section 3.3.1)	Gathering (section 3.3.2)	Terrestrial animal harvesting (section 3.3.3)	Logging (section 3.3.4)	Non extractive (section 3.3.5)
Estimates of number of species used **Note that estimates range widely depending on the source**	• Approximately 7,500 wild fish species (Chordata) used and traded (Fukushima, Mammola, & Cardoso, 2020) • 30% of crustacea species and 38% of Mollusca species are used by humans (FAO, 2020d) • 100% of cone snail species are used by humans (Marsh *et al.*, 2021)	Approximately 31,100 wild plant and 1,500 wild fungi species have documented uses (SOTWP, 2016; TPL, 2020; WFO, 2020)	• Approximately 5,600 terrestrial bird, mammal, amphibian, and squamate reptile species are used and traded globally (Scheffers, Oliveira, Lamb, & Edwards, 2019) • Approximately 2,000 species of invertebrates, amphibians, fish, reptiles, birds and mammals are used as wild meat across the world (Coad *et al.*, 2019) • 4,561 birds are used for food or as pets (Butchart, 2008) • Over 300 mammal species are used for hunting (William J. Ripple *et al.*, 2016), • Vertebrates (Chordata) are the most traded organisms (Fukushima *et al.*, 2020) • ~11% amphibians are used by people (Marsh *et al.*, 2021)	• Logging is reported to be a threat to approximately 7,400 tree species (27%) (Global Tree Assessment, 2021; IUCN, 2020b:3) • Approximately 34,000 tree species are used on a regular basis but not only for logging, (State of the World's Forest Genetic Resources (FAO, 2014c) • One in five tree species are recorded as having a specified human use and many have a variety of different uses (Global Tree Assessment, 2020) • ~6,000 tree species (10%) have medicinal or aromatic use (Global Tree Assessment, 2020) • ~3,716 tree species have timber use (IUCN, 2020) • ~2,500 wild species are documented sources of fuel or bioenergy (SOTWP, 2020) • most common uses for trees as recorded by the International Union for Conservation of Nature Red list (IUCN, 2020b:3): constructuction: 3,716 wild species, medicine:1,951 wild species, horticulture: 1646 wild species, fuels: 1444 wild species, human food 1,382 wild species, household goods:1,302 wild species	Non-extractive uses tend to be based in the whole ecosystem instead of species. For example, worship in sacred groves includes all the species in the grove and its vicinity. Recreational tourism may focus on charismatic species or taxonomic group (e.g. butterfly-watching) but encompasses the whole park/ coral reef experience. Forest therapy uses the whole forest, not single species.

Number of wild species & uses/ practices	Fishing (section 3.3.1)	Gathering (section 3.3.2)	Terrestrial animal harvesting (section 3.3.3)	Logging (section 3.3.4)	Non extractive (section 3.3.5)
Uses (average annual consumption OR trade volume)	• Average consumption of 90 million tons/year (FAO, 2020d) • Food fish consumption grew form 9.0 kg per capita in 1961 to 20.2 kg per capita in 2015 at an average rate of about 1.5 percent per year	• There are between 3.5 and 5.76 billion users of Alagae, fungi and plants globally (Charlie M. Shackleton & de Vos, 2022) • Sales of BioTrade beneficiary companies reached €4.3 billion (2015). • International trade volume for wild edible fungi was estimated at 1.23 million tons in 2017 (de Frutos, 2020) • Around 5 million people worldwide from collectors/fishers/ hunters, workers, among others are involved in BioTrade (UNCTAD, 2017) • 70% of the world's poor depend directly on biodiversity (UNCTAD, 2017) • The number of companies that report on biodiversity in their annual reporting is growing. 36 of the top 100 cosmetic companies and 60 of the top 100 food companies now mention biodiversity. • Medicinal wild plants: 60–90% of medicinal and aromatic plants in trade are wild collected • 14–15 billion United States dollars estimated value of trade in essential oils by 2025 (TRAFIC, 2018) • Global value of wild algae, fungi, plants and animal origin was estimated by the Food and Agriculture Organization of the United Nations as 20.6 billion United States dollars in 2010 (TRAFIC, 2018) • Global value of organic wild collected products to be between EUR 630 to 830 million (base year 2005 (IFOAM/ITC, 2007)	• Very different estimates of use, ranging from 5 million tons/year globally to 4.6 million tons/year in Congo Basin alone) • Central Africa: 1.6 to 11.8 million tons/year Brazilian Amazon: 0.07 to 1.3 million tons/year (Coad *et al.*, 2019)	• Timber trade as a whole (including wild) at over 200 billion United States dollars (TRAFIC, 2018) • 880 million people spending time collecting firewood or producing charcoal • ~1.2% global workforce is engaged in commercial fuel wood activities to supply urban centers (FAO & UNEP, 2020) • Global fuel wood production revenue in 2011: 33 billion United States dollars (FAO & UNEP, 2020) • 2.4 billion people use fuel wood for cooking (FAO & UNEP, 2020) • Over 1,500 tree species are traded internationally (BGCI, 2021) and ~2,400 tree species are actively managed for their products and/or services (State of the World's Forest Genetic Resources (FAO, 2014c) • Selective logging represents 15% of the global timber supply (Poudyal, Maraseni, & Cockfield, 2018) • Over 400 million ha, about 10% of global forests, are subject to selective logging practices (Poudyal, Maraseni, & Cockfield, 2018)	• 120.1 billion United States dollars in gross domestic product to the global economy (2018), including multiplier effects: 343.6 billion United States dollars sustaining 21.8 million jobs (WTTC, 2019a) • 8 billion visits to protected areas annually 600 billion United States dollars per year. (Balmford *et al.*, 2015)

Using Red List data, Marsh *et al.* (2021) analyzed species-level data for 30,923 species from 13 taxonomic groups which have been comprehensively assessed. Results of this study demonstrate widespread use across taxa, of approximately 40% of species (10,098 of 25,009 from 10 taxonomic groups with adequate data). This estimate is an important reminder of the relevance of the current assessment. According to this data source, wild plant groups tend to be used for more purposes than animal groups, including for food and animal feed, medicinal use, household goods and handicrafts /jewelry, fuels and chemicals. For aquatic animals, the top uses were human food (bony fishes and crustaceans), specimen harvest (cone snails), and pets and display animals (corals and bony fishes). Additional uses included handicrafts and jewelry (cone snails and corals) and medicine (cone snails). It should be noted that the majority of the taxa have multiple uses.

McRae *et al.* (2022) using the Living Planet index data (https://livingplanetindex.org/) to show the locations of populations which were coded as utilized (black diamonds) and non-utilized (white diamonds) across the globe for practices such as fishing, gathering and hunting (non-extractive uses were not included) **(Figure 3.1)**. Threat information from the International Union for Conservation of Nature Red List was available for 3,195 populations analyzed (1,694 utilized and 1,501 not utilized) (McRae *et al.*, 2022). Nearly three quarters of overexploitation threats of coded utilized populations were as result of practices such as hunting and gathering. The results show that the global trends for those wild populations analyzed were negative, and in populations where there is no management, decline was more rapid, especially in Africa and the Americas (section 3.2.1.2).

In reports from 91 countries submitted to the Food and Agriculture Organization of the United Nations (FAO) reports on the use of wild species (wild plant, animals and fungi) for food across different taxa, over 60% of responses in Africa, Asia, Latin America and the Caribbean and Near East and North Africa Caribbean (FAO, 2019a) refer to use of wild plants as food sources. The use of wild fish as food is most reported in North America and the Pacific, while the use of wild birds as food sources is most reported in Latin America and the Caribbean **(Figure 3.2)**.

In summary, no comprehensive global dataset was found for reporting status and trends of wild species that are directly used by humans. Furthermore, aggregating

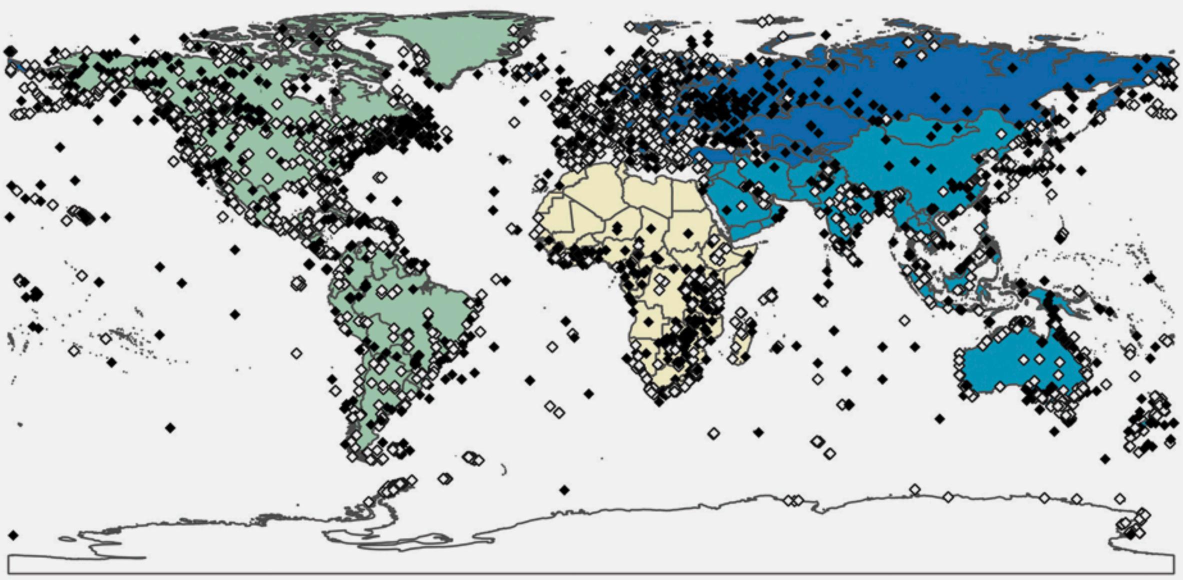

Figure 3 1 **Locations of utilized (black diamonds) and non-utilized populations (white diamonds).**

This map is directly copied from its original source (McRae et al., 2022) and was not modified by the assessment authors. The map is copyrighted under license CC BY-NC-ND 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

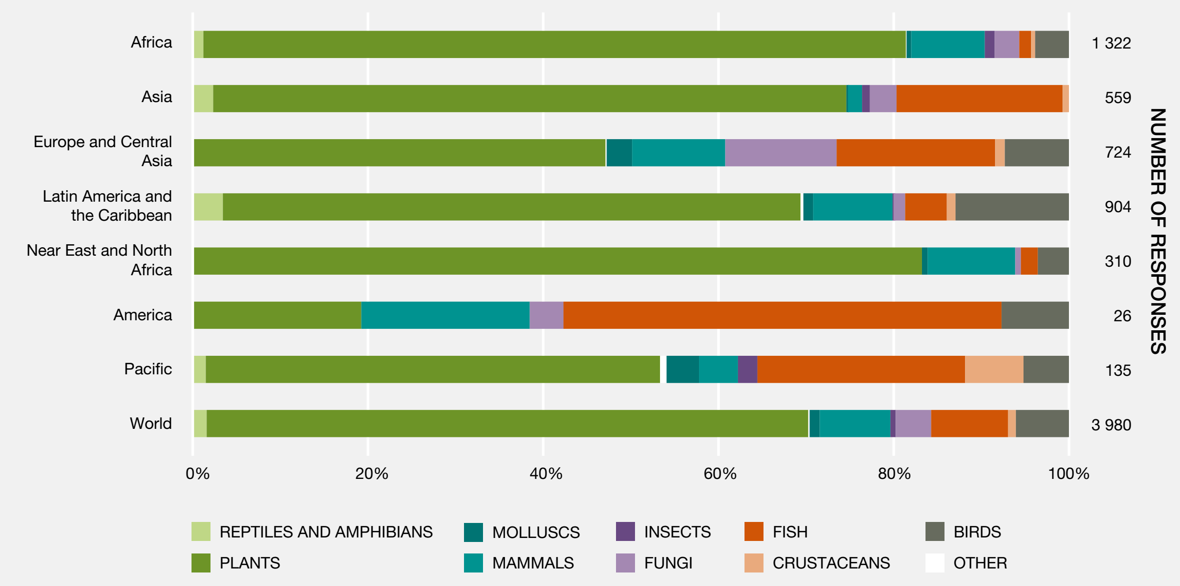

Figure 3 2 **Response on use of wild species for food reported by type and region.**

A "response" is the report of a given wild food species by a given country. Analysis based on 91 country reports. Source: (FAO, 2019a) under license CC BY-NC-SA 3.0.

estimates of species used across taxa would only serve to aggregate the levels of uncertainty within each data set. Therefore, information on use is presented by practice type. The following section details, in the context of these data constraints, the indicators available for assessing the sustainability of use of wild species across different practices. The practices are further analyzed in section 3.3.

3.2.1.1 Fishing

Fish are a valued food source throughout the world contributing both culturally and economically to food security, especially in coastal areas **(Figure 3.3)**. Capture fisheries constitute the largest wild food consumed by humans, with estimates from the FAO of a total capture fisheries harvest of 90 million metric tons per year over recent decades, of which about 60 million metric tons goes to direct human consumption and most of the rest as feed for aquaculture and livestock (FAO, 2020d).

The most widely used data on global fisheries is on fisheries landings from 1950 to present maintained by the FAO. Reporting includes landings by country, region, and taxonomic group (http://www.fao.org/fishery/statistics/global-capture-production/3/en). These data are widely accepted and used, while it is recognized that the landings of small-scale fisheries are almost certainly underestimated.

The FAO also presents a bi-annual report estimating what fraction of these fish stocks are underfished, sustainably fished, and overexploited. As of 2017, 34.2% of global fish stocks were overfished, 59.6% were fished in accordance with maximum sustainable yield guidelines and 6.2% were underfished (FAO, 2020d). The share of fish stocks within biologically sustainable levels (maximally sustainably fished or underfished) declined from 90% in 1974 to 65.8% in 2015 (FAO, 2020d). **Figure 3.3** below shows FAO estimates of capture production and aquaculture. These data are reported by individual countries and include only estimates of landing so do not include non-retained catch that are discarded at sea. Landings estimates for small scale fisheries are widely regarded to be significantly underestimated.

So far, there is no available global estimate of total number of wild fish species (marine and freshwater) used or how this varies across the globe (list of species across regions are incomplete to give an estimate). There are, however, reports that ~7,500 Chordata species traded globally are fish (Fukushima *et al.*, 2020). A wide range of countries and regional fisheries management organizations report the status and trends of individual fish stocks, and the University of Washington maintains a database (www.ramlegacy.org) of these giving abundance trends and status for about 1,200 individual marine species stocks constituting roughly half of global fish landings **(Figure 3.4)**. While there is data for IPBES regions such as Europe (e.g., https://www.eumofa.eu/) and North America, data for other IPBES regions are missing.

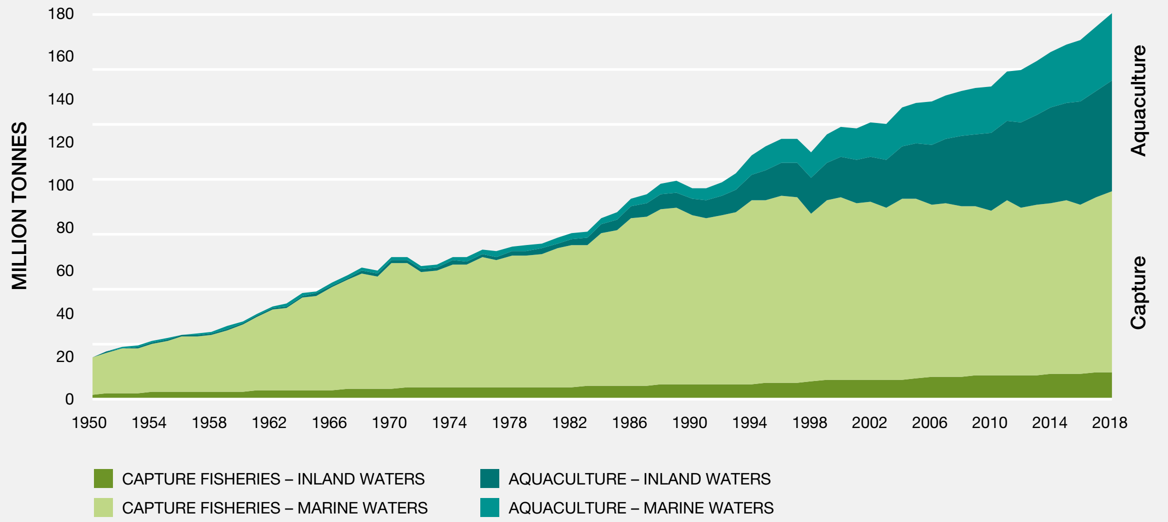

Figure 3 3 **Global trends in world capture fisheries and aquaculture production (excluding aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants).**

Source: (FAO, 2020d) under license CC BY-NC-SA 3.0 IGO.

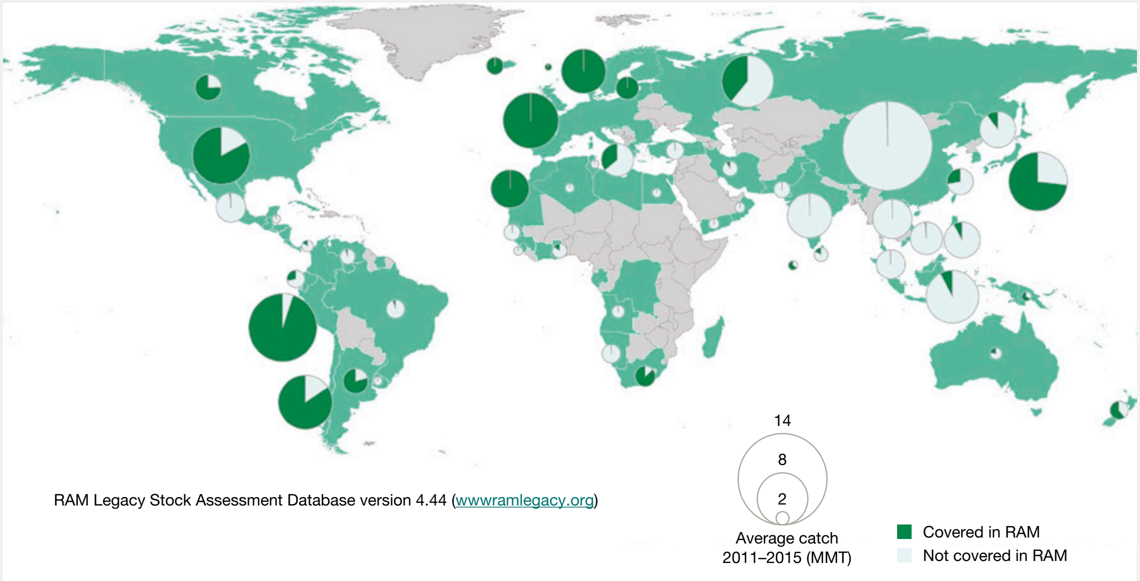

Figure 3 4 **Map showing the amount of total marine fish landings (MMT: millions of metric tons) in a country or region covered by stocks in the RAM Legacy Database.**

The area of circles is proportional to the total landings from the country or region, and the dark green portion represents the fraction of landings from stocks in the RAM Legacy Database. Green-shading of countries (or regions) on the map is applied for the top 50 countries (or regions) in terms of landings in the Food and Agriculture Organization of the United Nations' Capture Fisheries Landings Database. *This map is directly copied from its original source (RAM Legacy Stock Assessment Database, 2018) and was not modified by the assessment authors. The map is copyrighted under license CC-BY 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.*

3.2.1.2 Gathering

Both the State of the World's Plants (KEW, 2020) and Flora of China (FOC, 2020) estimate that there are approximately 31,100 wild plants with documented use. Although both datasets agree on the number of plant species used, they differ on the typologies of use. Kew royal botanical garden (2020) defines "useful plants" as plant species that have been described as fulfilling a particular need for humans, animals or the environment. This definition of use differs from that produced as parts of this assessment (see Chapter 1), however since it is the definition tied to the Kew data it is used for the remainder of this discussion. According to Kew (2020), the total number of wild plant species used for human food is of 5,538, and 3,649 species are used as animal food. Medicinal use is made of 21,695 plants for medicines (20,313) and social uses (1,321). Wild plants are also used as sources of fuel (1,621) and raw materials (11,365). The flora of China (FOC, 2020) reports economic use of species from 301 plant families: 1,068 species used as food, 3,815 species of medicinal plants, 713 plants for feed (grass/honey source), 531 plant species used for fiber, 1,318 timber species, 1,296 species used for ornamental purposes and 989 species used for oil (essential oils, gums, gels) (accessed June 2020).

Reviews of additional datasets such as "The Plant List "(http://www.theplantlist.org/) (TPL, 2020), "World Flora Online" (http://www.worldfloraonline.org/) (WFO, 2020) and the United States of America "Plant Germplasm System" (https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch) (GRIN-WEP, 2020) were not possible in the same way because those databases are not searchable in a way that allows identification of wild species and uses across different regions of the globe.

Despite the documentation from Kew (2020) and the Flora of China (2020), it remains challenging to provide an estimate on the number of wild plant species that are used across different regions. There are estimates showing that around 7,000 wild plant species are traded globally (Khoury *et al.*, 2019; UNCTAD, 2017), suggesting that approximately 22% (7,000 out of 31,000) of those collected are destined for formal markets (see section 3.2.3).

Other global estimates on wild plant use and associated gathering practices are from certification bodies such as the International Federation of Organic Agriculture Movements (https://www.ifoam.bio/) and International Trade Centre (https://www.intracen.org/). These provide an overview of organic and other standards that deal with wild gathering (mostly for certified organic) and wild harvested products worldwide. Acknowledging that these datasets likely underestimate gathering areas that are not certified, they are the best that were found at the time of the assessment. The study used certification bodies data (base year 2005) to estimate gathering areas, wild harvested products, harvest quantities, processing, collector households and sustainability across the globe. Results suggest that certified wild products are gathered across approximately 62 million hectares of land worldwide. The total global gathering area is estimated to be much larger than reported, as not all existing organic wild gathering projects were identified. According to this report, the global figure may in fact be between 78 and 104 million hectares. For comparison, the total land area of the planet is estimated at 13,003 million hectares, 4,889 million hectares of which are classified as 'agricultural area' by the FAO (this is 37.6% of the land area) (F.A.O., 2017).

The largest gathering areas were reported to be in Africa (26.8 million ha) and Europe (26.7 million ha). The ten countries with largest registered areas where wild products are gathered include Romania, Kenya, Zambia, Finland, Azerbaijan, China, South Africa, Uganda, Namibia and Bolivia. These countries cover nearly 92% of the total reported registered wild gathering area. In Europe, Finland and Romania were reported to have the largest gathering areas followed by Bulgaria, Iceland and Albania. The two countries in Africa with the largest reported gathering areas (Kenya and Zambia) have only few gathering activities officially recorded.

Globally, the ten products which are harvested in largest quantity are bamboo shoots, Brazil nut, lingonberry, rosehip, tea seed for oil, blueberry, iron walnut, green laver, coconut and white mushroom. These products make up 136,411 of the 223,754 tons (61%) of globally reported harvests (IFOAM/ITC, 2007). The highest quantity (138,426 tons) was reported harvested in Asia, from a relatively small area (6.2 million ha). Approximately 200 different wild plant products were reported harvested in Europe. Wild berries and mushrooms were reported to be the dominant wild harvested products there. The highest amounts were harvested in Romania, Russia and Bulgaria as well as Serbia and Montenegro, Bosnia and Herzegovina and Albania. In Africa, the most important products, in terms of quantity, were reported to be rosehip, argan oil, gum Arabic, shea butter and honeybush (International Finance Corporation (IFC), 2018). The most important wild harvested products in North America are wild rice, maple syrup, wild blueberries and blue green algae. Unlike Canada, organic wild gathering in the United States of America is of less significance. Brazil nuts were reported to be the most important wild harvested product in Latin America, harvested mostly in Bolivia, Peru and Brazil. Other important products are coconut, heart of palm and rosehip. In terms of gathering area Bolivia was reported to be the leading country, followed by Brazil, Peru and Guatemala.

Asia shows the widest variety of harvested products (approximately 241). Products such as bamboo shoots, walnuts, tea seeds, seaweed, berries and mushrooms are harvested in large quantities (International Finance Corporation (IFC), 2018). These products make up more than 80% of the total harvest. China is the leading country in Asia in terms of registered gathering areas (International Finance Corporation (IFC), 2018). An even larger area was reported in Azerbaijan, but the certification status was not clear. China is also the country with largest reported harvesting of organic wild harvested products in terms of weight. In Australia and Oceania, organic wild gathering has little commercial importance. Products include noni, sandalwood, sea weed, kangaroo grass and honey.

There was almost no data provided on registered areas or quantities.

Estimates of wild useful fungi, including those presented in the Kew reports (Willis, 2018), are largely based on a 2004 report from FAO (Boa, 2004) which is now somewhat out of date. The sustainable use assessment presents a comprehensive review of more recent literature on the various uses of wild fungi in section 3.3.2.3.4. A bit of information here demonstrates the complexities and rapid changes in this area. For example, 282 species of

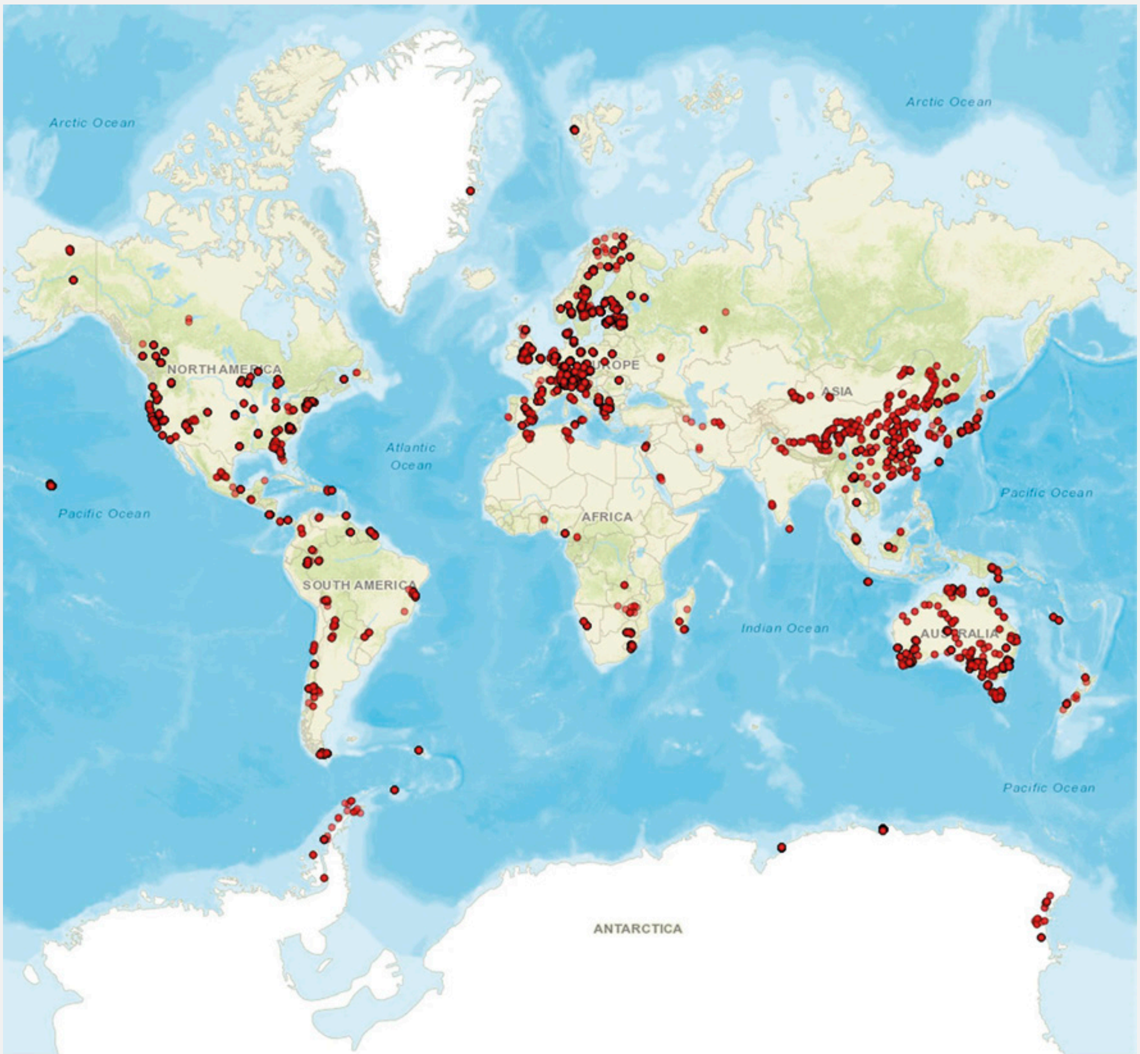

Figure 3 5 **Locations of samples in the global wild fungi database.**

This map is directly copied from its original source (Větrovský et al., 2020) and was not modified by the assessment authors. The map is copyrighted under license CC-BY 4.0 and copyright © 2019 Esri. *The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.*

wild fungi are listed on official governmental legislation or guidelines as 'fit for commercialization' in Europe alone (Peintner *et al.*, 2013). Moreover, taxonomic description of fungi is far from complete and an estimated 2 million species are yet to be described (Willis, 2018). In 2019 alone 1,886 species of fungi were scientifically named (SOTWP, 2020). This knowledge gap includes widely-used and internationally traded species. For example, a study of a packet of dried porcini mushrooms purchased at a supermarket contained three species of porcini relatives previously unknown to science (Dentinger & Suz, 2014). Use of fungi as a food source is particularly important in IPBES regions such as Central Asia and Europe. One of the most recent global datasets on fungi is presented in **Figure 3.5**. The global fungi database, from which this figure was generated, contains over 600 million observations of fungal sequences across the world and over 17,000 samples with geographical locations (Větrovský *et al.*, 2020).

3.2.1.3 Terrestrial Animal Harvesting

Humans use terrestrial animals for very different purposes, such as food-feed and pets. In 2013, the United Nations Environment Programme-Worl Conservation Monitoring Centre (UNEP-WCMC), in partnership with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) secretariat, brought various data-holdings together into one comprehensive data portal to assist Parties to implement biodiversity Multilevel Environmental Agreements using available data. This global dataset documenting use of terrestrial animals is called Species+ (https://speciesplus.net). Species+ contains information on all species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and other family listings and species included in the annexes to the European Union wildlife trade regulations.

A recent global estimate shows that of 31,500 terrestrial bird, mammal, amphibian, and squamate reptile species, 5,579 species (18%) are used and traded globally (Scheffers *et al.*, 2019). Reptiles, for example freshwater and marine terrestrial turtles, lizards, snakes, and crocodiles are widely used by indigenous people. There are very different estimates on the number of wild animals used as food sources. Estimates suggest that globally, as many as 2,000 species of invertebrates, amphibians, reptiles, birds and mammals are used for food and considered as wild meat (Ingram *et al.*, 2015a; Redmond, 2006; Stafford, Preziosi, & Sellers, 2017). However, Marsh et al (2021) (after Butchart (2008)) reported over 4,500 wild bird species alone are used for food and pets (Butchart, 2008).

Use of mammals for food is reported from North America, Africa, Europe and central Asia **(Figure 3.2)**. The International Union for Conservation of Nature Red List (version 2021.1) has coded 1,248 mammal and 250 reptile species for use as food. Global estimates of hunting (section 3.3.3) highlight regional differences and again challenges with data collection. Estimates of annual offtake rates from forests in Central Africa, for example, range between 1.6 and 11.8 million tons of meat per year. Estimates in the Brazilian Amazon range between 0.07 and 1.3 million tons per year. No similar reviews were found for Asia, where there are still insufficient site-level hunting data to make adequate comparisons. Off-take data are similarly scarce for animal communities in savanna habitats in Africa and South America (Coad *et al.*, 2019). A meta-analysis of 78 hunting studies from sites located in Central America, Amazonia and the Guiana Shield, recorded a total of 90 hunted mammal species including 12 primates, 6 ungulate and 8 rodent genera. As in Africa, ungulates and rodents make up the majority of the wild meat offtake in neotropical communities. In the Amazon Basin, with regional variations, much of the wild meat offtake is medium-sized ungulates such as white-lipped peccary *(Tayassu peccari)*, collared peccary *(Pecari tajacu)*, white-tailed deer *(Odocoileus virginianus)* and various brocket deer *(Mazama* species) and tapir *(Tapirus* species).

3.2.1.4 Logging

Estimates for the total number of tree species used vary somewhat. Both the global tree assessment (Global Tree Assessment, 2020) and estimates from the world flora online (WFO, 2020) list around 60,000 tree species across the world. Estimates differ on the number of wild tree species that are used. The FAO has previously reported 34,000 species, including fruit- and nut-trees and their wild relatives, are used on a regular basis for a range of uses, including logging, environmental, social and scientific purposes, and food (FAO, 2014c). The global tree assessment estimates 12,000 species as having at least one use, and many have a variety of uses (BGCI, 2021). According to the International Union for Conservation of Nature red list (IUCN, 2020b:3), 17,510 tree species (29.9% of all tree species), are considered threatened, 7,400 species (12%) from logging. The 2021 state of the world's trees report also state that "the second major threat to tree species, is direct exploitation, especially for timber, impacting over 7,400 tree species" (Global Tree Assessment, 2021).

Although the amount of timber harvested (volume) from wild and plantation forests is recorded in several global datasets, there is little or no information available about the ways in which those trees were felled and removed from the landscape. In other words, the practice is not recorded, only the result. It is well established that clear felling is prevalent in boreal and temperate forests, and selective logging is the dominant timber harvesting practice in natural tropical forests.

Over 20% of the world's tropical forests have been selectively logged (Bicknell, Struebig, & Davies, 2015). Furthermore, in the majority of the cases the data on selective logging refers only to the minimum felling diameter (normally between 45 and 60 cm diameter at breast height (DBH) only. However, selective logging practices also include other management actions such as type of cutting and regeneration planning. Therefore, the International Tropical Timber Organization estimates that less than 10% of the total permanent forest estate of tropical countries is managed sustainably (Poudyal, Maraseni, & Cockfield, 2018).

3.2.1.5 Non-extractive use

Global estimates on wild species use for non-extractive practices (section 3.3.5) tend to be undocumented, and therefore there are very limited global statistics available. In contrast with fishing, gathering, hunting and logging, non-extractive uses tend to be based in experiencing the whole ecosystem. For example, worship in sacred groves includes all the species in the grove and its vicinity. Recreational tourism may focus on charismatic species but encompasses the whole park / coral reef experience. Forest therapy uses the whole forest. Species-specific tourists, such as bird- / butterfly-watchers, aim to view every species in the taxonomic group and making these observations in their native habitats in part of the experience.

While non-extractive uses are not always directly tied to specific species, they are an important part of wild species use and generate significant amounts of revenue worldwide. Balmford *et al.* (2015) report 8 billion tourist visits per year to protected areas around the world, generating approximately 600 billion United States dollars. It is estimated that tourism revenues generate 120.1 billion United States dollars in gross domestic product to the global economy (WTTC, 2019a). Cultural and economic values from the United Nations Educational, Scientific and Cultural Organization (UNESCO) Word Heritage Sites are also linked to wild species **(Figure 3.6)**. For example, analysis of the data from United Nations on cultural landscapes (http://whc.unesco.org/en/, accessed February 2021) reveals that 23% (25 out of 113) of world heritage sites can be associated directly or indirectly with use of wild species (with different degrees of domestication). However, with the exception of recreational use of wild species, there is limited to no global data on the status and trends of other non-extractive uses such as ceremonial and cultural use, medicinal, and educational use (see section 3.3.5).

In addition of the datasets available for the different practices there are also worldwide repositories such as the Global Biodiversity Information Facility (GBIF) that gather data for different taxa. The Global Biodiversity Information Facility platform (https://www.gbif.org/), which currently houses 1,4 billion records (accessed 15th June 2020), documents the occurrence of a species at a given

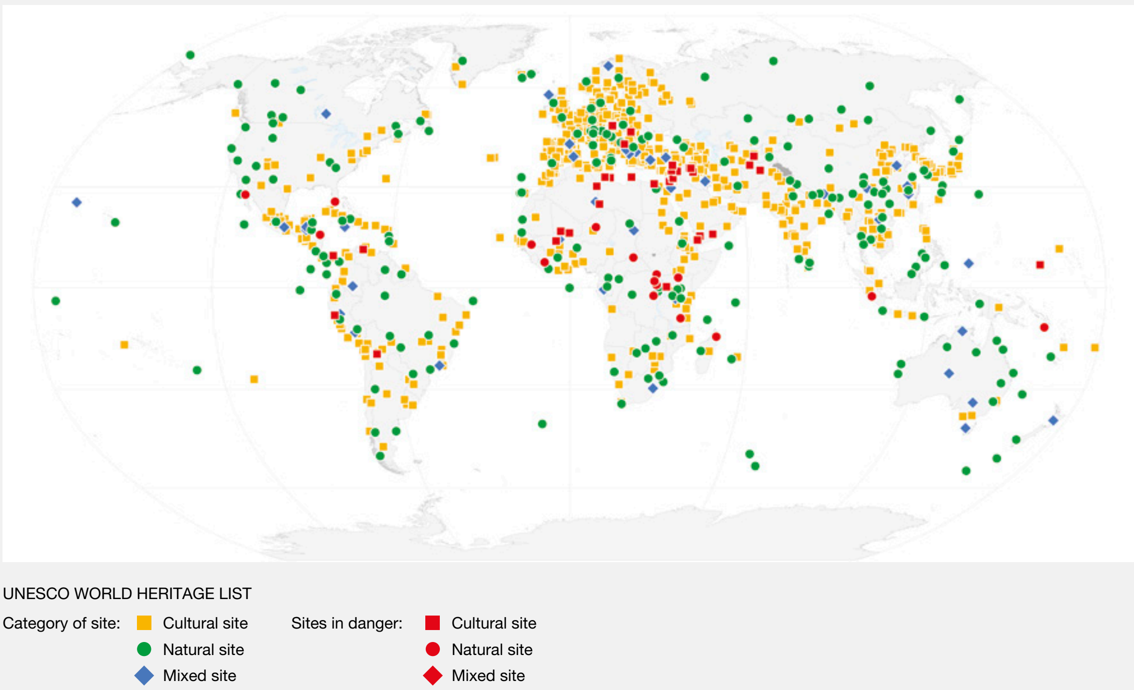

Figure 3 6 **Locations of UNESCO cultural and natural landscapes around the world.**

Based on (UNESCO, 2021) © 1992–2022 UNESCO/World Heritage Centre.
See data management report for the figure at https://doi.org/10.5281/zenodo.6462960.

time and place, however data on wild species use is not reported systematically.

The results of this review show that while there is a vast legacy of available data on species taxonomy and ecology for different taxa, most datasets do not distinguish wild from domesticated species, making this assessment on the use of wild species (as defined in the sustainable use assessment scoping document) very challenging. Although there is available data on taxonomy and ecology for different taxa, particularly in germplasms/herbariums across the world, lists of wild species available for some taxa are very incomplete. Even for the taxa where there are lists of wild species available, the focus is on biological conservation or economic value related to trade and markets rather than specifically on use as defined here. These reports are framed under different perspectives and goals (see Chapter 2) and on a practice by practice or use by use basis.

Another concern regarding the available datasets is that while the reporting focuses on a use-by-use basis, a single wild species is often used for a variety of purposes. As shown in **Table 3.1**, single species of wild plants, animals and fungi often are used for a variety of reasons (as food source, raw materials, rituals, culture and community identity). Successful and sustainable use is often associated with specialized knowledge and skills of the multifunctional use (Carvalho Ribeiro *et al.*, 2018). Throughout generations indigenous peoples and local communities often cultivate specialized knowledge and maintain skills in ways that support community well-being and maintain nature's contributions to people. These comprehensive uses of single species are not yet captured in global datasets.

In sum, although there have been advances in recent decades, there is not yet a global, harmonized observation system for delivering regular, timely data on species status and trends of biodiversity change, particularly on species that are used by humans. Core elements of this developing data infrastructure have been prototyped. For example, the "Map of Life" website (http://mol.org/) couples raw data on species biology (but not on use) with modelling approaches to inform policy making (Jetz *et al.*, 2019).

3.2.2 Global Indicators

IPBES, in the context of the global and regional assessments, reviewed and systematized a list of 345 global indicators (IPBES Technical Support Unit on Knowledge and Data, 2021). From the list of indicators reviewed by experts in the context of the IPBES global assessment of biodiversity and ecosystem services, the ones likely suitable for measuring status and trends in the sustainable use assessment were selected. In order to update this list, additional indicators from the Biodiversity Indicators Partnership (https://www.bipindicators.net/; accessed October 2020) were included. The Biodiversity Indicators Partnership provides the best available information on status and trends of biodiversity, which helps to monitor progress towards the Convention on Biological Diversity and other multilateral environmental agreements. At the moment, the Biodiversity Indicators Partnership integrates indicators grouped into 8 themes. The themes on sustainable use (22 indicators) and species (42 indicators) are those most likely to apply to the sustainable use assessment.

Most of the indicators reviewed by IPBES are from the Sustainable Development Goals and the Aichi Biodiversity Targets. There are 241 indicators to assess progress towards the achievement of Sustainable Development Goals (https://unstats.un.org/sdgs/indicators/; accessed October 2020). There are 22 indicators as part of the Biodiversity Indicators Partnership. For the current assessment, indicators were selected based on a three-stage process from these three sets (IPBES, SDG – Sustainable Development Goals, and BIP – Biodiversity Indicators Partnership). Indicators were chosen through a set of recurrent stages (initial selection, narrowing, assigning usefulness):

Stage 1 - Initial selection

1. Covers those boxes and arrows of the IPBES conceptual framework that are particularly relevant to sustainable use of wild species,

2. Relevant for different stakeholders and end users (i.e., policy- and/or decision-relevant),

3. Reflects various knowledge systems, diverse worldviews and multiple conceptualizations of values,

4. Relevant at different spatial and temporal scales.

Stage 2 - Narrow the set of indicators (IPBES global assessment used ~30 indicators) taking the following into consideration which indicators

1. Contributes best to the socio-ecological narrative for sustainable use (i.e., reflects both ecological and social aspects),

2. Provides the most useful information on the sustainability of the use of wild species,

3. Need to be developed to reflect the multi-dimensionality of sustainable use of wild species,

4. Provide the most relevance for future monitoring of sustainable use of wild species,

5. Reflect interdependencies and trade-offs (indicators more connected to others provide more nuanced information),

6. Apply across taxa and practices (generic indicators). If not possible, selections should include specific indicators for the major taxa and practices,

7. Are most useful for ongoing assessments.

Stage 3 - Further considerations on the usefulness of the indicator for the sustainable use assessment

1. Are data already available (X) or under active development (Y)?

2. Is the indicator suitable for communication?

3. Is there a possibility for aggregation or disaggregation of data used elsewhere (e.g., National data aggregated to form a global indicator)?

4. Is it an indicator for the Sustainable Development Goals?

This review resulted in a total of 47 meaningfully useful indicators for the assessment as defined in this assessment. Fifteen indicators were likely to meaningfully contribute to estimating status and trends of (sustainable) use of wild species **(Table 3.2)**. Thirty-two indicators relate specifically to the sustainable use assessment practices/uses **(Box 3.1)**. This is a notably small number of indicators given that we reviewed approximately 1000 possible indicators against these criteria (including 245 indicators used for the Sustainable Development Goals, 345 from IPBES, and 300 from the Biodiversity Indicators Partnership).

The analysis of the selected indicators started by associating each indicator to the list of key elements of sustainable use reviewed in Chapter 2 (section 2.2.6):

1. Respect laws, policies and institutions
2. Respect local community rights and access
3. Effective interlinkages among levels of governance
4. Local communities empowered
5. Respect customary law
6. Management and monitoring plans in place
7. Adaptive management specified

Table 3 2 **Selected status and trends indicators.**
Abbreviations: SDGs: Sustainable Development Goals.

	Source	Name and brief description of the indicator
1	McRae *et al.*, (2022)	A global indicator of utilized wild species populations: regional trends and the impact of management
2	Marsh *et al.*, (2021)	Prevalence of sustainable and unsustainable use of wild species inferred from the International Union for Conservation of Nature's Red List
3	Biodiversity Indicator Partnership, Tierney *et al.*, (2014)	"Use it or lose it"
4	Biodiversity Indicator Partnership, Khoury *et al.*, (2019)	Comprehensiveness of conservation of socioeconomically as well as culturally valuable species
5	IPBES-SES	Species Habitat Index (wild species) Species Status Information Index
6	Aichi Biodiversity Target 13	Red List Index (impacts of utilization/wild relatives of domesticated animals)
7	Biodiversity Indicator Partnership, IPBES	Proportion of local breeds (wild species) classified as being at risk, not-at-risk or at unknown level of risk of extinction
8	Biodiversity Indicator Partnership	Biodiversity Intactness Index
9	Sustainable Development Goal 2	Indicator 2.5.1 Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities (wild species)
10	Biodiversity Indicator Partnership	Number of species extinctions (birds and mammals) (used species)
11	Faitrade International	Trade volume in Fairtrade certified goods (wild)
12	Sustainable Development Goals/ Organization for Economic Cooperation and Development	Number of intangible cultural heritage practices – under the category of 'knowledge and practices concerning nature' per country (sustainable use)
13	Sustainable Development Goals /Organization for Economic Cooperation and Development	Number of countries with national instruments on biodiversity-relevant taxes, charges and fees
14	IPBES	Biodiversity Engagement Indicator
15	Biodiversity Indicator Partnership	Living Planet Index (utilized/non utilized species)

8. Participatory approach to decision-making
9. Use of multiple knowledge systems
10. Minimize ecological impacts
11. Minimize waste
12. Restore/improve ecological context
13. Foster socioeconomic benefits
14. Provide local capacity building
15. Fair and equitable sharing of benefits
16. Additional community benefits
17. Raise understanding and awareness

These key elements were included into broad categories such as governance (1 to 5), management and monitoring (6 to 9), ecological impacts (10 to 12), socio economic benefits (13 to 16) and education (17) (see Chapter 2). Although these global indicators tend to fill in one (or in the maximum two) principles there are no indicators that cover all principles: governance, management & monitoring, ecological impacts, socioeconomic benefits and education.

This suggests a need to adapt these global indicators sets to better represent the holistic dimensions of sustainable use of wild species.

Our review of the global indicator sets also shows that most of the indicators developed and used by the Sustainable Development Goals, the Convention on Biological Diversity (Biodiversity Indicators Partnership) and IPBES would need to be adapted in order to target wild species that are used. **Table 3.2** lists indicators that can currently be used to assess status and trends in the use of wild species. The ones in bold are described in more detail below the table. The additional sources are included here for reference, but are not included in the more detailed analysis.

The following text provides details regarding the key sources listed in **Table 3.2**. Those presented in more detail are those that report on the most recent global indicators from the peer-reviewed literature.

Figure 3 7 **Index of utilized populations for IPBES Regions.**

Abbreviations: TFW: Terrestrial and Freshwater, M: Marine Source (McRae *et al.*, 2022) under license CC BY-NC-ND 4.0.

Source 1: The global indicator developed by McRae *et al.* (2022) follows the method used to calculate the Living Planet Index (https://www.bipindicators.net/indicators/living-planet-index). McRae *et al.*, (2022) used a global data set of over 11,000 time-series to derive indices of 'utilized' and 'not utilized' wild species and assess global and regional changes, principally for mammals, birds and fish. Their work also explored the role that targeted management has in predicting population trends in utilized populations. The results of this work show that from 1970–2016 wild species population trends globally, both used and non-used, are negative **(Figure 3.7)** for both terrestrial and freshwater (TFW) and marine (M) species for all IPBES regions. Note that the trends being shown here are for populations, not for sustainable use.

On average, utilized populations declined by 50% over the 46-year period (0.41-0.62) and non-utilized populations declined by 3% (0.80-1.18). **Figures 3.7** and **3.8** show the estimated total change from the best linear mixed-effect model (binomial and location as random effects). Coefficients show the estimated overall change (log10) for mammals, fish and birds. This work found no significant interaction between taxonomic group and utilization; however, it does show utilized populations tend to decline more rapidly, especially in Africa and the Americas (McRae *et al.*, 2022). However, where utilized populations are managed, there is a positive impact on the trend. This work corroborates that use of species can either be a driver of negative population trends, or a driver of species recovery, with numerous species and population specific case examples making up these broader trends (see section 3.3 for more details and case studies).

The role of management, especially with regards to trade, has been controversial. A considerable body of research on vertebrate species in international trade reports an overall perverse trend in use, with management having a limited mitigating effect sustainability species (Morton, Scheffers, Haugaasen, & Edwards, 2021). International trade databases such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (https://trade.cites.org/) can shed light on this by reporting both negative and positive effects on population status. In some cases, economic incentives to use a listed species can be directly linked to facilitating recovery and demonstrating non-detrimental use. The role of the Convention on International Trade in Endangered Species of Wild Fauna and Flora can therefore be pivotal for linking use of species with its management and recovery plans.

Source 2: the International Union for Conservation of Nature red list data assess species risk of extinction in relation to threat categories: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CE). Red list data show that while use is considered a threat for some species, for others use is not associated with red list threat categories. For example, the work by Marsh *et al.* (2021) shows that for the 10,000 wild species where use and trade data are reported, use

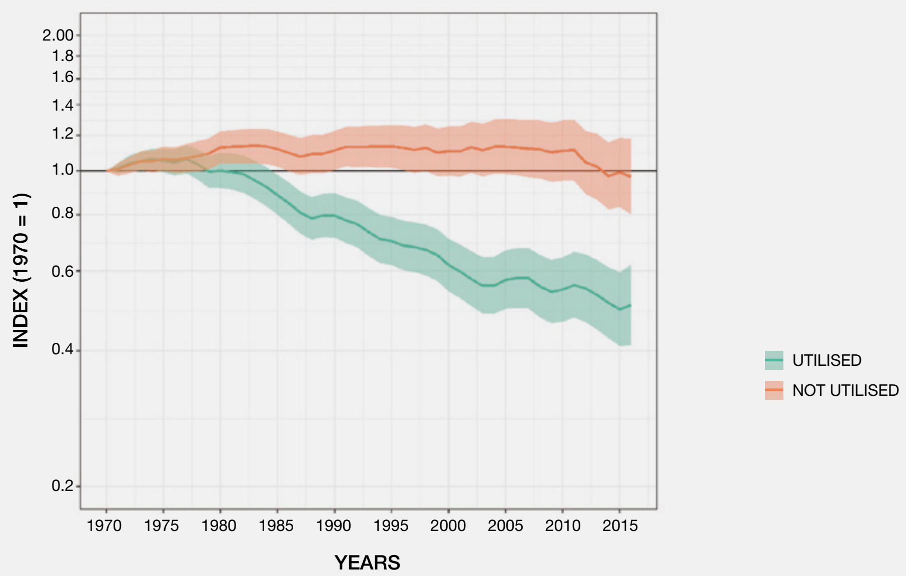

Figure 3 8 **Global trends in utilized vs non utilized species for species of bird, mammal and fish.**

Source (McRae *et al.*, 2022) under license CC BY-NC-ND 4.0.

is likely unsustainable for 16% of species. However, the majority (72%) of species that are used are not threatened, with 34% of used species having stable or improving population trends. Marsh and colleagues (2021) suggest that use is likely to be sustainable for the majority of the species analyzed.

Across Near Threatened (NT) and threatened species, a higher overall proportion of aquatic species than terrestrial species have intentional biological resource use coded as a threat. Among aquatic groups, the taxa with highest prevalence are corals (388 species) and almost all cartilaginous fishes (314 out of 318 species), with fishing the predominant threat. In the terrestrial groups, cycads appear most affected (147 –152 of 255 species), largely due to gathering (147 species) **(Figure 3.9)**. For 48% of the total number of species assessed it was not possible to determine the associations between use and status and trends of the species (Marsh *et al.*, 2021).).

Source 3: The "use or lose it" by Tierney *et al.* (2014) measures trends in the use of wild species, with a focus on both terrestrial and aquatic vertebrate arctic species using two indicators which they developed: the Utilized Species Index (applied at the global scale based on the Living Planet Index) and the Harvest Index (applied in the Arctic region only). The examined data is on amphibian, bird, fish, mammal and reptile species from freshwater, marine and terrestrial realms.

The results of the utilized species index show that between 1970 and 2007 populations of utilized freshwater species declined by 3% and utilized marine species declined by 17%. The populations of utilized terrestrial species decreased 21% over the same period. However, according to this study since the early 2000s the rate of decline of utilized marine and terrestrial species indices has slowed or stabilized. The utilized freshwater species index has been increasing steadily since 2000. The index for species used

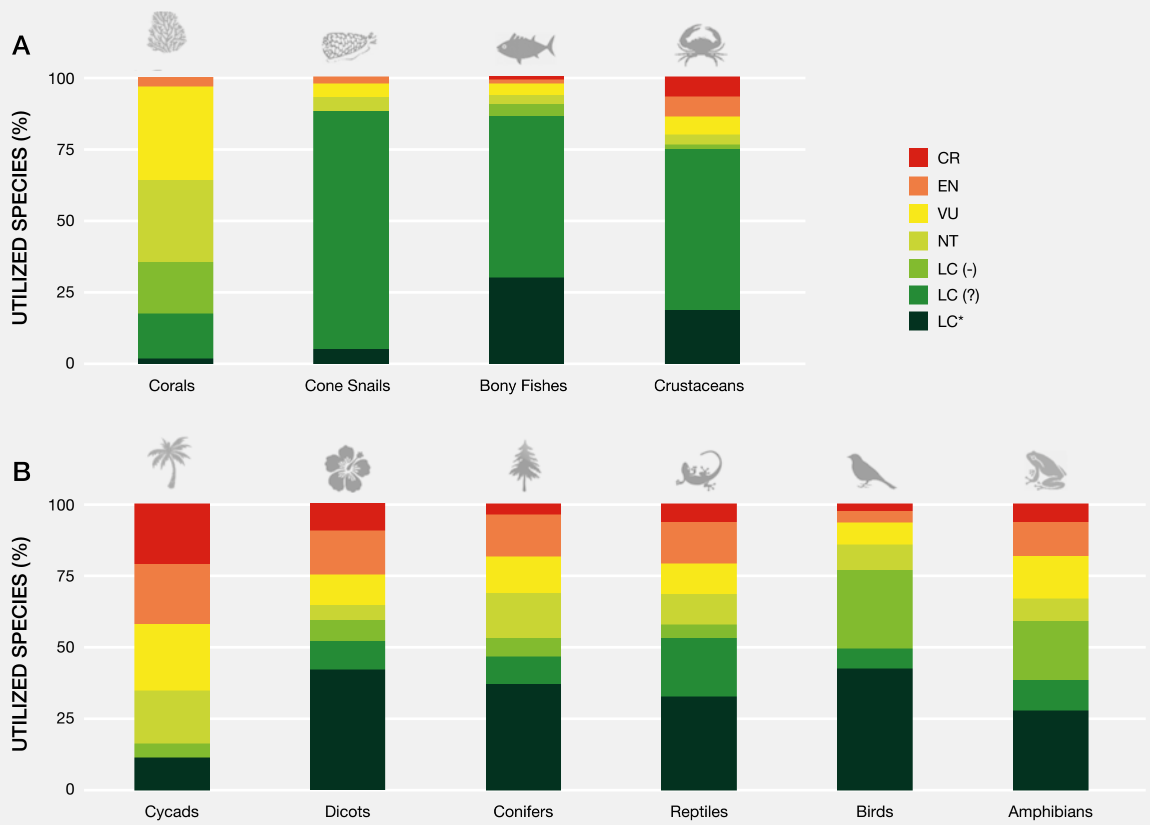

Figure 3 9 **Percentage species by the International Union for Conservation of Nature Red List Category in (A) aquatic and (B) terrestrial groups that are subject to use and trade.**

Legend: LC(-) = Least Concern species with declining population trend; LC(?) = Least Concern species with unknown population trend; LC (*) = Least Concern species with stable or increasing population trend. Note that being LC and having a declining population trend, or being threatened and being subject to use and trade, does not imply that use is a major threat. NT =Near Threatened, Vu =Vulnerable, EN= Endangered, CR=Critically Endangered. Source: (Marsh *et al.*, 2021) under license CC-BY.

reports that from 1997 to 2007 wild species population used for food and species used as pets declined by 17% and 9%, respectively. However, like with terrestrial species, after 2000 this trend inverted **(Figure 3.10)**.

Despite these initial reviews, it remains challenging to undertake comparisons of population trends between utilized and non-utilized species. Most of the datasets available lack the detail needed to do meaningful comparisons amongst utilized vs non utilized species. In this context it is difficult to account for the range of influential factors that could be influencing these trends. Without the ability to account for additional factors and correlated them with these datasets, it is incorrect to assume that use is the primary driving factor of decline or increase in population size.

Source 4: The "Comprehensiveness of conservation of useful wild plants" by Khoury *et al.*, (2019) was included in the Biodiversity Indicators Partnership. In developing the indicator, 6,941 wild plants native to different countries were selected from the United States of Amercia dataset "GRIN-WEP" (2020). The resulting *in situ* indicator shows the extent to which wild species economically used across

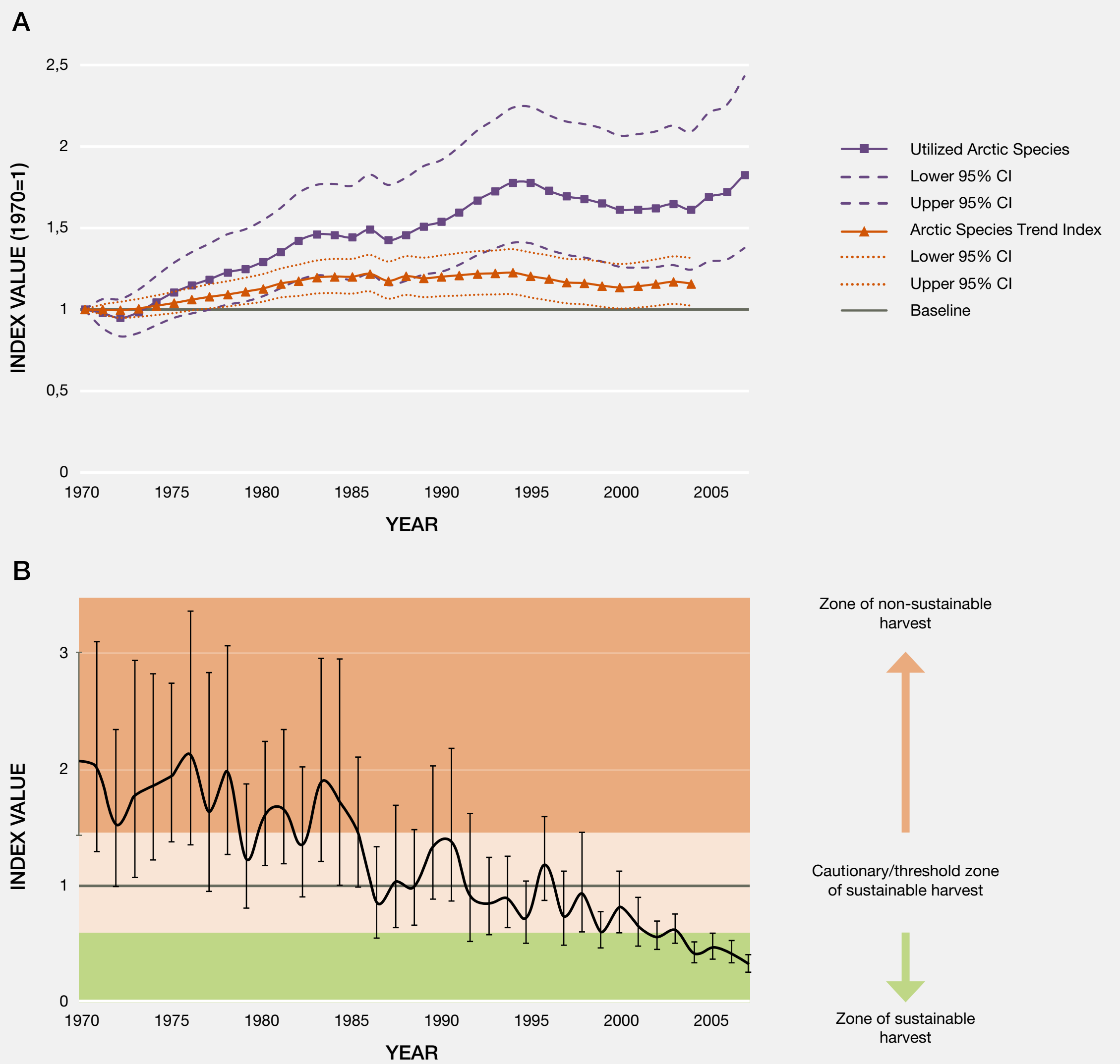

Figure 3 10 **Trends (-/+ 95% CI) in (A) utilized Artic species compared to the Artic Species Trends Index between 1970 and 2007 and (B) Harvest Index of Artic Species between 1970 and 2006, with zones of unsustainable, cautionary and sustainable harvest levels shown.**

Source (Tierney *et al.*, 2014), © Cambridge University Press, license number 5146950749639 CC-BY NC.

the world are conserved *in situ* (through conservation areas). This indicator ranges from 1 (Andorra, Falkland Islands, Gibraltar, Kiribati, Niue, Palestinian Territory, St. Helena, Timor-Leste, and United States of America minor outlying islands) to 642 (Turkey). The mean number of species used across countries is 141; the median is 86. An interactive version of this indicator is available at https://ciat.cgiar.org/usefulplants-indicator/. Areas where *in situ* conservation is likely low are concentrated in Asia and to a lesser extent in Sub-Saharan Africa **(Figure 3.11)**.

In addition to the 16 indicators listed above **(Table 3.2)** there are indicators which can be used to characterize the specific practices detailed in section 3.3 **(Box 3.1)**. The review of indicators highlights that while information on harvesting of terrestrial species is limited, there is a diversity of indicators tracking the off-take and use of marine species. Although there are several indicators used for fisheries, they do not capture the specificities of small-scale fisheries and inland fisheries. These topics are discussed in greater detail in section 3.3.

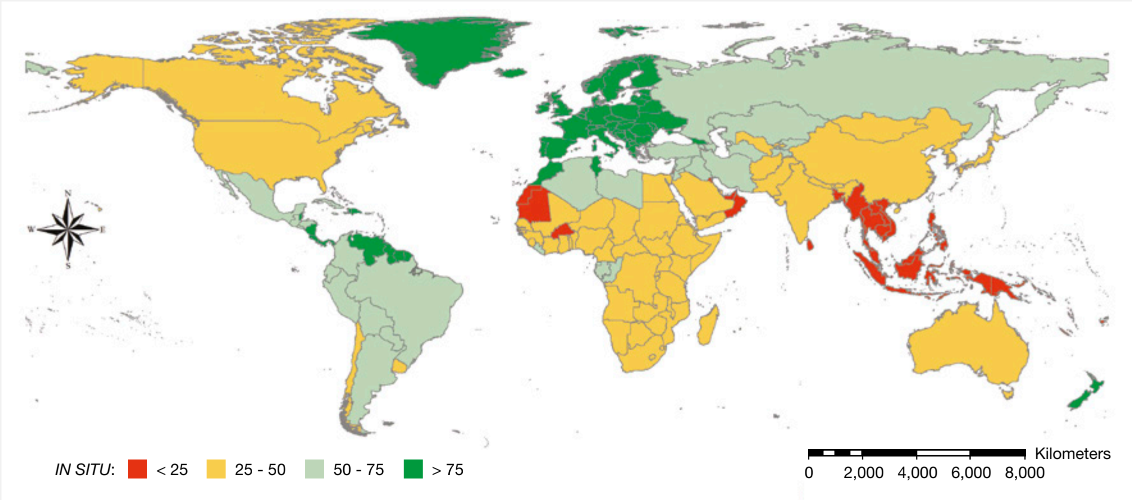

Figure 3 11 ***In situ* conservation indicator.**

This map is directly copied from its original source (Khoury et al., 2019) and was not modified by the assessment authors. The map is copyrighted under license CC-BY 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

Box 3 1 **List of possible indicators by practice (selected from indicators developed for the Sustainable Development Goals, Biodiversity Indicators Partnership & IPBES).**

FISHING (13)

1. Sustainable Development Goals indicator 14.4.1 Proportion of fish stocks within biologically sustainable levels
2. Sustainable Development Goals indicator 14.6.1 Degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing
3. Sustainable Development Goal indicator 14.b.1 Degree of application of a legal/regulatory/policy/institutional framework which recognizes and protects access rights for small-scale fisheries
4. Number of Marine Stewardship Council's (MSC) chain of custody certification holders by distribution country
5. Number and volume of Marine Stewardship Council certified, consumer-facing products by distribution country
6. Marine Stewardship Council certified catch, Ocean Health Index
7. Red List Index (impacts of fisheries) & number of species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora
8. Cumulative human impacts on marine ecosystems
9. Living Planet Index (trends in target and bycatch species)
10. Large reef Fish, policies make adequate provisions to minimize impacts of fisheries on threatened species
11. Illegal, unreported and unregulated fishing
12. Full access to marine resources
13. Inland fishery production

Box 3 1

GATHERING (5)

1. Quantity of mushrooms and truffles, yield (hectogram/ hectare) per country
2. Species richness of medicinal plants per country
3. Indigenous and local knowledge trends associated with medicinal plants
4. Number of contracting Parties to the International Treaty on Plant Genetic Resources for Food and Agriculture (adapted for wild species)
5. Red List Index (wild species used for food and medicine) & number of species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora

TERRESTRIAL ANIMAL HARVESTING (6)

1. Agreement on International Humane Trapping Standards (AIHT) database
2. Red List Index (internationally traded wild species) & number of species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora
3. The Living Planet Index (a measure of the state of global biological diversity based on population trends of vertebrate species from around the world)
4. The species abundance per country (for selected species)
5. Animal individuals hunted yearly per country (for selected species)
6. Proportion of traded wild species that was poached or illicitly traded

LOGGING (5)

1. Sustainable Development Goal indicator 15.2.1 Progress towards sustainable forest management (wild species)
2. Area of forest under sustainable management (wild species): total forest area under management certification (Forest Stewardship Council and Programme for the Endorsement of Forest Certification)
3. Red List Index (forest tree specialist species) & number of species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora
4. Timber trade volume in Fairtrade certified goods
5. Total wood removals

NON-EXTRACTIVE PRACTICES (3)

1. Sustainable Development Goal indicator 12.b. Number of sustainable tourism strategies or policies and implemented action plans with agreed monitoring and evaluation tools
2. Importance of protected areas for stimulating eco-tourism and nature-related leisure activities
3. Proportion of jobs in sustainable tourism industries out of total tourism jobs

These global indicators cover different dimensions associated with sustainability and sustainable use **(Box 3.1)**. For example, while most of the indicators for gathering focus on the extent of harvest as a function of area per country, indicators for terrestrial animal harvesting tend to focus on trends in use (overall use increasing or decreasing). Terrestrial animal harvesting indicators also tend to emphasize trade data sources such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which may exclude a large number of species which are harvested but not formally traded.

In summary, despite the importance of wild species to economies and livelihoods, relatively few global datasets and indicators have been developed specifically to monitor the status and trends of wild species that people use, except for economically valuable fish species reported on by the biannual reports "State of world fisheries and aquaculture" prepared by the FAO. Particularly lacking are attempts to examine how indicators of species use and sustainable harvest could be linked to provide a broader picture of what, where and how people are using wild species (Tierney *et al.*, 2014).

3.2.2.1 Indigenous Indicators

The importance of wild species in a diversity of livelihood strategies is well recognized, particularly for indigenous peoples and local communities. However little attempt has been made in the available global indicator sets to comprehensively quantify the spatial and temporal scales of sustainable use of wild species occurring specifically in indigenous and local communities across the globe. The United Nations are aware of this gap. The permanent forum requested the inter-agency support group on indigenous peoples' issues, specifically those agencies working on land tenure and changes in land use, to step up cooperation in order to operationalize indicators on these topics as they pertain to traditional territories (lands and waters) of indigenous peoples. The goal was to create a global multipurpose indicator in order to report on status and trends, in line with the Convention on Biological Diversity, the 2030 Agenda for Sustainable Development and the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP).

The permanent forum recommended that the inter-agency and expert group on Sustainable Development Goal indicators provide support for the inclusion and methodological development of core indicators for indigenous peoples in the global indicator framework (https://www.un.org/development/desa/indigenouspeoples/mandated-areas1/data-and-indicators/recs-data.html). In particular, the inclusion of an indicator on the legal recognition of land rights of indigenous peoples for the targets under Sustainable Development Goals 1 and 2 was requested (United Nations Department of Economic and Social Affairs, 2020).

A key data point for indigenous indicators is regarding spatial patterns of occupancy of indigenous communities around the globe, including estimates for total area and sizes of land plots for habitation and a range of traditional livelihood practices. A recent effort to map the occupancy patterns of indigenous lands at the global scale was undertaken by Garnett *et al.* (2018). In this study, the authors show that indigenous lands seem to have the appropriate scale to support the implementation of several global conservation and climate agreements while also maintaining sustainable local use and local governance institutions. However, details on the scale of sustainable use (both spatial and temporal) were not explicitly presented in this study.

Contrary to the large size of most indigenous lands (large extents that can be mapped at coarse resolutions), identifying the spatial patterns of occupancy of "other" traditional livelihoods, (plots with smaller sizes than can only be mapped at finer grained resolutions) is very challenging. Yet, actors at smaller scales are active natural resource users within many social-ecological systems. The failure to so far comprehensively map and measure the multi-scaled and interwoven distributions of traditional communities' and livelihoods' diverse spatial occupancy patterns likely make these users of wild species invisible to policy makers. For example, in order to estimate scale of use of wild species supporting different types of livelihoods one can, to some extent, explore the spatial scale (grain and extent) of the land consigned by law to different communities and map their rights of use and land tenure regimes. Indeed, traditional communities and their rights are defined by law (including international agreements).

Recognizing and identifying these diverse legal frameworks and the associated spatial occupancy patterns of their territories can be a way forward to estimate the spatial scale of use of wild species globally. However, territoriality and tenure clarification are highly complex, politically driven and often a very slow process. Moreover, while *de jure* standards may be defined, the *de facto* realities might show evidence of positive long-term care and stewardship or negative effects such as failed law enforcement, denied constitutional protections, and in some cases a weak and indiscriminate rule of law. Other data/indicators can then be used, that can complement land ownership datasets in order to provide the best estimate available for different types of uses of wild species.

The next section provided a brief review of key aspects of the temporal scale of use (3.2.3) and economic, ecological and social contexts for sustainable use across the globe (3.2.4). Section 3.3 goes into detail on a practice-by-practice basis.

3.2.3 Temporal scale and use

Use of wild species varies over time. Although there is evidence that temporal scale influences sustainability of use of wild species, based on the review above the temporal dimension has been overlooked in global datasets (section 3.2.1.1) and the global indicator system (section 3.2.1.2). The dedicated attempt here to introduce longer-term temporal indicator dimensions to sustainable use indicators is therefore very much a step forward. There are many insights to be gathered from longer term perspectives, many of which directly challenge more temporally constrained conclusions. Correlative reasoning is sometimes entirely displaced through longer term trend reviews. Another important reason to consider temporal scale for assessing sustainable use is that harvesting intervals vary widely across species. Some species may be subject to seasonal, periodic or annual harvests, others may be biennial or triannual. Timber is often harvested according to a decadal cycle. Other species, such as some wild edible fungi, may be harvested sporadically when they fruit abundantly.

Perception and organization of time is very basic to the internal ordering of all cultures and there are strong evidences of such calendars from all continents across the globe (Dhyani, 2018; Dhyani, Maikhuri, & Dhyani, 2011). Seasonal calendars reveal a body of knowledge about the relationship between people and the environment and underpin local Natural Resource Management (NRM) strategies. These knowledge systems have been built through strong observational, practice-based methods that have been used for centuries. They continue to be enacted and tested, and have sustained consecutive generations by adapting continually, if incrementally, to the local context over time (Woodward & Marrfurra McTaggart, 2019).

Seasonal calendars have been used by indigenous peoples and local communities for generations for monitoring and adaptive management of natural resources, agricultural systems (Bhagawati, Sen, & Shukla, 2017; Jiao *et al.*, 2012; Saylor, Alsharif, & Torres, 2017), climate change (Balehegn, Balehey, Fu, & Liang, 2019; Cochran *et al.*, 2016; Fu *et al.*, 2012; D. Yang & Pomeroy, 2017), water (Woodward, Jackson, Finn, & McTaggart, 2012), and to guide eco-health decision making (SantoDomingo, Castro-Díaz, González-Uribe, Wayúu Community of Marbacella and El Horno, & Barí Community of Karikachaboquira, 2016).The temporal scale of use is also important for measuring the nutritional value and food availability across the "seasonal evenness": when there are many species in the system, the likelihood is increased that one species or another is "in season" at all times (FAO, 2017a; Powell *et al.*, 2015). Seasonal calendars have been relevant in cross-cultural interpretation of indigenous ecological knowledge and a relevant communication tool. While seasonal knowledge for temporal scale of use of wild species has not been sufficiently utilized in sustainable use of wild species or natural resource management (Franco, 2015; Prober, O'Connor, & Walsh, 2011; Woodward *et al.*, 2012), this is beginning to change.

One of the best-known representations of indigenous seasonal calendars in Australia is the poster series developed by multiple researchers and indigenous communities, supported and collated by the Commonwealth Scientific and Industrial Research Organization (CSIRO https://www.csiro.au/en/). This series started with the Ngan'gi seasons calendar in 2009 (on the Daly River, Northern Territory, see **Figure 3.13**) and includes the Tiwi seasons calendar (Prober *et al.*, 2011) (see **Figure 3.14**). The main focus is ecological knowledge and customary activities of resource use.

Examples:

1. **Fodder and leaf litter removal calendars.** Fuelwood and fodder gathering from nearby forests is a frequent and year-round activity, but leaf litter removal is a seasonal practice occurring only during dry winter months (November-March) when there is a lot of leaf litter available on the forest floor (Dhyani, 2018; Dhyani *et al.*, 2011) **(Figure 3.12)**. Seasonal harvesting is enforced by local village forest management committees to ensure sustainable harvest of fodder, fuelwood, litter and other wild plants and fungi (Misra, Maikhuri, Kala, Rao, & Saxena, 2008).

2. **Seasonal migratory calendars of Tibetan pastoralist communities in Tibet** (an autonomous region of China) **and Western Himalayas, India.** Pastoralists in high mountains of Tibet and Indo-Mongoloid Bhotiya tribal sub-communities (Tolchha, Marcha and Jad) primarily adopt centuries old ancestral seasonal migratory livestock raising as a key mechanism for enhancing their ecological sustainability and use first hand observations as ecological indicators

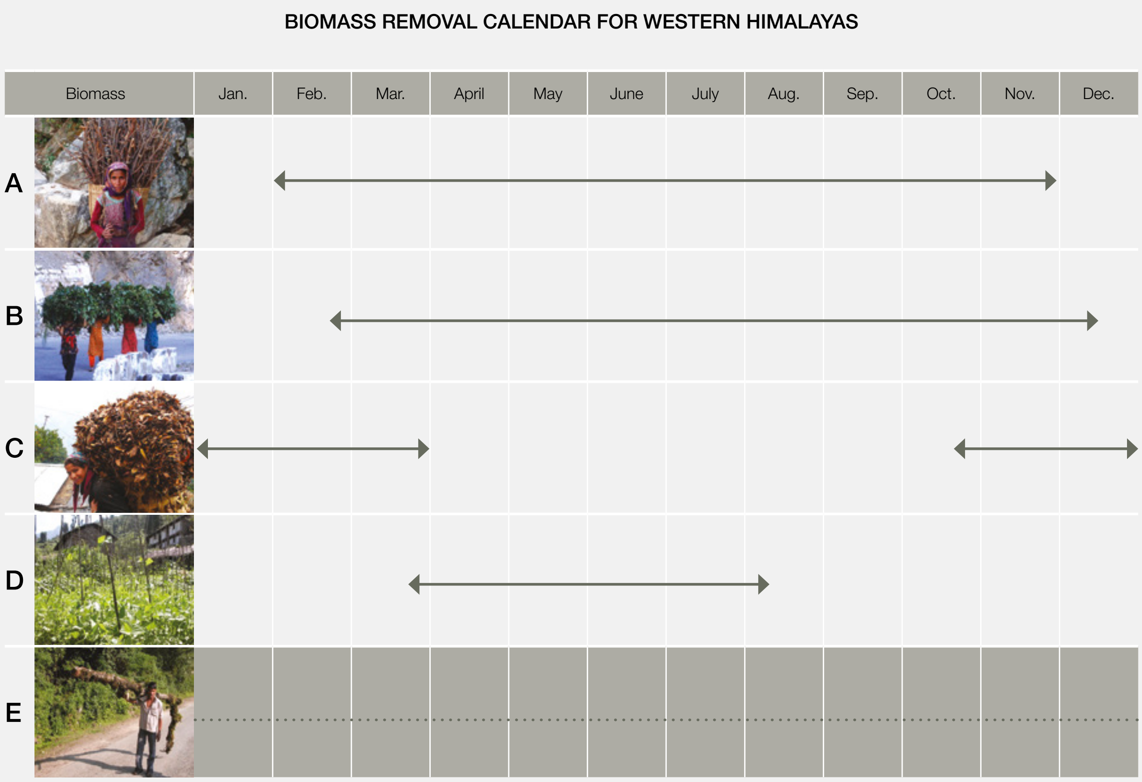

Figure 3 12 **Annual local biomass removal calendar for Western Himalayas.**

A: Fuelwood, B: Fodder, C: Leaf litter, D: Crop support and other wild algae, fungi and plants, E: Timber.
Source: (Dhyani, 2018) © International Society for Tropical Ecology CC-BY NC.

to decide the timing of seasonal activities (Fu *et al.*, 2012; Maikhuri *et al.*, 2011; H. Yang *et al.*, 2019).

3. **Calendar of Tajik community, Xinjiang,** China. Tajik people perceive indicators, including the appearance of migratory birds (*Motacilla alba* and *Motacilla citreola*), the height of grass and the conditions of farmland for conducting their activities for the aims of food production, livestock keeping, and fodder and gathering medicinal plants. They have also developed strategies to keep themselves protected from firewood shortage due to high elevations. These indicators are recognized by local people, associated with their seasonal activities, and passed down through generations.

4. **The Ngan'gi seasons calendar.** This is an indigenous temporal management approach practiced by remote indigenous communities of Pine Creek and Naiuyu Nambiyu in the Daly River catchment, Australia. The Ngan'gi Seasons calendar has informed the scientific understanding of patterns of resource use and relationships between people, subsistence use and river flows in the Daly River catchment (Woodward *et al.*, 2012) **(Figure 3.13)**. The calendar is a relevant guidance approach for sustainable and rotational gathering, hunting and fishing of wild resources. Hunting and gathering of resources start towards the end of the Wet season, known as Wudupuntyurrutu in the calendar, with the harvest of fruits. Saltwater crocodile *(Crocodylus porosus)*, echidna *(Tachyglossus aculeatus)* and rock python *(Liasis olivaceus)* are also actively hunted during this period. The dry season, known as Wurr wirribem filgarri, brings active hunting for freshwater prawn *(Macrobrachium rosenbergii)* in the river and creeks. Indicators of the start of dry season are wind flow from the east and presence of dragonflies that indicates fishing time for barramundi *(Lates calcarifer)*. Wurr bengin derripal, a late wet/early dry season, is a good time to harvest the eggs of magpie goose *(Anseranas semipalmata)* and catfish (*Arius* spp.), but is not yet time for hunting other fish. Resource gathering increases in Wirirr margu with hunting for turtles (*Carettochelys insculpta*; *Chelodina rugosa*; *Emydura* spp.; *Elseya* spp.) and also fish (black bream, *Hephaestus fuliginosus*; archer fish, *Toxotes chatereus*; mullet *Liza* spp.; and freshwater species). During the beginning of the wet season a range of lilies and other water-dependent plants are gathered from swampy areas that include waterlily, red lotus lily, and water chestnut. At this time, native peanut, and bush banana are also harvested. With lower water levels it is easier to harvest mussels, and crabs from creeks and springs.

5. **Urban foraging calendars.** Urban foraging as modern gathering practice has received attention around the world (Friedlander, Stamoulis, Kittinger, Drazen, & Tissot, 2014). Urban foragers make and share foraging calendars that guide them on what to gather in urban landscapes, where and in what seasons. National Geographic developed a guide for the United Kingdom (https://www.nationalgeographic.co.uk/travel/2020/07/a-year-round-foraging-calendar-what-to-pick-and-where-in-the-uk).This not only informs foragers about better foraging approaches but also promotes more sustainable harvesting of wild species from urban spaces that already have a lot of pressure on natural urban green spaces.

6. **Tiwi seasons calendar.** Traditional owners from the Tiwi Islands and the Tiwi land council collaborated with the Commonwealth Scientific and Industrial Research Organization to develop two calendars, a calendar of Tiwi seasonal ecological knowledge and a calendar of wild plants and animals of Tiwi significance **(Figure 3.14)**. The development of the calendars came from a desire to document seasonal-specific knowledge and ecological knowledge of the Tiwi Islands in an appealing format accessible to both students and the broader community, as well as a strong concern about the loss of knowledge as older people pass away.

7. **Seasonal round of harvest activities in Fort Yukon.** The Gwich'in Athabaskans of Fort Yukon, Alaska, follow a strict seasonal round established by their ancestors over centuries. Their calendar of activities has evolved in response to northern environmental conditions such as animal migrations which make them seasonally abundant or absent, ice and snow cover which affect travel and access to resources, and preferences for certain qualities found in resources at specific times of the year (https://www.culturalsurvival.org/publications/cultural-survival-quarterly/wild-food-its-season-seasonal-round-harvest-activities).

8. **Hawaiian moon calendar for responsible fishing practices.** The community in the Ho'olehu Hawaiian Homesteads on the island of Moloka'i is strengthening community influence and accountability for the health and long-term sustainability of their marine resources through revitalization of local traditions and resource knowledge. The traditional system in Hawai'i emphasized social and cultural controls on fishing with a code of conduct that was strictly enforced. Local resource monitors, in conjunction with visiting scientists, are creating a predictive management tool based loosely on the Hawaiian moon calendar to guide responsible fishing practices. Community-sanctioned norms for fishing conduct are being reinforced through continual feedback based on local resource monitoring, education, and peer pressure. Hawaiian community

Figure 3 13 **The Ngan'gi Seasons calendar.**

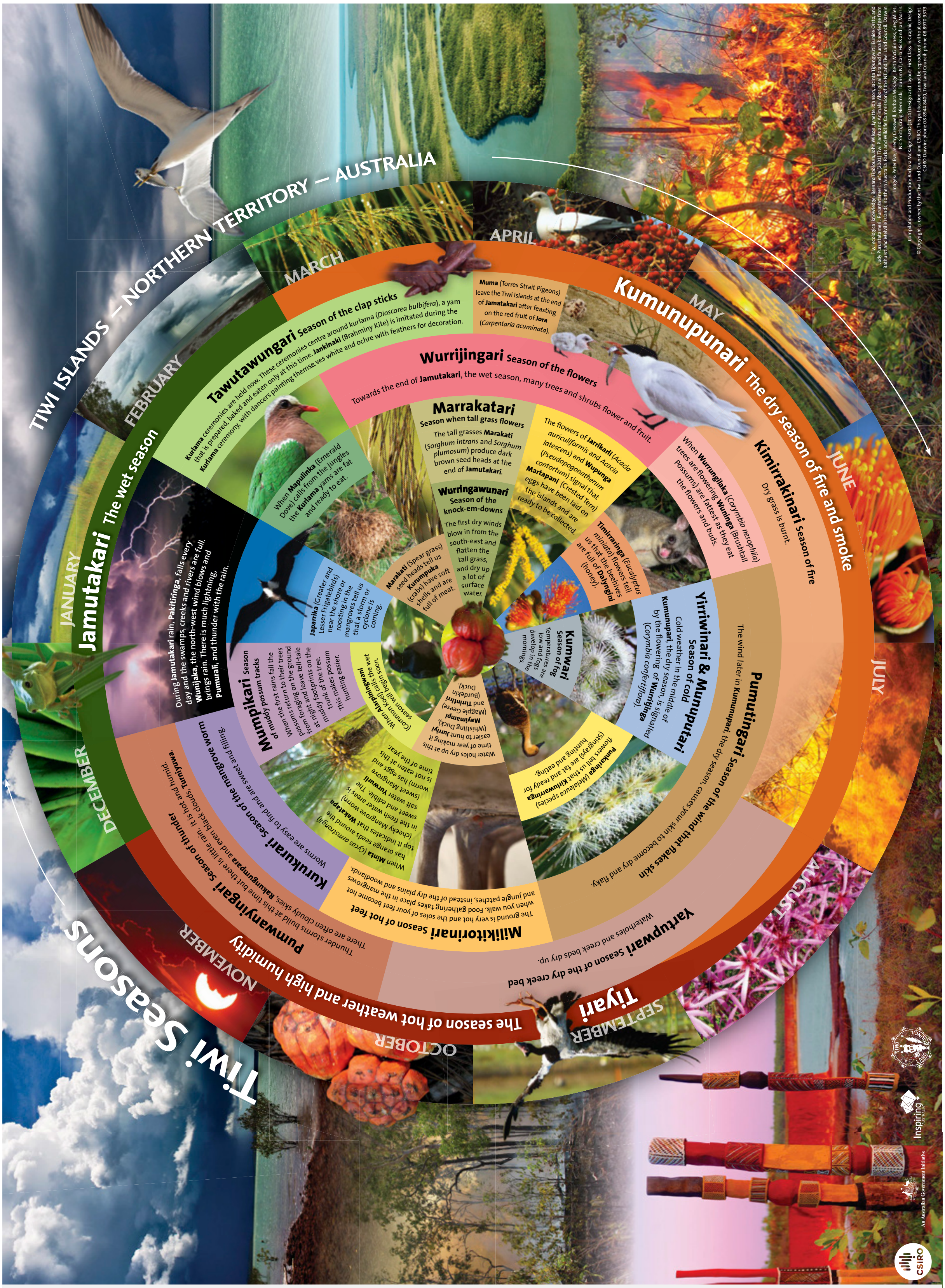

Figure 3 14 **Tiwi seasons calendar.**

This calendar show month of year in the outermost ring, then three "major" Tiwi seasons recognized by weather. Note that Kuwunupunari does not have a shar boundary with Tiyari. Within this ring are smaller seasons recognized by weather or ecological and associated with particular activities. Source: (CSIRO, 2014) © Tiwi Land Council and CSIRO. CC-BY NC.

building and proper cultural protocols are essential to understand and revitalize marine conservation traditions (Friedlander *et al.*, 2014).

9. **Seasonal calendar of Manangis in the Trans-Himalayas, Nepal.** The Manangis, a group of indigenous peoples and local communities, have maintained a dynamic cultural landscape of the trans-Himalayas, Nepal through different socio-economic activities that are reflected in the seasonal calendar of Manang. The seasonal calendar clearly exhibits the typical lifestyle of people influenced by the cold climate: longer photoperiod for agricultural crops, inadequate food materials, important forest and water resources, high tourism activities, skilled trading activities, and topographic obstacles. The Managis sustainably collect the wild resources from common lands only during specified periods. Species include vegetables (*Allium* species), mushrooms including caterpillar fungus *(Ophiocordyceps sinensis)*, and winter fodder grass (Chaudhary, Aase, Vetaas, & Subedi, 2007). The seasonal calendar including harvest of wild species is regulated by traditional knowledge of the indigenous peoples and local communities and social norms monitored by community leaders.

These calendars also reflect seasonal circumstances of access to different areas to hunt and gather. In some areas, the wet season results in tall, matted grasses, which need to be burned when the dry season arrives before people can walk to different areas to hunt and gather. It is a selective rotational system associated with discrete wet (flooding, rain, long grass) and dry seasons (drying, floodwaters abate, grasses are burned, isolated billabongs reappear) in both Day and Tiwi areas – across the whole of the wet-dry tropics – like Llanos and Pantanal in Latin America.

These and other seasonal calendars (e.g celtic tree calendar) are well known amongst indigenous indicators. Indigenous indicators have been recently evolving in the literature, challenging more technocratic views and highlighting that there is an alternative way of including values for guiding indicator development and selection. This work recognizes areas where conventional sustainability indicators cannot be developed for measuring crucial socioecological functions (J. Reid & Rout, 2018, 2020).

3.2.4 Economic, ecological, and social contexts of sustainable use

Wild species are used by billions of people in very different socioecological systems and circumstances around the world. Subsistence gathering, hunting and fishing occur worldwide, as documented in previous IPBES assessments for Africa (IPBES, 2018d), the Americas (IPBES, 2018c); Asia and the Pacific (IPBES, 2018a), and Europe and Central Asia (IPBES, 2018b). Estimates on the number of people who use nontimber forest products, for example, range from 3.5 billion to 5.76 billion globally (Charlie M. Shackleton & de Vos, 2022). FAO also estimated 18% of respondent countries (65% of nation-members of the Organization for Economic Cooperation and Development (OECD) and 4% of countries outside the Organization for Economic Cooperation and Development) are engaged in recreational harvesting of wild foods. Activities commonly undertaken include hunting, angling, mushroom gathering and berry picking (FAO, 2019b). One of the reasons these and the following data range so widely is that many products are used by the harvester themselves or informally traded in small quantities in small village markets, neighborhood exchanges, or amongst kin (see section 3.1 for explanation of informal vs. formal grade).

Individuals, groups, and even companies engage in informal trade. The state of world's forests (FAO, 2014) is one of the few sources available for estimating the value of informal markets across the globe. For the year 2011, FAO estimated the value of global informal trade to be 88,013 million United States dollars. Estimates of informal trade value were higher for Asia and Oceania (FAO, 2014b). Wild species contributions to household income are highly variable ranging from 17% in Acre and Amazonas states in Brazil (Carvalho Ribeiro *et al.*, 2018) to 28.6% of average household income across Latin America, whereas in Asia and Africa forest income shares are 20.1% and 21.4%, respectively (Angelsen *et al.*, 2014). In general, roughly 25-30% of household income in tropical forest countries was from wild forest products in the early 2000s, a percentage almost as high as agriculture (Wunder, Angelsen, & Belcher, 2014).

The same level of market informality is also present in fisheries; especially in developing countries where there are informal markets for small-scale coastal and freshwater fisheries. Although informal and largely unreported, the catch from small-scale fisheries may be large and this informal trade is important to local economies (e.g., in villages or small cities) and to the food security and nutrition of impoverished peoples living in remote areas. Small scale fishing is discussed extensively in section 3.3.1. The lack of monitoring may render the importance of these activities to local communities and some of their environmental impacts, invisible to decision makers (Bartley, De Graaf, Valbo-Jørgensen, & Marmulla, 2015; Doria, Athayde, Lima, Carvajal-Vallejos, & Dutka-Gianelli, 2020).

While subsistence uses often occur somewhat "under the radar" in the informal economy, there is a very large formal economy surrounding wild species. This formal economic activity is collectively referred to by the United Nations as BioTrade (UNCTAD, 2017): the collection, production, transformation and commercialization of goods and services derived from native biodiversity (species and ecosystems) under environmental, social and economic sustainability criteria. Under the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, parties are to issue internationally recognized certificates (IRCC) of compliance evidencing that access to genetic resources was based on prior informed consent and that mutually agreed upon terms were established between local communities and research and industry stakeholders. India leads by far in the number of internationally recognized certificates of compliance worldwide (accessed June 2020).

BioTrade subscribes to the objectives of biodiversity-related multilateral environmental agreements including the context of sustainable development and responsible business. It stresses that 70% of the world's poor depend directly on biodiversity and businesses it fosters. BioTrade partners estimate that 86% of species (and their potential uses) are still unknown (UNCTAD, 2017). There are seven established BioTrade Principles and Criteria (BT P&C) as follows: (P1) Conservation of biodiversity, (P2) Sustainable use of biodiversity, (P3) Equitable benefit-sharing, (P4) Socioeconomic sustainability, (P5) Compliance with international legislation and agreements, (P6) Respect for actors' rights, and (P7) Clear land tenure and resources access. These, combined with the four distinctive approaches described within BioTrade (value chain, sustainable livelihoods, ecosystem and adaptive management), greatly contribute to the sustainability of trade in wild species.

While only 20 countries officially participate in BioTrade partnerships, over 12,000 companies worldwide in more than 70 countries have signed up to the United Nations Global Compact, committing to greater environmental responsibility. The number of companies that report on biodiversity in their annual reporting is growing. For example in 2015, thirty-six of the top 100 cosmetic companies and 60 of the top 100 food companies mentioned biodiversity. Sales of BioTrade beneficiary companies reached 5.1 billion United States dollars (UNCTAD, 2017). Approximately 5 million people worldwide from collectors/fishers/ hunters to workers, among others are involved (UNCTAD, 2017).

3.3 PRACTICES AND USES

The use of wild species includes three interacting systems: the wild species themselves, the human practices by which they are obtained from nature, and the uses for which they are intended (Chapter 1, Figure 1.6). Here the status and trends of the use of wild species are reported, organized according to the practices defined at length in Chapter 1: fishing (including lethal and non-lethal use), gathering, terrestrial animal harvesting (including lethal and non-lethal use), logging, and non-extractive practices. These practices are somewhat intuitive, but not always. Thus, readers should be attentive to the definitions and explanations of the practices and why certain organisms (e.g., living shellfish vs. shells) or certain parts of organisms (e.g., tree branches vs. tree fruits, leaves and sap) are discussed in a particular practice category.

Each section begins with an overview presented in a format consistent with ways of thinking most prevalent in that field. This is followed by specific information relevant for the practice. The following section reviews uses according to the structure detailed in Chapter 1: ceremonial/cultural, decorative/aesthetic, energy, food/beverage, medicine/hygiene, recreation, science/education, shelter/construction, and other (see Chapter 1, Figure 1.6). Only the relevant uses are reported upon in each practice section. These categories are not exclusive, and many species have more than one use depending on a range of variables including their biology, habitat, life cycle, knowledge on utilization, existing rules, and regulations. There may thus be some overlap in the reporting. A selection of cases of multiple and complex use systems is discussed in section 3.4 to demonstrate some of the complexities of reporting on status and trends at national and international scales.

When possible, the use categories have structured the reporting in this section. However, in many cases the knowledge about the sustainability of use is not organized according to these use categories. Therefore, in order to increase accessibility to policy makers, in sections where the bulk of knowledge is reported using a different system, hybrid organizing structures were created as an attempt to be attentive both to the organizing structure of this assessment, and the expectations of the readers.

3.3.1 Fishing

3.3.1.1 Introduction

Prior to 1950 large-scale motorized fishing was mainly confined to the North Atlantic and Japan. Marine capture fishery has substantially expanded in the last 70 years in terms of geospatial and vertical distribution, and intensity of catch effort. Automatic identification systems data indicates that industrial fishing currently occurs in over 55% of the global ocean (Kroodsma *et al.*, 2018) although a much smaller footprint is estimated from the same data when a spatial grid of finer resolution is used in the calculation (Amoroso, Parma, Pitcher, McConnaughey, & Jennings, 2018). Relative to coastal ecosystems, high seas ecosystems are much less affected (Halpern *et al.*, 2008; Jackson, 2001). However, reported landings from the high seas has been accelerating since the mid- 20th century with under two million tons in 1950 to over ten million tons in 2008 (FAO, 2010c).

The history of sustainable use of capture fisheries is closely tied with several key events and international agreements. Prominent among those is the United Nations Convention on the Law of the Sea ratified in 1982 by 157 parties. One of its most significant provisions was the establishment of 200-mile exclusive economic zones and introducing the concept of maximum sustainable yield as the default goal of fisheries management. The 200-mile exclusive economic zone allowed countries to exclude wide ranging foreign fishing fleets that earlier were able to legally fish within 12 miles of the national coastline. As a result, several countries established fisheries management systems (e.g., scientific assessment, regulation of harvest) for the newly expanded waters under their jurisdiction. This also led to expansion of many domestic fishing fleets.

The legal framework of the United Nations Convention on the Law of the Sea did not include several fish stocks across multiple exclusive economic zones or in the high seas. The United Nations fish stocks Agreement from 2001 provided international protocols for managing these "straddling stocks" (G. R. Munro, 2000). It mandated the formation of Regional Fisheries Management Organizations (RFMO) to sustainably manage high seas and the straddling stocks. Following the Agreement, there are now 17 Regional Fisheries Management Organizations that cover almost all the high seas fisheries and associated straddling stocks outside national exclusive economic zones. Regional Fisheries Management Organizations are competent and mandated to establish binding conservation and management measures. They provide a formal mechanism for fishing states and states in whose jurisdiction fishery resources occur to meet their international obligation to cooperate to sustainably govern shared living marine resources throughout their distributions (the United Nations Convention on the Law of the Sea Articles 63, 66(5), 118; Code Articles 7.1.5, 6.12 (FAO, 1995a); Agreement on Port State Measure (PSMA) Article 4(1)(b) (FAO, 2010a). Regional Fisheries Management Organizations have played a critical role in multilateral fisheries governance of stocks that straddle or occur beyond national jurisdictions and are highly migratory. While spatial and taxonomic gaps remain, a large proportion of global marine fisheries are now managed by one or multiple Regional Fisheries Management Organizations, and they cover most areas of the high seas **(Figure 3.15)**.

Fishing has impacts on marine ecosystems other than the target species. A range of international agreements have evolved to provide guidance on managing non-target species and vulnerable marine ecosystems (VMEs). Legal instruments establishing international responsibility to conserve associated and dependent species are relatively recent, which first became an obligation under the 1982 Law of the Sea Convention, and was reiterated and clarified further in subsequent United Nations resolutions (United Nations 1982 [Article 119], 1995 [Article 5(f), Article 10(d), and Annex 1]; 2006a, b). These provisions were elaborated further in subsequent instruments and guidance from other multilateral organizations. This includes the 1995 code of conduct for responsible fisheries of the FAO, which calls for the sustainable use of aquatic ecosystems and promotes the conservation of biodiversity and ecosystems by minimizing fisheries impacts on non-target species and the ecosystem in general (FAO, 1995a). FAO has also produced a voluntary international plan of action on reducing the incidental capture of seabirds in longline fisheries (FAO, 1999), an international plan of action on the conservation and management of sharks (FAO, 1999b), international guidelines on reducing marine turtle fishing mortality (FAO, 2009), and broad guidelines on managing fisheries bycatch (FAO, 2011). These new instruments and international guidelines broadened the mandate of pre-existing Regional Fisheries Management Organizations, expanding their mandates from one target species to meet newer expectations for ecosystem-based management and precautionary approaches, i.e., establishing explicit limits of acceptable impacts on fish and non-fish bycatch species, associated or dependent and threatened species (Fisheries Agency of Japan, 2007; Lodge, Anderson, & Lobach, 2007; United Nations, 2006b, 2006a).

Fisheries targeting relatively fecund species can have profound impacts on co-occurring incidentally caught or bycatch species with delayed maturation, low fecundity and other life history traits that make them vulnerable to anthropogenic causes of mortality. While target stocks may be sustainable, the conservation status of bycatch species and other associated and dependent species is often not known. For instance, 47 of 68 fisheries that catch marine resources managed by Regional Fisheries Management Organizations have no observer coverage (Gilman, Passfield, & Nakamura, 2014); for the vast majority of the ca. 4.6 million fishing vessels globally, information on non-retained catch is absent. In most fisheries, there are large gaps in understanding of life histories for many marine species. Information on total cumulative anthropogenic levels of fishery removals from an individual population, knowledge of the conservation status of individual populations, and deficits in monitoring are all unknown. Data

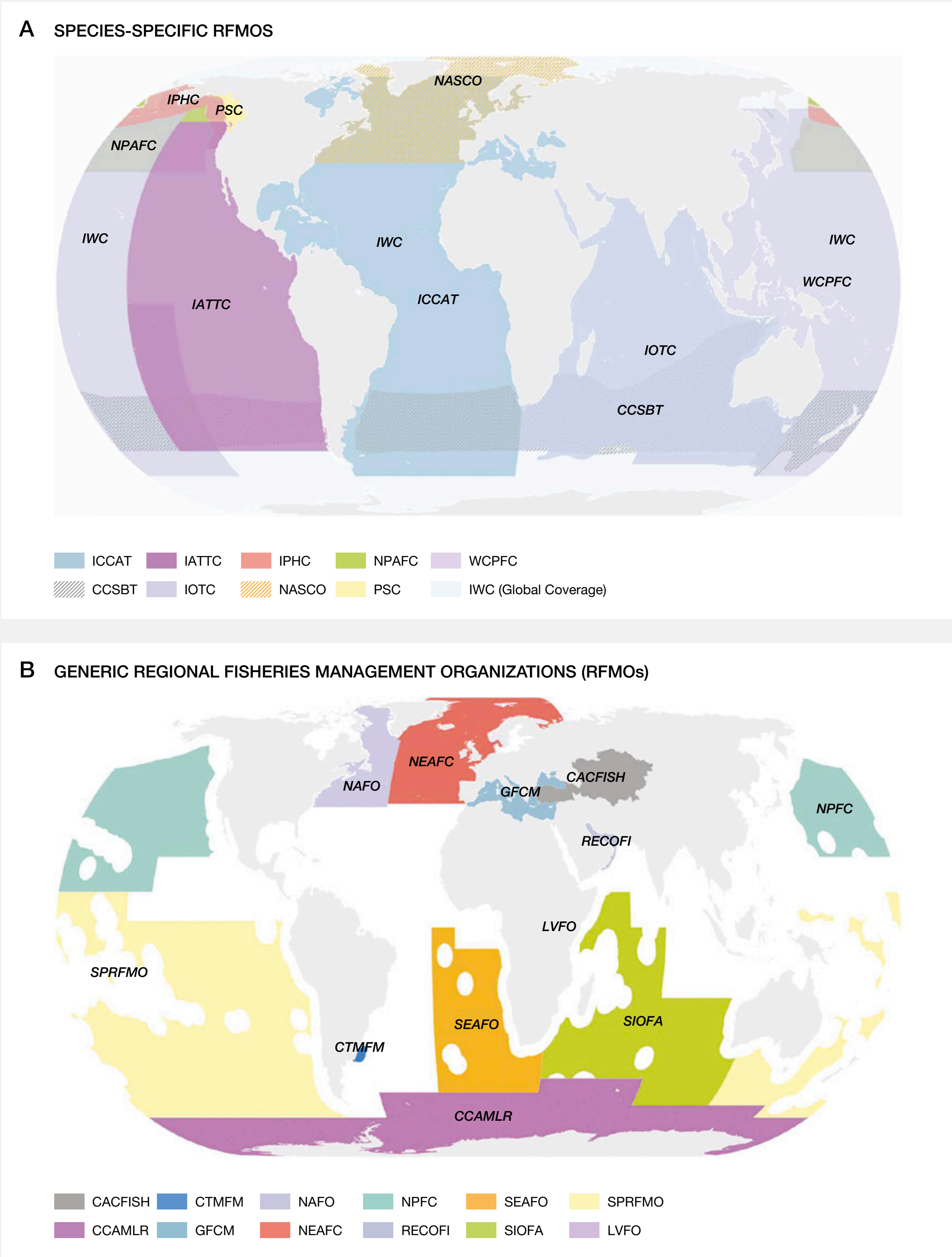

Figure 3 15 **Species-specific regional fisheries management organizations (top) and other regional fisheries management organizations (bottom).**

Abbreviations: ICCAT: International Commission for the Conservation of Atlantic Tunas; IATTC: Inter-American Tropical Tuna Commission, IPHC: International Pacific Halibut Commission; NPAFC: North Pacific Anadromous Fish Commission; WCPFC: Western and Central Pacific Fisheries Commission; CCSBT: Commission for the Conservation of Southern Bluefin Tuna; IOTC: Indian Ocean Tuna Commission; NASCO: North Atlantic Salmon Conservation Organization; PSC: Pacific Salmon Commission;

IWC: International Whaling Commission; CACFISH: Central Asian and Caucuses Regional Fisheries and Aquaculture Commission; CTMFM: Joint Technical Commission of the Maritime Front; NAFO: Northwest Atlantic Fisheries Organization; NPFC: North Pacific Fisheries Commission; SEAFO: South East Atlantic Fisheries Organization; SPRFMO: South Pacific Regional Fisheries Management Organization; CCAMLR: Commission for the Conservation of Antarctic Marine Living Resources; GFCM: General Fisheries Commission for the Mediterranean; NEAFC: North-East Atlantic Fisheries Commission; RECOFI: Regional Commission for Fisheries; SIOFA: Southern Indian Ocean Fisheries Agreement; LVFO: Lake Victoria Fisheries Organization. These maps are directly copied from its original source (Løbach, Petersson, Haberkon, & Mannini, 2020) and was not modified by the assessment authors. The maps are copyrighted under license CC BY-NC-SA 3.0 IGO. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.Salmon Commission; IWC: International Whaling Commission; CACFISH: Central Asian and Caucuses Regional Fisheries and Aquaculture Commission; CTMFM: Joint Technical Commission of the Maritime Front; NAFO: Northwest Atlantic Fisheries Organization; NPFC: North Pacific Fisheries Commission; SEAFO: South East Atlantic Fisheries Organization; SPRFMO: South Pacific Regional Fisheries Management Organization; CCAMLR: Commission for the Conservation of Antarctic Marine Living Resources; GFCM: General Fisheries Commission for the Mediterranean; NEAFC: North-East Atlantic Fisheries Commission; RECOFI: Regional Commission for Fisheries; SIOFA: Southern Indian Ocean Fisheries Agreement; LVFO: Lake Victoria Fisheries Organization. *These maps are directly copied from its original source (Løbach, Petersson, Haberkon, & Mannini, 2020) and was not modified by the assessment authors. The maps are copyrighted under license CC BY-NC-SA 3.0 IGO. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.*

collection protocols, observer coverage rates, and sufficient time-series to detect the response in absolute population abundance of long-lived species to this anthropogenic mortality source are also knowledge gaps in various global fisheries (Gilman *et al.*, 2020; Lewison, Crowder, Read, & Freeman, 2004; Musick, 1999a; Pérez Roda *et al.*, 2019).

United Nations Resolution 61/105 (UNGA, 2006) provides for responsible management of vulnerable marine ecosystems and non-target species as a legally binding instrument. It provides for collection of data on the impacts of fishing on vulnerable marine ecosystems and specific actions to protect them. Another important international protocol is the Agreement on Port State Measures (FAO, 2016a) aimed at preventing, deterring and eliminating illegal, unreported and unregulated fishing by preventing vessels engaged in illegal, unreported and unregulated fishing from using ports and landing their catches (FAO, 2021a).

Outside of formal international agreements, there have been many efforts to improve management both by non-governmental organizations and national governments. The 1990s were an era of greatly expanding concerns about overfishing, in many ways stimulated by the highly publicized collapse of the northern cod fishery in Canada (Finlayson, 1994; Kurlansky, 1997; Rice, Shelton, Rivard, Chouinard, & Fréchet, 2003). The Marine Stewardship Council was formed in 1997 with the goal to use market pressure to improve fisheries sustainability, and now is a major force in market access, particularly in Europe (MSC, 2021). Many environmental non-governmental organizations formed marine conservation divisions, and entirely new non-governmental organizations appeared with a focus on marine ecosystems. These were, to a great extent, funded by United States of America foundations with amounts up to 500 million United States dollars per year spent by environmental non-governmental organizations and foundations on marine conservation (Hilborn & Hilborn, 2019).

Since the 1990s national governments have expanded the science and management efforts through changes in legislations such as the United States of America Magnuson-Stevens act and revisions, and the creation of the Common Fisheries Policy in the European Union.

Finally, there has been increasing attention paid to consider impacts on fishing dependent coastal communities in almost all countries. As examples, Canada guarantees the first 90,000 tons of cod quota to small-scale inshore fishers, the United States of America allocates 8% of the allowable catch in the large industrial fisheries of the Bering Sea to local communities, and in Chile fishing cooperatives can apply for and be granted exclusive ownership of local inshore resources.

3.3.1.2 Status and trends in global marine capture fisheries

For the purposes of this assessment, in accordance with Chapter 1, fishing is defined as the harvest of entire organisms or parts of organisms that result in mortality of the aquatic animals, for example commercial fisheries or shark finning. Non-lethal fishing is defined as harvesting of entire or parts or products of organisms without intended mortality. Examples of non-lethal fishing include harvesting fish for the aquarium trade, catch and release fishing, or the extraction of blood from horseshoe crabs.

The status and trends of wild fish are estimated by a range of methods including scientific surveys, size or age distribution, catch per boat day and other estimates based on catch rate / fishing gear. A sophisticated method, known as "stock assessments", combines all these types of data to provide scientific estimates of the trend in abundance and harvest rate for fish stocks. The most robust approaches now involve multispecies and ecosystem-level assessments, an improvement over conventional single stock assessments, even though single stock assessments remain the dominant approach. Produced by national fisheries agencies and international regional fisheries management organizations, these scientific assessments are publicly available for roughly half of the global fish catch. Considerable effort in recent years has been towards increasing understanding of the status of stocks that produce the other half of global marine catches. This effort is ongoing.

The most cited stock status assessment comes from the state of world fisheries and aquaculture of the FAO(2020d), which uses a sample of roughly 500 fish stocks from around the world to describe the status of stocks. When scientific assessments are not available, expert knowledge is often used to make some sort of assessment. The material presented below follows this approach.

The status of fish stocks can be described in many ways. The most common approach is to compare the current abundance of the fish stock to target abundance, usually a target based on maximizing the long-term harvest, often called "maximum sustainable yield". In FAO terminology, stocks that are above this target level are called "underfished", stocks below the target are "overfished" and stocks with abundance close to the target are called "maximally sustainably fished." FAO uses the range 0.8 to 1.2 of the abundance as an indicator of maximum sustainable yield. Because fish stocks fluctuate naturally, sometimes over orders of magnitude of abundance, a better evaluation of the status of the fishery is to look at the fishing pressure relative to the targets. Fishing harder than the target rate is called "overfishing". Some assessments of stock status are based solely on the trends in catch. When catch declines it is assumed that the stock is in poor shape. Comparisons may also be made between the current abundance of fish stocks to estimates from before significant fishing began, which is most commonly done using various kinds of ecosystem models **(Figure 3.16)**.

A common misinterpretation of the above data is that stocks that are "maximally sustainably fished" are somehow being pushed to the limit and this is an undesirable state. In fact, "maximally sustainably fished" means that stocks are at an abundance level that will provide long-term maximum sustainable yield. Another misinterpretation is that stocks that are overfished are headed towards extinction or necessarily declining. "Overfished" simply means an abundance lower than would produce maximum sustainable yield, and many stocks remain at this level for decades; if fishing pressure is reduced these stocks can rebuild. Despite this common understanding, there is no agreed upon definition of what is overfished. The FAO defines overfished as the stock biomass being below 80% of the

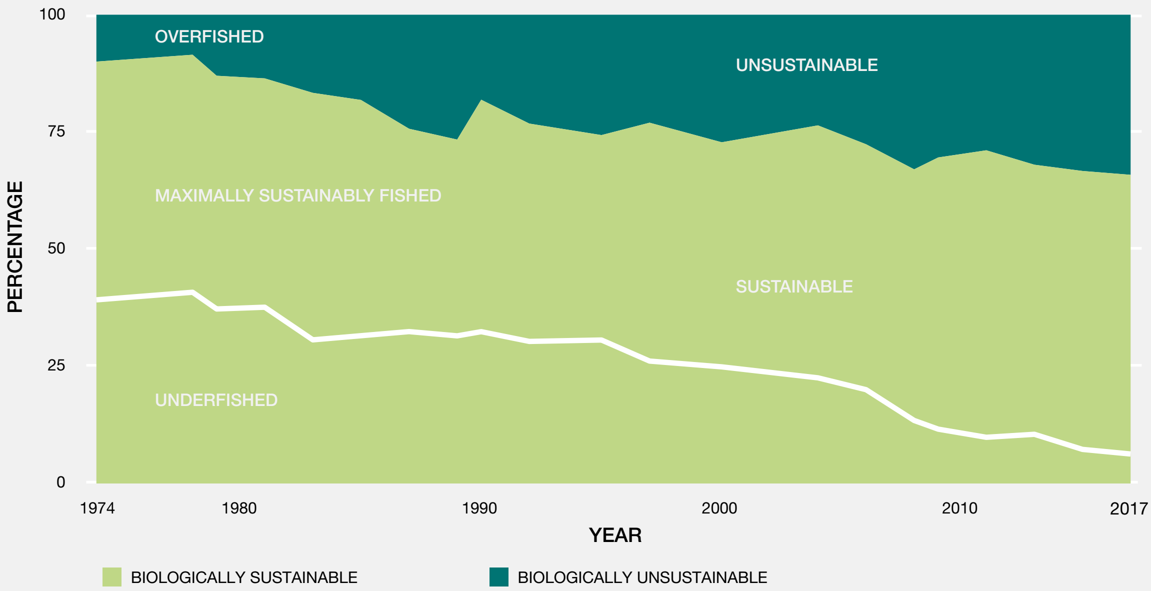

Figure 3 16 **Global trends in the state of the world's marine fish stocks, 1974–2017.**

Source: (FAO, 2020d) under license CC BY-NC-SA 3.0 IGO.

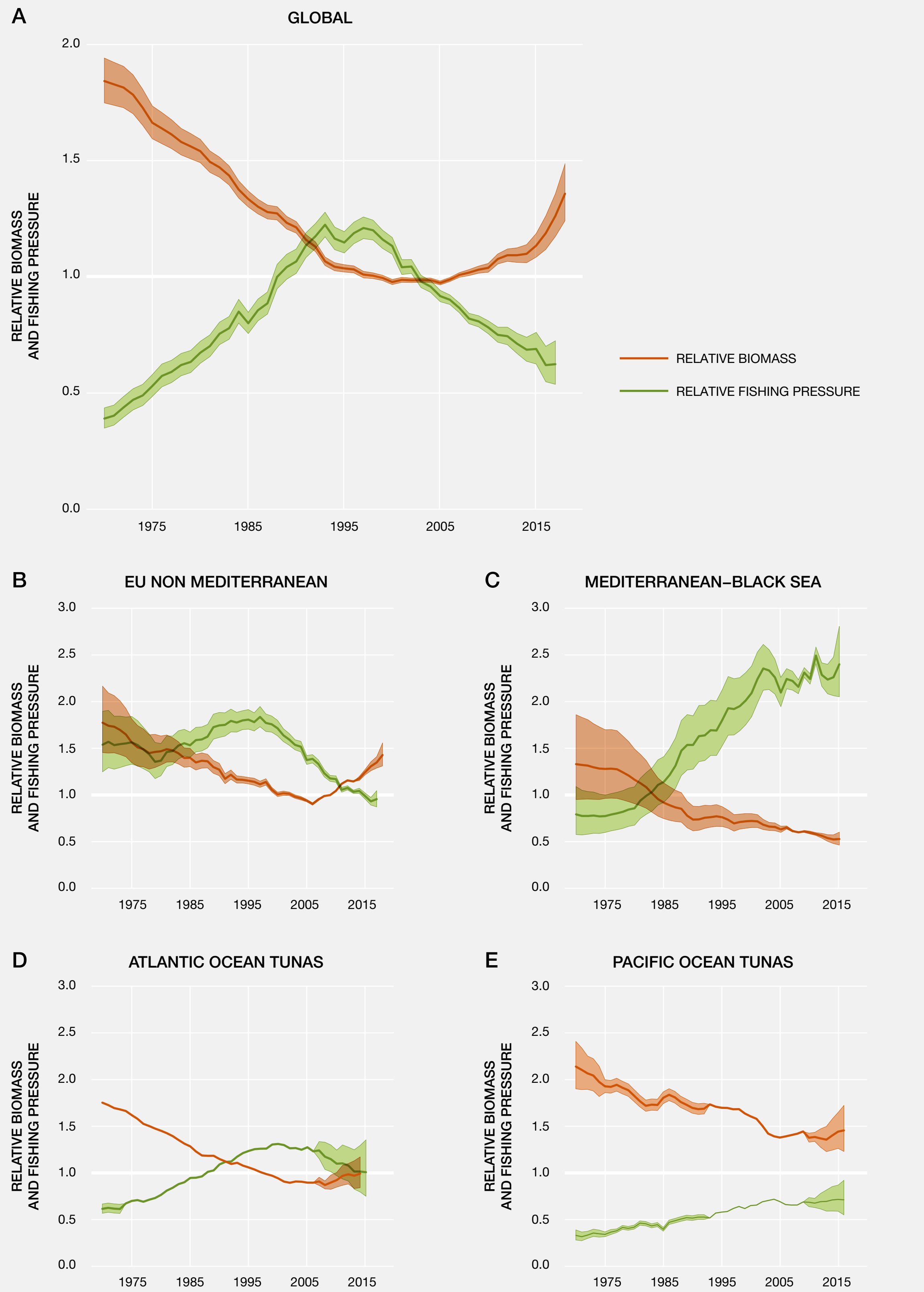

Figure 3 17 **Estimated abundance of global fish stocks 1970–2016.**

(A), European Union non-Mediterranean fish stocks **(B)**, Mediterranean-Black Sea fish stocks **(C)**, and Atlantic **(D)** and Pacific **(E)** ocean tuna fish stocks. Estimated abundance (B/BMSY -Biomass relative to the biomass that produces Maximum Sustainable

Yield- in orange) and fishing pressure (U/UMSY -Fishing pressure or mortality relative to the fraction of the population harvested- in green) are shown for the stocks that are scientifically assessed around the world from 1970 to 2016 – shaded area is the confidence intervals. The biomass and fishing pressure are scaled to the level that would produce maximum sustainable yield. See data management report for the figure at https://doi.org/10.5281/zenodo.6452917.

abundance that would produce maximum sustainable yield; the United States of America and New Zealand use a 50% cutoff, while many tunas' Regional Fisheries Management Organizations define overfished as being below the target level.

From a conservation perspective, stocks that are fished to very low abundance, where recovery is often very slow, are a concern due to lack of knowledge of potential recovery. Neubauer *et al.* (2013) conclude that "prolonged intense overexploitation, especially for collapsed stocks, not only delays rebuilding but also substantially increases the uncertainty in recovery times. Furthermore, when stocks become depleted, catch rates are lower and therefore the effort needed to catch a given volume of fish is higher and so is its environmental footprint.

For those fisheries that produce half of the world's marine catch for which good data is available, on average fish stocks are increasing because fishing pressure is lower than levels that would produce maximum long-term yield, and abundance is above target levels **(Figure 3.17)** (Hilborn *et al.*, 2020).

Figure 3.17A shows the estimated abundance (B/BMSY -Biomass relative to the biomass that produces Maximum Sustainable Yield- in orange), fishing pressure (U/UMSY -Fishing pressure or mortality relative to the fraction of the population harvested- in green), and catch (in blue) for the stocks that are scientifically assessed around the world from 1970 to 2016. The biomass and fishing pressure are scaled to the level that would produce maximum sustainable yield. Abundance declined from 1970 to 1995, then leveled off for 10 years and about 2005 began to increase. This is consistent with increased fishing pressure from 1970 to the mid 1990s, then declining pressure since that time **(Figure 3.17)**. When looking at different regions where there is good scientific understanding of stock status, one notes contrasting trends **(Figure 3.17 B-E)**. The European Union **(Figure 3.17B)**, Atlantic and Baltic stocks were already fished hard in 1970 and harvest rates increased up to about 1995, and then declined. Stocks were above target levels in 1970, declined to about 2005 and then began to increase. Mediterranean stocks **(Figure 3.17C)** have seen increasing fishing pressure since 1970 and declining abundance. Fishing pressure is far above target levels and abundance well below. One species specific estimate is included here **(Figure 3.17 D** & **E)**. Global tuna fisheries were not fully developed in 1970 and saw generally increasing fishing pressure and declining abundance until recent years when abundance leveled off at or above target levels. Atlantic tuna fisheries were fished harder and earlier than Pacific **(Figure 3.17)** that would produce maximum sustainable yield.

In the FAO's state of the world fisheries and aquaculture annual reports there are many stocks that are evaluated using expert knowledge because there is no scientific stock assessment. Melnychuk *et al.*, (2017) used an expert opinion survey of the 28 countries landing the most fish to determine the status of stocks and found that generally temperate stocks were considered to be in good shape while tropical stocks where not **(Figure 3.18)**.

Costello *et al.* (2012) attempted to estimate the status of the half of the world's fisheries that are not scientifically assessed and combine this with the data from assessed stocks to provide a global estimate of status. They grouped stocks into four classes; (i) large assessed (large industrial fisheries of the world where a scientific assessment of status and trends is performed); (ii) large unassessed, (iii) small assessed and (iv) small unassessed stocks. The trends estimate showed that the large stocks, both assessed and unassessed, are on average about target levels, but small assessed stocks were declining and small unassessed stocks were well below target levels **(Figure 3.19)**.

Rosenberg *et al.* (2018) combined four different methods (one being the Costello *et al.* (2012)) to estimate the status of unassessed stocks using an approach called ensemble modelling **(Figure 3.20)**. However, when the stock status was compared to the status for stocks that were scientifically assessed, the performance was rather poor and the ensemble method provided roughly similar status estimates both in regions where scientific assessment show stocks are in very poor shape such as the Mediterranean Sea, and also in regions where stocks are in very good shape such as the Northeast Pacific. Thus, we know the status of fish stocks which provide half of the world's catch – largely from the temperate North, and do not know the status of the other half of the global catch – largely from Southeast Asia.

Christensen *et al.* (2014) examined 200 marine food web models covering the period 1880 to 2007 and compared the change in abundance of different trophic levels of fish. They estimated that high trophic level fish had declined by 2/3 (to roughly the level that would produce maximum sustainable yield) while the far more numerous low trophic level species would have more than doubled.

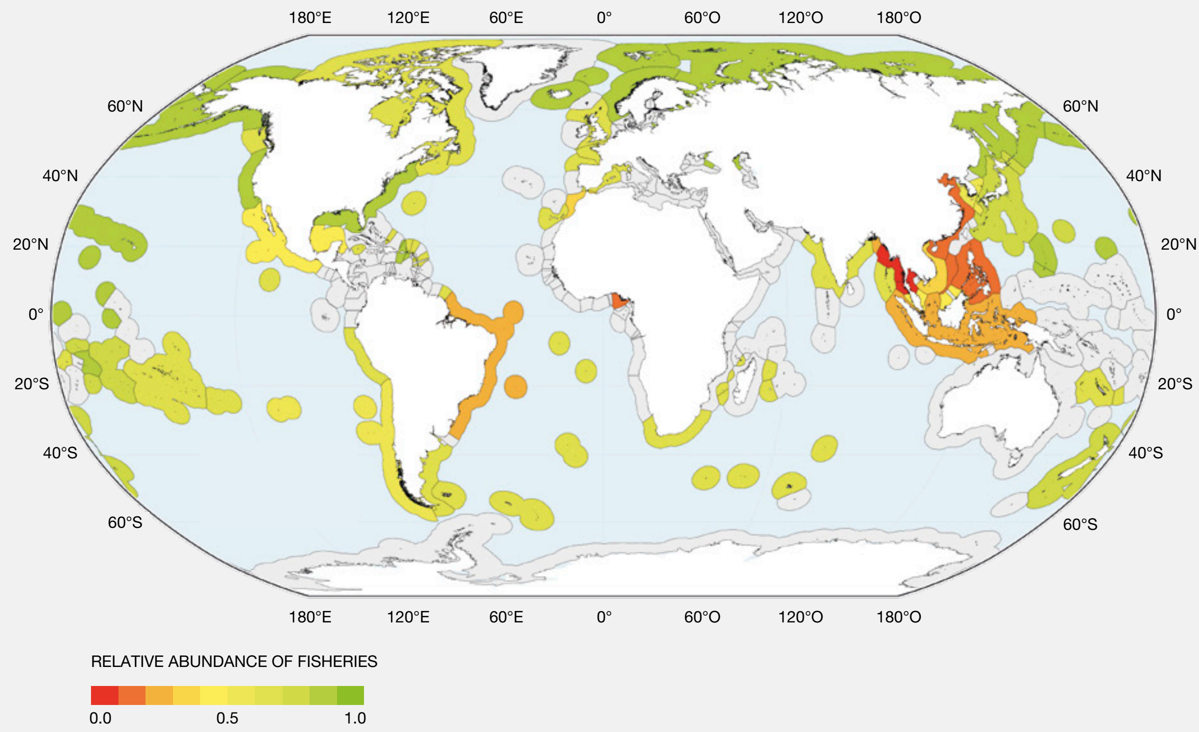

Figure 3 18 **Global abundance by coastline based on expert estimates.**

Green indicates experts believe that most stocks are at abundance consistent with long term maximum sustainable yield, red indicates few stocks are at that level.
Data from (Melnychuk *et al.*, 2017). See data management report for the figure at https://doi.org/10.5281/zenodo.6452953.

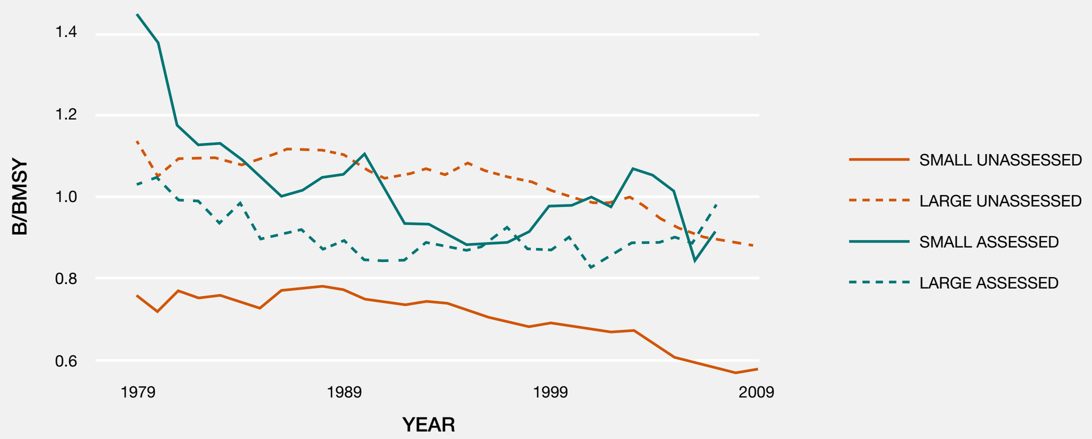

Figure 3 19 **Trend estimates for global large and small stocks.**

The black lines are for stocks scientifically assessed and are generally the same stocks as used in Hilborn *et al.*, 2020. The red lines are estimates of the trends for stocks not scientifically assessed. Source: (Costello *et al.*, 2012) © 2012, American Association for the Advancement of Science. CC-BY NC.

The performance of marine fisheries in terms of providing food security can be measured by comparing levels of sustainable yield at the current fishing pressure and if people fished at rates that would provide maximum sustainable yield. This is only available for the assessed fish stocks of the world. The status of assessed stocks is maintained on-line in the RAM Legacy Stock Assessment Database (Ricard, Minto, Jensen, & Baum, 2012). Using the data from assessed stocks and calculation of lost yield (Hilborn, 2018) the **Figure 3.21** shows the amount of potential yield that

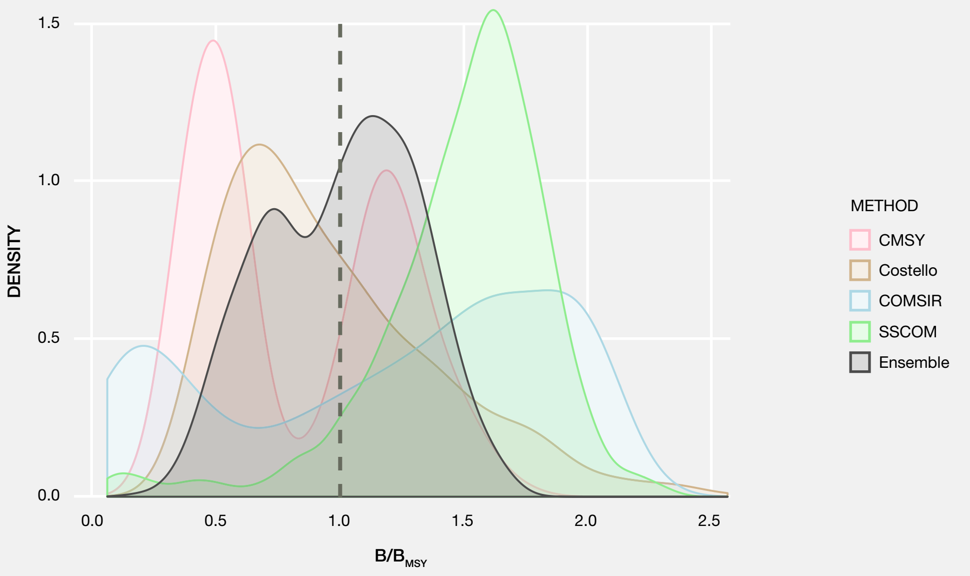

Figure 3 20 **Estimation of the status of unassessed stocks by several data poor methods.**

Abbreviations: B_{MSY}: Biomass that would support Maximum Sustainable Yield, C_{MSY}:Catch Biomass that would support Maximum Sustainable Yield, COMSIR: catch-only-model with sampling-importance resampling, SSCOM: state-space catch-only model. Source: (Rosenberg *et al.*, 2018) under license CC BY 4.0.

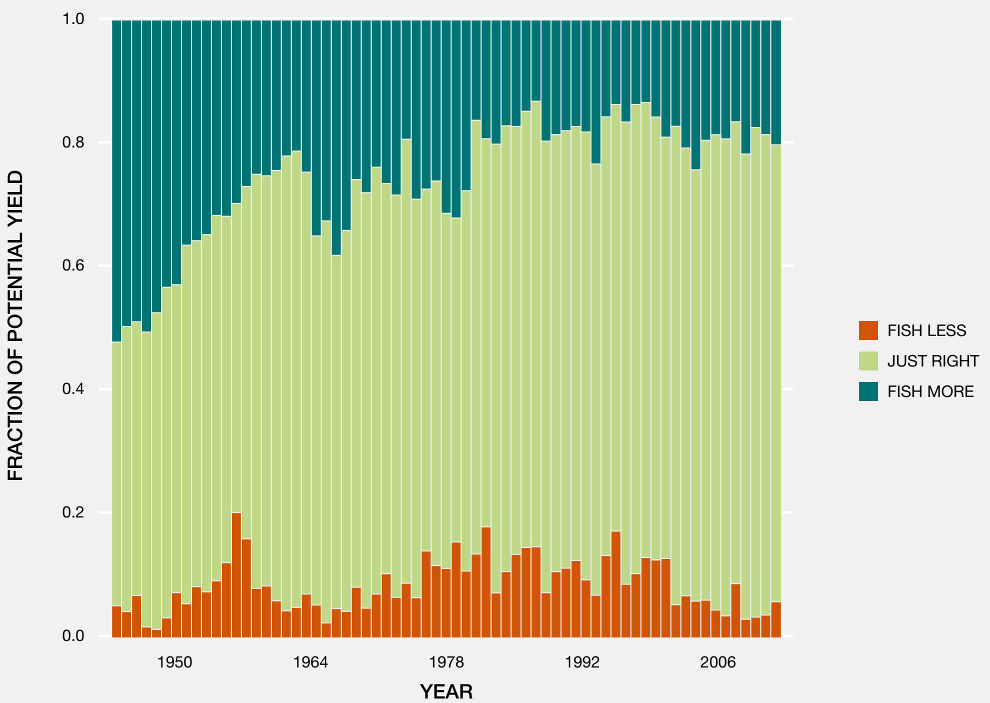

Figure 3 21 **The fraction of potential yield lost in each year by overfishing (red), and by fishing less than the Maximum Sustainable Yield (blue).**

Green shows the fraction of potential yield achieved at the fishing pressure for that year. See data management report for the figure at https://doi.org/10.5281/zenodo.6453019.

is lost by fishing too hard (red), or too little (blue) and how much of the potential yield is achieved at current fishing pressures (blue). It is estimated that in 1950 when the data began, roughly half of the potential yield was lost by low fishing pressure and there was little loss from fishing too hard (overfishing). The loss from overfishing rose to between 10% and 20% during the 1980s and 1990s and has now declined to about 5%. Potential increase in yield by fishing harder is now about 17%, and across these stocks the current fishing pattern is achieving about 73% of potential yield **(Figure 3.21)**. These calculations are based on the assumption that parameters that determine the productivity of fish stocks will remain unchanged at current estimated values. Note that fish production is not just a function of how hard people fish, but it depends on variable environmental conditions (temperature, food, ocean currents, etc.), including conditions affected by climate change.

3.3.1.3 Status and trends in selected fisheries

As no satisfactory global reviews were found in the literature, significant effort was invested in a systematic review of small-scale fisheries because of their importance for local communities. Due to high variability, the review of marine and inland small-scale fisheries was made by geographic region (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Three other sections dedicated to distinct fisheries were also developed: (i) small to medium pelagic or forage fish fisheries that are mainly coastal and provide about 25% of world capture fisheries; (ii) tuna and tuna-like fisheries, which are of high economic value and are widely spatially distributed from coastal regions to the high seas; (iii) industrial demersal fisheries in coastal areas, which are a complex set of heterogeneous fishing fleets using diverse fishing gears active within the exclusive economic zones of coastal countries. When necessary, for taxonomic groups of special concern, we added information on their status and trends in dedicated boxes (e.g., **Box 3.2**).

3.3.1.4 Small-scale fisheries

Small-scale fisheries are strongly anchored in local communities where fisheries represent a way of life (FAO, 2015). Despite their importance, small-scale fisheries around the world are facing major challenges from the effects of global change, e.g., climate change, urbanization, industrialization, aquaculture intensification, and large-scale fisheries (Berkes, 2015; Chuenpagdee, 2011). Ongoing threats to small-scale fisheries affect entire production systems (harvest, processing, retail and transport) and create vulnerabilities that have no easy solution (Chuenpagdee, 2011; Jentoft & Chuenpagdee, 2009). In many cases, these challenges have placed the livelihoods, economy, food security, values and identity, and the viability of small-scale fisheries communities at risk (Bavinck, Jentoft, & Scholtens, 2018; Bundy *et al.*, 2016; Jentoft & Chuenpagdee, 2015; Jentoft & Eide, 2011; Nayak & Armitage, 2018). An estimated 5.8 million fishers in the world who earn less than 1 United States dollars per day (FAO, 2014d). Ommer *et al.* (2007) characterize these large-scale, globalized processes as a crisis in social-ecological 'health', with dire consequences on small-scale fisheries communities.

The COVID-19 pandemic will affect many small-scale fisheries and coastal communities worldwide, especially those more vulnerable, mainly through reduced (or closure of) markets, decreases in revenues from tourism, increases in health risks to fishers and traders and increased occurrence of illegal fishing due to lack of enforcement. Mitigation of these factors would likely require institutions to provide short- and long-term responses (N. J. Bennett *et al.*, 2020). There can be some positive outcomes from the pandemic crisis, including enhanced local cooperation among fishing communities and other institutions, valorization of local markets, food sharing and some recovery of fishing resources (N. J. Bennett *et al.*, 2020).

The state of inland capture-fishery resources that includes small-scale inland fisheries is more difficult to monitor (Welcomme, 2011) for a number of reasons, including the diffused character of the practice due to: (i) large numbers of people being involved in the seasonal and subsistence nature of fisheries activities; (ii) much of the catch being consumed locally or traded informally; and (iii) fisher populations being greatly affected by activities other than fishing, including stocking from aquaculture and diversion of water for other uses such as agriculture and hydroelectric development (FAO, 2012c).

This section is based on a comprehensive review of 350 studies on small-scale fisheries from 107 countries worldwide **(Figure 3.22)**. With regard to ecological sustainability, 39 studies indicate sustainable fisheries but almost half the studies (#165) indicate unsustainability. Whereas fisheries reported by 129 studies were considered to be partially sustainable; a few studies (#16) do not assess ecological sustainability but include some accounts on economic or social sustainability. Most of the reviewed literature on small-scale fisheries addresses the use of fish as food and feed, and is presented in detail below by major world regions. Other uses for fish are also mentioned in some regions (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). This review supports the text below, considering the available evidence from most of the revised studies (for details on the reviewed studies, see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

Box 3 2 **Status and trends of sharks, rays, and chimaeras: implications for species, the environment, and people.**

There are approximately 1,250 species of sharks and rays found throughout the world's marine, and some freshwater, habitats. Sharks and rays are relatively large-bodied predators and, hence, are both highly susceptible to a wide range of fishing gears (predominantly trawls, longlines, gill and tangle nets) and highly sensitive to fishing mortality because of their long generation lengths and low fecundity resulting in very low maximum population growth rates and low density-dependent compensation (Forrest & Walters, 2009; Eric Gilman *et al.*, 2008; Pardo, Kindsvater, Reynolds, & Dulvy, 2016). Consequently, they are highly vulnerable to overfishing compared to the teleost fishes they are caught alongside and are particularly prone to disappearing prior to adequate monitoring (Myers & Worm, 2005; Yan *et al.*, 2021).

Global shark and ray catches reported to FAO rose to a peak in 2003 and declined at least 17% thereafter, likely due to overfishing (Davidson, Krawchuk, & Dulvy, 2016; Dent & Clarke, 2015). However, the global catch is underestimated and is likely to be two-to-four times greater (Clarke *et al.*, 2006). Based on these FAO data and accounting for discards and illegal, unreported, and unregulated fishing, it is possible that 63–273 million individuals were captured in the early 2000s (Boris Worm *et al.*, 2013). Only 4% of the global estimated catch is managed sustainably, based on 65 fisheries stock assessments from 47 species from Canada, United States of America, Australia, and New Zealand (Simpfendorfer & Dulvy, 2017). Catch estimates of unassessed data-poor fisheries show that large coastal sharks have been very unsustainably fished since 1975 (B/Bmsy – Biomass relative to the biomass that produces Maximum Sustainable Yield < 0.5) (Costello *et al.*, 2012). Consequently, steep regional declines of coastal sharks have been documented (Ferretti, Osio, Jenkins, Rosenberg, & Lotze, 2013; MacNeil *et al.*, 2020). Oceanic sharks and rays have limited spatial refuge from fisheries (Queiroz *et al.*, 2019) and declined by 71% since 1970 due to an 18-fold increase in relative fishing pressure (Pacoureau *et al.*, 2021). Sharks and rays from the tropical and subtropical coastal seas are currently at higher risk (Dulvy *et al.* 2021).

The International Union for Conservation of Nature Red List provides a framework for integrating disparate data sources ranging from historical ecology, to catch data and stock assessments (International Union for Conservation of Nature Standards and Petitions Committee, 2019; Mace *et al.*, 2008; Sherley *et al.*, 2020, p. 20). These comprehensive global assessments of sharks and rays offer a unique opportunity to calculate Living Plant and Red List indices to track progress toward the Convention on Biological Diversity and Sustainable Development Goals (Pacoureau *et al.*, 2021; Walls & Dulvy, 2021).

Shark and ray extinction risk has been rising over the past half century (Pacoureau *et al.*, 2021, Walls and Dulvy, 2021). Now, one one-third (391 of 1,199; 32.5%) of sharks and rays are classified as threatened (vulnerable, endangered, or critically endangered) (Dulvy *et al.*, 2021). Assuming the 155 data deficient species are threatened in the same proportion to the other species then an estimated 449 species are threatened (37.5%, range 32.6–45.5%). Three species are critically endangered (possibly extinct), because they have not been recorded for over 80 years but there have been insufficient surveys to confirm their extinction (Dulvy *et al.*, 2021). A further eight species are regionally extinct in one or more countries and there have been at least 28 local extinctions (Dulvy *et al.*, 2014, 2021). The shark and ray extinction rate of 25 E/MSY (extinction per million spesies-year) is 25–250 times greater than the background fossil record extinction rate and 2.5 times greater than the proposed target rate of 10 E/MSY (extinction per million spesies-year) over the next century (Rounsevell *et al.*, 2020). Nearly all (99.6%) species are taken incidentally, but are valuable and are retained for food: half (51.5%) for human consumption of the meat only, with remaining species used for food in combination with the production of animal feed, skins, and liver oil (Dulvy *et al.*, 2021). The International Union for Conservation of Nature classification scheme does not record shark and ray fins or devil ray gill plates (Mobulidae), but these significant trades are subject to increasing international regulation (Cardeñosa, Quinlan, Shea, & Chapman, 2018; Friedman *et al.*, 2018). The global value of the shark and ray trade is worth 4.1 billion United States dollars, with the meat trade (2.6 billion United States dollars) exceeding the value of the global fin trade (1.5 billion United States dollars) (Niedermüller *et al.*, 2021).

Widespread overfishing of sharks and rays will likely have profound consequences for the environment and people. The depletion and loss of sharks and rays, particularly in the tropics, does not bode well for the livelihoods of many coastal human populations, dependent on their meat and products for food and income (Booth, Squires, & Milner-Gulland, 2019; Seidu *et al.*, 2022). Indeed, the depletion of sharks and rays reflects increasing evidence that the target teleost fisheries are overfished in South America, Africa, and Southeast Asia (Dyhia Belhabib, Greer, & Pauly, 2018; Lam & Pauly, 2019).

A systematic literature review on small-scale fisheries was undertaken based on literature obtained through various combinations of a set of keywords: fisheries, sustainable, sustainability, small-scale, coastal, freshwater, catch, trend, success, local knowledge, use, fishers, co-management, increasing, review, catches, fish, and ecological. These keywords were selected to get a manageable number of hits (literature) to assess and to direct the search results to those articles analyzing sustainable fisheries, or at least to those showing trends of an increase in catches. The database SCOPUS was used for articles from the last 20 years (since 2000), which initially retrieved a total of 1635 articles. A complementary search was made on Google Scholar using a subset of these keywords. However, due to the large amount

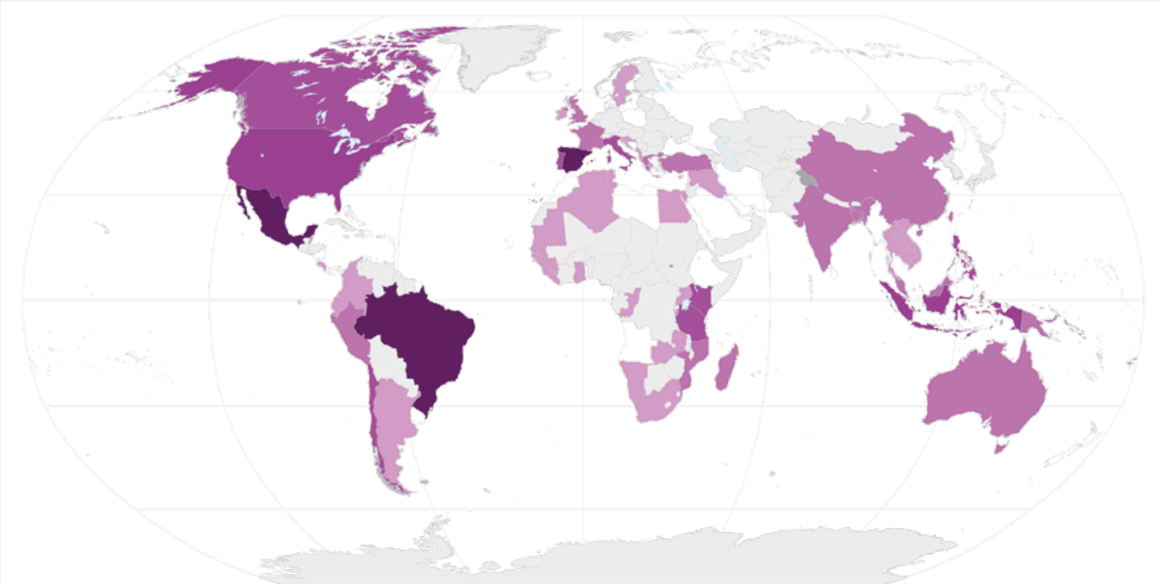

Figure 3 22 **Global distribution of the 350 reviewed studies on small-scale fisheries among 107 countries (countries in gray means that no study was included).**

See data management report for the figure at https://doi.org/10.5281/zenodo.6453056.

of literature retrieved (34300 hits), only the first 200 hits were reviewed on Google Scholar, including some of the more recent articles from the last 10 years. A total of 447 articles on small-scale fisheries were selected after an initial screening, including only articles that reported some data on fisheries, preferably trends and some kind of indicator, such as abundance, size or catch per unit of effort, or fishing effort among others. Articles addressing details of management or policy options which did not include data, or theoretical approaches and effects from drivers, such as climate change, pollution, or development projects, were not included.

These 447 articles were sorted by major regions and the case studies on small-scale fisheries were selected from these (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). This literature review was complemented with relevant articles inserted by the authors from their personal libraries, by suggested articles from internal and external reviewers, and through cross-reference from the selected articles. Our review did not retrieve a large number of articles dealing with uses other than food (ornamental, medicinal, etc.) and those addressing social and economic dimensions of sustainability in small-scale fisheries.

The selected studies were sorted across a gradient of ecological sustainability, ranging from fully sustainable (exploited populations stable, no habitat damage, no ecological filters or shifts in the composition of exploited species) to unsustainable (exploited populations declining or overfished). Intermediate or partial sustainability included situations in which current exploited populations are stable, but some higher valued species were depleted or extinct, which are considered here as ecological filters (see also section 3.3.1.4.2), or the fishing practice has caused habitat damage or bycatch. Fisheries lacking data on temporal trends to clearly indicate sustainable catches were also allocated to these partially sustainable categories (for details on the reviewed studies, see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

A major challenge in evaluating the sustainability of small-scale fisheries is the lack of data on catches and measures of exploited stocks (size, proportion of juveniles caught, etc.), especially over broader spatial or temporal scales. Nevertheless, participatory research in collaboration with fishers and analyses of the fishers' knowledge about fishing resources have contributed evidence to assess patterns of sustainability, catches and fishing effort.

Relatively few studies have evaluated the economic sustainability of small-scale fisheries. A review on global marine fisheries indicates that well-managed and locally supported small-scale fisheries could be a more sustainable option to provide employment and food than the current subsidy-driven industrial fisheries, which may increase effort in spite of declining fishing resources (Zeller & Pauly, 2019). However, conventional economic models that have been applied to assess fisheries economic viability may not be appropriate to small-scale fisheries, which need inclusion of social and environmental variables to conduct economic viability analyses that go beyond profit maximization (Schuhbauer & Sumaila, 2016).

The literature search retrieved 49 studies of global scope, which encompass multiple countries from more than one of the broad regions defined here, of which 18 studies were included in this review (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Among these, studies 15 address coastal fisheries, two address inland fisheries and two include both coastal and inland. These studies usually have a broad coverage in space or time, grouping data from many regions and communities and sometimes showing long time series of 50 up to 600 years (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). One of these studies, which brings data for over 1,900 coastal indigenous communities around the world, representing 27 million people across 87 countries, claims that sustainability depends on increased recognition and directed research regarding the marine knowledge and resource needs of indigenous peoples, whose needs must be explicitly incorporated into management policies (Cisneros-Montemayor, Pauly, Weatherdon, & Ota, 2016).

Other studies point to the potential overfishing of marine invertebrates (including cephalopods, shellfish, lobsters, crabs, sea cucumbers) estimating that, in 2004, 34% of invertebrate fisheries were over-exploited, collapsed, or closed, as global invertebrate catches have increased 6-fold (Anderson, Flemming, Watson, & Lotze, 2011). This problem is especially severe for sea cucumber fisheries, 81% of which show population declines from overfishing, and 35% had declines in the average harvested body size. Harvesters moved from near- to off-shore regions in 51% of cases and from high- to low-value species in 76% of these fisheries (Anderson, Flemming, Watson, & Lotze, 2011). Similarly, a global survey indicates that sawfishes (family Pristidae) have been heavily affected by intense harvesting and habitat degradation and these sawfish are now extinct in 55 of the 90 nations where they originally occurred (Yan *et al.*, 2021).

A study comparing the fisheries in Florida (Atlantic) and Hawaii (Pacific) over a period of 600 years indicated that, although fishing had been sustainable in Hawaii for 400 years, landings have declined and some species are recorded as overexploited in both the study regions (Mcclenachan & Kittinger, 2013). A study reviewing context and attributes of co-management initiatives in small-scale fisheries concludes that more research is needed to discern when co-management initiatives can transform pre-existing conflicts, challenge power asymmetries and distribute benefits more equitably (d'Armengol, Prieto Castillo, Ruiz-Mallén, & Corbera, 2018). However, another study indicates that fishers perceived improved livelihoods and compliance in co-managed sites, thus evidencing contributions of co-management to improve social sustainability (Cinner *et al.*, 2012).

EUROPE AND CENTRAL ASIA

Out of the 56 papers reviewed for Europe (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). The vast majority cover mainly the coastal and marine/oceanic fisheries in Europe or in European archipelagos in the Atlantic Ocean, the Mediterranean Sea (and its internal seas, like the Adriatic, the Aegean, the Marmara) or in the Black Sea. Ocean or marine small-scale fisheries is discussed in 48 papers, whereas only a small number of those (eight) investigated the European inland small-scale fisheries. A majority of these papers focused on Iberian freshwater fishing (Antunes, Cobo, & Araújo, 2015; Braga, Pereira, Morgado, Soares, & Azeiteiro, 2019; Marcos, Torres, López-Capel, & Pérez-Ruzafa, 2015; Maynou, Martínez-Baños, Demestre, & Franquesa, 2014), although there are other very important fishing practices, such as the trout fisheries, taking place in many different countries of the region (Shephard *et al.*, 2019).

The vast majority of the papers discuss the exploitation of fish species, but other organisms are also discussed, including a large diversity of targets in single fishing systems such as crustaceans and mollusks (Alonso-Fernández *et al.*, 2019; Antunes *et al.*, 2015; Azzurro *et al.*, 2019; Battaglia *et al.*, 2017; Carrà, Monaco, & Peri, 2017; Colloca, Scarcella, & Libralato, 2017; Corral & Manrique de Lara, 2017; Fabio, Silvia, Paolo, & Anelli Monti, 2016; Grati *et al.*, 2018; Guyader *et al.*, 2013; Palmer *et al.*, 2017; Quetglas *et al.*, 2017). A small number of papers also cover exploitation of crustaceans (Carvalho, Vasconcelos, Piló, Pereira, & Gaspar, 2017; Rivera *et al.*, 2016; Rivera *et al.*, 2017), mollusks (Baeta, Breton, Ubach, & Ariza, 2018; Duncan, Brand, Strand, & Foucher, 2016; Öndes, Kaiser, & Güçlüsoy, 2020; Pereira, Vasconcelos, Moreno, & Gaspar, 2019; Silva *et al.*, 2019; Szostek, Murray, Bell, & Kaiser, 2017), benthic invertebrates (Bastari, Beccacece, Ferretti, Micheli, & Cerrano, 2017; Fourt, Faget, Dailianis, Koutsoubas, & Pérez, 2020; Pita *et al.*, 2019) and even sea mammals (Maynou *et al.*, 2011). The diversity of topics is a sign of the high diversity of fishing practices, technologies and techniques present in the European small-scale fishing.

Contrary to the pattern observed in other regions, the literature on fishing rarely mentions lack of data on European small-scale fisheries. Still, lack of data does remain a concern in a number of cases including inaccuracy, large underestimation of parameters, undeclared information, and lack of stock assessment analysis for some fishing systems. Contrary to what is observed in the literature about the small-scale fisheries in other regions, no major cases of illegal, unreported and unregulated(Colloca *et al.*, 2017; Ulman *et al.*, 2013, 2015a) activities are focused upon in these studies (Colloca *et al.*, 2017; Dinesen *et al.*, 2019; Hornborg & Främberg, 2019; Marcos *et al.*, 2015).

Small scale fishing is an economically, socially, and culturally significant practice throughout Europe. It is well established that small-scale fishing plays an important role in many national economies (Guyader *et al.*, 2013; Lloret *et al.*, 2018), and almost 80% of the European fishing fleet belongs to small-scale fisheries (Quetglas *et al.*, 2016). Sometimes, in general terms, this fishing is more profitable than the large-scale fishing industry since costs are lower and catches are similar (Almeida, Vaz, Cabral, & Ziegler, 2014). In some parts, the increase in the tourism industry and, less conspicuously, the increase in recreational fishing, led to a slight expansion in local economies (Marengo, Culioli, Santoni, Marchand, & Durieux, 2015) and generated new incomes and additional revenues in the form of concessions and permits (Antunes *et al.*, 2015). On the other hand, it is also well established in the literature that small-scale European fishing is threatened by the competition among different uses of aquatic resources and by decreasing profitability, detected in almost all systems evaluated (Maynou *et al.*, 2014).

When European small-scale fishing systems are analyzed, the majority of the papers describe activities that are still profitable (Roditi & Vafidis, 2019; Ünal & Franquesa, 2010), but that these profits dropped consistently in recent decades (Maynou *et al.*, 2014; Pita *et al.*, 2019; Quetglas *et al.*, 2016). The reduction in market values and revenues is causing a marked change in local economies and in employment rates (Ünal & Franquesa, 2010), with serious impacts on traditional fishing communities. It is estimated that the European small-scale fisheries dropped from 30-50% in terms of income over this time period (Lloret *et al.*, 2018). But in most of these cases small-scale fisheries continues as an important source of employment (Baeta *et al.*, 2018) even if fishers have to work additional jobs to maintain their livelihoods (Braga *et al.*, 2019; Pereira, Vasconcelos, Moreno, & Gaspar, 2019b). The drop in profits, revenues and wages are not only due to overexploitation of stocks, the decrease in market values or to climate change. Competition is also increasing due to the introduction of industrial and recreational fishing, which have caused major reductions to commercial small-scale fisheries landings and profits (Marengo *et al.*, 2015; Maynou *et al.*, 2013).

European small-scale fishing the literature also highlights the exploitation of economically important and profitable high-valued stocks (Grati *et al.*, 2018), with particular emphasis on scallops (Duncan *et al.*, 2016; Szostek, Murray, Bell, & Kaiser, 2017), large demersal fish species (Quetglas *et al.*, 2017), octopuses (Silva *et al.*, 2019), carps (Hornborg & Främberg, 2019), cod (Dinesen *et al.*, 2019), barnacles (Carvalho *et al.*, 2017) and salmon (Antunes *et al.*, 2015). Some of the additional profits can also come with the opportunity or possibility to exploit "labels of topicality" (Dinesen *et al.*, 2019; Sartor *et al.*, 2019). There are increasing trends in the demand of international market for these items, and their market values may pose a threat to their stocks (Antunes *et al.*, 2015; Lloret *et al.*, 2018). Most of these high-valued stocks were severely overexploited for a long time, and some of them are only now recovering after the introduction of more careful management measures (Rivera *et al.*, 2016; Rivera *et al.*, 2017).

The strong economic and technological changes experienced in the last 60 or 80 years are accompanied by consistent social and cultural importance of these practices (Carvalho *et al.*, 2017). Most of the local populations show a marked dependence on small-scale fisheries, in terms of food security, for the maintenance of local employment and for the resilience of cultural heritage (Braga *et al.*, 2019; Colloca *et al.*, 2017; Grati *et al.*, 2018; Pereira *et al.*, 2019; Ünal & Franquesa, 2010). In some European countries, more than 50% of the fishers are linked to one of the small-scale fishing systems in place (Antunes *et al.*, 2015; Quetglas *et al.*, 2016; Sartor *et al.*, 2019; Silva *et al.*, 2019). Small-scale fisheries employ twenty-four times more fishers than large-scale fishing (Leleu *et al.*, 2014).

The history of more traditional fishing systems goes back thousands of years (Antunes *et al.*, 2015; Marcos *et al.*, 2015). This strengthens cultural and historical bonds, and provides ongoing social meaning for indigenous people and local communities (Guyader *et al.*, 2013). With the technological changes in the last 50 to 60 years, the efficiency of the fishing systems has (Alonso-Fernández *et al.*, 2019; Pita *et al.*, 2019; Quetglas *et al.*, 2017; Ünal & Franquesa, 2010). Besides unemployment, other problems such as mechanization (Lloret *et al.*, 2018).

While some unemployed fishers searched for new jobs, better wages or other sources of income (Maynou *et al.*, 2013), many families had to close down business and sell their fishing equipment and boats to larger companies (Dinesen *et al.*, 2019). The collapse of fishing systems and the overexploitation of stocks created new social contexts which demanded new and stricter management rules and improved governance, also seen as means to avoid social conflict (Marengo *et al.*, 2015). These needs were partially met with the official management measures adopted in many areas, with distinct levels of success. Apparently, the recovery of social recognition of those engaged in this practice and the relevance of the small-scale fisheries was also an outcome of successful management initiatives at some places (Carvalho *et al.*, 2017).

AFRICA

From the initial selection of 63 papers, this evaluation on African small-scale fisheries is based on 51 papers covering mainly the coastal and marine/oceanic small-scale fishing, which was the subject of approximately 40 papers (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Despite the importance of established fisheries in tropical and subtropical African rivers, the reviewed literature focused on inland small-scale fishing in the great African lakes and small rivers. The fishing practices in African great lakes was studied in eight papers (Bulengela, Onyango, Brehm, Staehr, & Sweke, 2019; Hara & Njaya, 2015; Jamu, Banda, Njaya, & Hecky, 2011; Kolding, Béné, & Bavinck, 2014; Mgana *et al.*, 2019; Mkuna & Baiyegunhi, 2019a, 2019b; van der Knaap & Ligtvoet, 2010). Similar analysis for fishing practices in some African smaller lakes was published in three studies (Kininmonth *et al.*, 2017; Obegi *et al.*, 2020; Tefera, Zerihun, & Wolde-Meskel, 2019), and there were a few examples of small river fishing in South Africa and Egypt (McCafferty, Ellender, Weyl, & Britz, 2012; Samy-Kamal, 2015). The majority of the papers describe fishing for fish species, but a small number also include fishing for crustaceans (Bush *et al.*, 2017; Cochrane, Eggers, & Sauer, 2020; Fulanda, Ohtomi, Mueni, & Kimani, 2011; Le Manach *et al.*, 2012; Le Manacha, Goughb, Humberb, Harperc, & Zellerc, 2011; Mirera, Ochiewo, Munyi, & Muriuki, 2013).

There is scarce published data about African small-scale fishing. However, it is well established that many peoples rely on small-scale fishing for their subsistence and livelihoods throughout Africa (Musembi, Fulanda, Kairo, & Githaiga, 2019). Absence or inadequacy of data, under-estimates, and lack of stock assessment analysis were consistently mentioned by almost all papers reviewed. Those data sets supported by the FAO in many countries are usually underestimates since they are based only on landings, not considering data from illegal, unreported and unregulated fishing. Some papers present a reconstruction of data series, which attempted to include illegal, unreported and unregulated catch (Barnes-Mauthe, Oleson, & Zafindrasilivonona, 2013; Jacquet, Fox, Motta, Ngusaru, & Zeller, 2010; Le Manach *et al.*, 2012; Seto *et al.*, 2017).

Only one third of the papers reviewed presented any socioeconomic evaluation of fishing sustainability across the continent, and only two papers were focused on this topic. All other social evaluations demonstrated the high level of dependence of local communities on fishing practices (Belhabib, Greer, & Pauly, 2018; Bush *et al.*, 2017).

Formal economic review shows that market prices either kept stable or increased in the last 60 years. This is an important factor to explain the increase in fishing effort and overexploitation of most stocks. Pressure from international markets for some high value species for exportation also added pressure on the stocks. This increased pressure led to increased competition between international fleets and local boats and sometimes conflict (Belhabib *et al.*, 2016; Seto *et al.*, 2017).

LATIN AMERICA

For the purpose of this assessment, Latin America includes the countries in South and Central America, Mexico and Caribbean Islands based on the similarities in their small-scale fisheries and social-ecological characteristics. This review is based on 107 articles (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651) from the review sources and those added by the assessment authors. These studies address coastal and inland small-scale fisheries in 15 countries with large numbers of studies from Brazil (55) and Mexico (20), which may reflect a larger number of fisheries scientists working in these countries rather than greater small-scale fisheries activity there. A selection of the studies provides international comparisons (Defeo *et al.*, 2016; Maldonado, Lopes, Fernández, Alcala, & Sumalia, 2017) or continental level comparisons (Brotz *et al.*, 2017). Most studies (78) addressed the use of finfish but also reported on sharks, shellfish, lobsters, octopus, crabs and jellyfish. More than two thirds of the studies (78) deal with coastal fisheries with fewer (29) studies addressing inland fisheries, and most of these (25) were in the Amazon region (for details on the reviewed studies, (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). More than half of the studies (56) had short time series ranging from 1 to 15 years of data collection. A few studies (17) included long range data series of 50 years or more, some of which included indigenous and local knowledge through interviews with seniors.

As expected, those well managed and ecologically sustainable fisheries were also considered to be economically sustainable and showed improved economic indicators such as increased prices or profits from sales of managed resources. These offset eventual decreases in total catches due to management measures, as observed among coastal invertebrate fisheries under territorial rights in Chile and Mexico (Álvarez, Espejel, Bocco, Cariño, & Seingier, 2018; De la Cruz-González, Patiño-Valencia, Luna-Raya, & Cisneros-Montemayor, 2018; Defeo *et al.*, 2016; Gelcich *et al.*, 2010). Nevertheless, the territorial users' rights fisheries management in Chile also caused economic shortages through the collapse of a clam fishery and reduced economic opportunities to fishers not engaged in territorial users' rights fisheries management, who relied on depleted open access areas (Aburto & Stotz, 2013; Garmendia, Subida, Aguilar, & Fernández, 2021).

The positive economic effects observed in coastal shellfish fisheries were also observed in the pirarucu co-managed fishery in the Brazilian Amazonian rivers (Campos-Silva & Peres, 2016; Castello, Viana, Watkins, Pinedo-Vasquez, & Luzadis, 2009), where increased revenues from co-management led to further social benefits, through gender equality and improved income for women (Freitas, Espírito-Santo, Campos-Silva, Peres, & Lopes, 2020). Other studies on coastal small-scale fisheries employed economic modelling, which indicate that a fishery of octopus *(Octopus maya)* in Mexico would be more sustainable under current management, as economic performance does not improve under alternative management scenarios (Duarte, Hernández-Flores, Salas, & Seijo, 2018a). Similarly, the recovery of shellfish through co-management in a Mexican community was shown to be profitable under two of four estimated future economic scenarios (Palacios-Abrantes, Herrera-Correal, Rodríguez, Brunkow, & Molina, 2018).

One study on fisheries in French Guiana evaluated various sustainability indicators, which suggested average sustainability for ecological, economic and social dimensions. Smaller fishing fleets were considered to be more sustainable (Cissé, Blanchard, & Guyader, 2014). Several coastal small-scale fisheries considered to be less economically sustainable were the fishing of spawning aggregations of reef fish in Mexico (Erisman *et al.*, 2010) and the shark fishing in Mexico (Martínez-Candelas, Pérez-Jiménez, Espinoza-Tenorio, McClenachan, & Méndez-Loeza, 2020) and Brazil (Martins *et al.*, 2018). The decline in the economic sustainability of shark fishing is attributed to decreases in shark fishing activity, revenues and profits from shark fins.

Other economic problems refer to inequalities in the distribution of profits among crew members and boat owners (De Figueiredo Silva, Camargo, & Estupiñán, 2012), low prices paid to fishers by the middlemen, the concentration of profits in large private companies (Gamboa-Álvarez, López-Rocha, Poot-López, Aguilar-Perera, & Villegas-Hernández, 2020a; Jimenez, Barboza, Amaral, & Lucena Frédou, 2019) and increasing costs related to fishing operations such as fuel to reach more distant fishing grounds (Daw, 2008). A study with crab gatherers in the Brazilian Amazonian coast considers the fishery ecologically sustainable (catches and sizes of crabs did not change), but not economically and socially sustainable. The relative revenue for fishers also declined, which sometimes led to social conflicts (Glaser & Diele, 2004).

The social aspects of small-scale fisheries were addressed by only 19 of 78 studies on coastal small-scale fisheries and 5 of 29 studies on inland small-scale fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Some of the territorial co-management coastal fisheries of invertebrates, mainly in Chile and Mexico, show social benefits such as improved perceptions among fishers about the fishery, more time available to dedicate to other activities, decreased conflicts over resources, reinforced property rights over resources, improved institutional collaboration, community organization and capacity building (Álvarez *et al.*, 2018; Defeo *et al.*, 2016; Gelcich *et al.*, 2017, 2010; Palacios-Abrantes, Herrera-Correal, Rodríguez, Brunkow, & Molina, 2018). Similarly, the co-managed pirarucu fisheries in the Brazilian Amazon have improved social sustainability through more equalitarian distribution of income, sense of pride, stronger culture and indigenous and local knowledge (Campos-Silva & Peres, 2016; Freitas *et al.*, 2020).

In coastal small-scale fisheries some problems undermining social sustainability are ongoing conflicts between fishers and managers of protected areas (De Figueiredo Silva *et al.*, 2012; Jimenez *et al.*, 2019; Lopes, Rosa, Salyvonchyk, Nora, & Begossi, 2013; Lopes, Silvano, Nora, & Begossi, 2013). These include increased theft of fishing gear and potential competition for space with industrial vessels (Daw, 2008), high risk practices, such as diving, which can involve accidents (Gamboa-Álvarez *et al.*, 2020; Guebert-Bartholo, Barletta, Costa, Lucena, & Da Silva, 2011) and disruption of fishing cooperatives (Rubio-Cisneros, Aburto-Oropeza, Jackson, & Ezcurra, 2017). Even in the relatively successful co-managed Chilean shellfish. Other social problems at the Brazilian coast include increased commercialization and price of shark meat, which decreases the availability of shark meat for local people and threatens their food security (Barbosa-Filho *et al.*, 2019).

Scientific and indigenous and local knowledge informed assessments have at times differed about the sustainable use of certain fisheries. For example, in a Colombian lagoon community social conflict arose between fishers and researchers due to differences in how they conceptualize sustainability, (Torres-Guevara, Lopez, & Schlüter, 2016). A similar situation was observed in the Dominican Republic where fishers, based on their indigenous and local knowledge, considered the fisheries as more depleted through catches of juvenile fish of most species but scientists believed the fisheries targeted mostly adult fish and would thus be in a better state (Mclean & Forrester, 2018). Both cases draw attention to the need for better dialogue and cooperation between fishers and scientists.

The main social problems related to the inland ornamental fisheries in the Brazilian Amazon are the negative effects of a reduced trade in the Negro River and a potential collapse of exploited species in the Xingu River, which will drastically reduce income and negatively affect the livelihoods of many impoverished riverine people, most of whom lack employment alternatives (Evers, Pinnegar, & Taylor, 2019a). Another social problem of this fishery is the health issues related to the labor-intensive fishing performed mostly by aged fishers. Younger people are less and less involved in these activities. Not only does this have negative impacts on the labor distribution, but may also disrupt knowledge transmission of indigenous and local knowledge (Ladislau *et al.*, 2020).

NORTH AMERICA

From a total of 28 sources on coastal and inland small-scale fisheries in temperate North America retrieved, 22 are included in this review (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651), which are evenly distributed between the United States of America (12) and Canada (9). One study addressed both countries, which is also the only study on inland fisheries (Cooke & Murchie, 2015). The reviewed studies include a variety of fishing resources, such as coastal and reef fishes, crabs, lobster, shellfish and sea cucumbers (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). We also include a case study on the sustainability of small-scale whaling activities in the north (see **Box 3.4**).

Six studies focus on economic and 12 studies highlight social considerations in small-scale fisheries of Canada and the United States of America (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Some of these studies underscore the high economic value of the recreational fisheries practice in Florida, which provides jobs and revenues (Ault, Bohnsack, Smith, & Luo, 2005). For example, the catch-and-release fishery in South Florida (and the Caribbean) has an estimated value of at least half a billion dollars per year (Kroloff *et al.*, 2019). Similarly, the lobster *(Homarus americanus)* fishery is very important to the region of the Gulf of Maine in Canada (Boudreau & Worm, 2010). Some studies indicate potential negative interactions among economic activities. For example, commercial fishing coupled with the expansion of sports (recreational) fishing in the last decades may had affected yelloweye rockfish *(Sebastes ruberrimus)* populations (Eckert *et al.*, 2018). Similarly, food security in Alaska has been negatively affected by the development of export-oriented commercial fisheries and tourism-oriented sport fisheries (Harrison & Loring, 2016). Another study reports changes in fishing area or practices in response to changing market infrastructure (e.g., switch to frozen from salt cod), besides changes in economic factors external to the fishery, such as loss of other income generating activities, which can affect the economic sustainability of cod *(Gadus morhua)* in Newfoundland, Canada (Murray, Neis, & Schneider, 2008).

Some of the studies that mention social characteristics of small-scale fisheries comment on the relevance of fishing resources to local peoples' livelihoods and food security (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). For example, fishing of Arctic char *(Salvelinus alpinus)* has high value for food security, cultural identity and local economic development among Arctic communities (Roux *et al.*, 2019). Conversely, the observed decline in the catches of the Dungeness crab may compromise the ability of indigenous fishers to access traditional foods in Canada (Ban *et al.*, 2017). Other studies emphasize the relevance and benefits of integrating multiple knowledge sources in fisheries assessments, including fishers' indigenous and local knowledge, which may improve dialogue, cooperation and social relations between fishers and scientists (Ambrose *et al.*, 2014; Ban *et al.*, 2017; Murray, Neis, Palmer, *et al.*, 2008; Murray, Neis, & Schneider, 2008; Rehage *et al.*, 2019). The study on inland fisheries mentions that food security and the move towards eating locally may create new markets for freshwater fish, as long as they have low contaminant loads and are considered healthy (Cooke & Murchie, 2015).

ASIA-PACIFIC

The Asia-Pacific region includes countries from Asia, Oceania and the South Pacific Island countries. From a total of 119 sources originally retrieved for this region, 96 studies were included in the review, in conjunction with literature from assessment authors. These studies cover small-scale fisheries in more than 36 countries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651) from Southeast Asia (Mattson, 2006), Western Asia (Al-Abdulrazzak, Zeller, Belhabib, Tesfamichael, & Pauly, 2015) and the Pacific (Cohen & Foale, 2013; Cruz-Trinidad, Aliño, Geronimo, & Cabral, 2014; Eriksson *et al.*, 2018; Kronen, Magron, McArdle, & Vunisea, 2010; D. Zeller *et al.*, 2015). Several countries appeared in only one or two studies; more studies addressed small-scale fisheries in Indonesia (18), the Philippines (10), Australia (7), India (9), Bangladesh (5) and the Solomon Islands (5). The overwhelming majority (82%) of studies addressed coastal or marine and only 10 studies focused on inland small-scale fisheries, whereas three recent studies in Southeast Asia included both coastal and inland fisheries (Jahan, Ahsan, & Farque, 2017; Liao *et al.*, 2019; Millar *et al.*, 2019). Most studies report the uses of finfish, while fewer studies focus on other organisms (sharks, invertebrates). Several studies included many species (finfish and other organisms), evidencing the multi-species characteristic of these small-scale fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

Although some studies had short time series of up to one year, several studies analyzed time series of 10 years or more (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651) and at least one study included indigenous and local knowledge and archeological data to analyze a time series of 3,000 years in American Samoa (P. Craig, Green, & Tuilagi, 2008). Among the studies analyzing long time series of 50 to 60 years, some include indigenous and local knowledge on temporal trends (Lavides *et al.*, 2016; Muallil, Mamauag, Cababaro, Arceo, & Aliño, 2014; Selgrath, Gergel, & Vincent, 2018a, 2018b; Thurstan, Buckley, Ortiz, & Pandolfi, 2016a), while others apply a methodology to reconstruct catches along time series with missing data (Al-Abdulrazzak *et al.*, 2015; Léopold *et al.*, 2017; D. Zeller *et al.*, 2015).

Considerations or analyses related to economic sustainability were included in 45 and 11 of the reviewed studies on coastal and inland (or coastal and inland) small-scale fisheries, respectively (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Some of the ecologically sustainable or partially sustainable coastal fisheries also show net economic benefits due to improved or maintained catches, as observed for the shrimp fisheries in Indonesia (Anna, 2017) and abalone fisheries in Australia (Mayfield, Mundy, Gorfine, Hart, & Worthington, 2012).

Fishing is an important economic activity for the Pacific Island countries located in the coral triangle area (Cruz-Trinidad *et al.*, 2014). Some of the co-managed reef fisheries in Pacific Island countries can deliver tangible economic benefits to local communities in the form of increased catches (Tilley, Hunnam, *et al.*, 2019; Webster *et al.*, 2017; Yang & Pomeroy, 2017), for example, through periodic harvesting in protected areas, which can provide a needed boost to local economies (Cohen, Cinner, & Foale, 2013). However, some highly valued economic resources, such as sea cucumbers or lobsters *(Panulirus ornatus)*, have been overfished, particularly in the Philippines and Indonesia, due to increased market demands (Hair, Foale, Kinch, Yaman, & Southgate, 2016; Macusi, Laya-og, & Abreo, 2019; Prescott, Riwu, Prasetyo, & Stacey, 2017). The sea cucumbers fishery has high export value and provides an economic insurance for island populations of Pacific Island countries, but some of these fisheries had to be closed to recover, which compromised the economic benefits (Eriksson *et al.*, 2018; Hair *et al.*, 2016).

The economic sustainability of coastal fisheries could also be negatively affected by long market chains with strong inequalities in the distribution of profits between fishers and final retailers (Ferse, Glaser, Neil, & Schwerdtner Máñez, 2014). The low price paid to fishers can interact with increased costs of fuel and other components of the fishing activity, prompting fishers to intensify their fishing effort to cover fishing trips to more distant fishing grounds (Sebastian Ferse, Knittweis, Krause, Maddusila, & Glaser, 2012; G. M. N. Islam, Noh, Sidique, & Noh, 2014; Muallil, Mamauag, Cababaro, *et al.*, 2014; Rhodes, Tupper, & Wichilmel, 2008).

Aspects related to the social and cultural sustainability were presented in 32 and 8 of the reviewed studies on coastal and inland small-scale fisheries, respectively (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Several studies highlighted the social benefits of these fisheries in the form of food provision and sustaining livelihoods of local communities (Al-Abdulrazzak *et al.*, 2015; Butler, Tawake, Skewes, Tawake, & McGrath, 2012; Cruz-Trinidad *et al.*, 2014; Friedlander *et al.*, 2014; Golden, Naisilsisili, Ligairi, & Drew, 2014; Rassweiler *et al.*, 2020). Fishing is also an important cultural and social activity among many of the coastal fishing communities, reinforcing cultural identity and social practices, such as sharing fish, in the Pacific Island countries (Golden *et al.*, 2014; Rassweiler *et al.*, 2020). Indeed, Maori coastal fishers in New Zealand have perceived declines in culturally important nearshore resources (fish and invertebrates), which has negative cultural effects on communal activities, social connections, traditions, connections to nature and loss of pride of being able to feed themselves and guests by using seafood (Mccarthy *et al.*, 2014).

Besides improving catches and increasing the abundance of fishing resources, the commons-based management systems implemented in Pacific Islands can promote social sustainability through empowerment of local communities, increased compliance with management rules and the development of a sense of ownership of fishing resources (Butler *et al.*, 2012; Cinner *et al.*, 2012; Friedlander *et al.*, 2014; Webster *et al.*, 2017; Yang & Pomeroy, 2017). These co-management systems often include community rules and beliefs, sometimes resulting in social benefits by participating communities even before perceived improvements on fisheries (Tilley, Hunnam, *et al.*, 2019).

Fishery closures imposed by co-management may exclude some social groups, such as women or immigrants, from access to fishing grounds, besides imposing social costs in the form of restricted harvestings (Ayunda, Sapota, & Pawelec, 2018; Cohen & Foale, 2013). The relationship between fishers and middlemen can either improve or undermine social sustainability. For example, in Indonesia, some of the middlemen (locally called patrons) may have social ties with fishers and contribute to social welfare by providing social security for impoverished fishers in need, whereas other, wealthier patrons (big patrons), may not have these social ties. This may result in provision of credit and loans to fishers to buy fishing gear (including illegal and high impact types) which may result in unsustainable fishing practices and further exploit fishers by making them sell catches at low prices (Ferse *et al.*, 2014; Ferse *et al.*, 2012).

3.3.1.4.1 Indicators of small-scale fisheries sustainability

Across the 350 small-scale fisheries studies the main indicators adopted were: (i) catch biomass or composition (landings' data) in 214 studies, (ii) measures of catch per unit of effort, in 78 studies), (iii) abundance estimates and trends (72 studies), (iv) based on either fishers' knowledge or biological sampling, fishing effort, such as number of boats and other measures (73 studies), (v) size of harvested species (57 studies) and varied measures of stock assessment (51 studies). The majority (214) of reviewed studies included indigenous or local knowledge from fishers to inform the indicators outlined here, so fishers' knowledge can be also considered an important indicator and information source for small-scale fisheries. Some studies have also included economic related indicators, such as market prices, costs, revenues (83 studies) or social indicators, such as culture, governance or management (46 studies), see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651 for more detailed data.

EUROPE AND CENTRAL ASIA

A very diverse set of indicators using three perspectives (i.e., ecological, economic and social) was employed to assess sustainability in the papers reviewed. The use of parameters from stock assessments analysis as indicators for ecological sustainability assessments is not very common in the literature and only a few studies use them in conjunction with other indicators, such as maximum sustainable yield (Colloca *et al.*, 2017; Dinesen *et al.*, 2019; Hornborg & Främberg, 2019; Marcos *et al.*, 2015), or different measurements of stock abundance and distribution (Bastari *et al.*, 2017; Braga, Pardal, & Azeiteiro, 2018; Damalas *et al.*, 2015; Lloret *et al.*, 2015; Macdonald, Angus, Cleasby, & Marshall, 2014; Shephard *et al.*, 2019; Szostek, Murray, Bell, & Kaiser, 2017).

The use of fish biometry and size distributions in cohort analysis is not usual, but is present (Grati *et al.*, 2018; Shephard *et al.*, 2019; Vasconcelos *et al.*, 2020), also in association with other methods and indicators. However, as expected, most of the ecological assessments reviewed (41 out of 63 papers) support their conclusions with landing statistics (production/catch biomass, catch composition) and related parameters to measure fishing effort and catch-per-unit-of-effort.

Catch biomass or biomass landed (58.2% of reviewed studies), catch-per-unit-of-effort (40.3%) and catch composition or species landed (13.4%) were the indicators used more frequently in the ecological evaluations of small-scale fishing in Europe (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). In addition, the use of indicators of local ecological knowledge from local fishers in association with other indicators, is notable (Azzurro *et al.*, 2019; Braga *et al.*, 2017, 2019; Coll *et al.*, 2014; Corral & Manrique de Lara, 2017; Damalas *et al.*, 2015; Dinesen *et al.*, 2019; Figus *et al.*, 2017; Lloret *et al.*, 2015; Maynou *et al.*, 2011; Öndes, Kaiser, & Güçlüsoy, 2020).

Socioeconomic assessment alone was a rare approach in the literature of fishing sustainability (Ünal & Franquesa, 2010). Nevertheless, the assessment of economic and social aspects of European small-scale fisheries as part of ecological assessments was not that unusual, and made use of a set of related indicators such as values of landings, market values, market prices, revenue and income generation, both by the fleets and by the individual fishers (Carvalho *et al.*, 2017; Grati *et al.*, 2018; Guyader *et al.*, 2013; Lloret *et al.*, 2018; Maynou *et al.*, 2014, 2013; Pita *et al.*, 2019; Quetglas *et al.*, 2017; Rivera *et al.*, 2016; Rivera *et al.*, 2017; Roditi & Vafidis, 2019; Sartor *et al.*, 2019; Silva *et al.*, 2019b; Tzanatos *et al.*, 2013; Ulman *et al.*, 2013).

Despite the fact that a very limited number of assessments based on the social perspective was found in the reviewed literature, these studies applied a diverse set of indicators. Those indicators were based on tradition (cultural, historic values) and on the level of dependence of the local communities on the fishing practices for their livelihoods (Guyader *et al.*, 2013; Ünal & Franquesa, 2010). The more frequent approach for social assessments was the use of the indicators of governance efficiency and effectiveness of fishers' organizations in charge of co-management, or participatory management systems of aquatic resources (Baeta *et al.*, 2018; Morales-Nin *et al.*, 2017; Silva *et al.*, 2019b). These may represent the main critical issues that are discussed by experts on the social perspectives of the European small-scale fishing and fishers.

AFRICA

Since proper stock assessments are not very common (due to high costs, lack of personnel, time and other means) the authors used a diverse set of indicators. Only a small number of studies used stock assessments to produce estimates of maximum sustainable yield, yield per recruit, or cohort analysis and species-specific life table parameters (Fulanda *et al.*, 2011; Hara & Njaya, 2015; Jamu *et al.*, 2011; Meissa, Gascuel, & Rivot, 2013; Rehren, Wolff, & Jiddawi, 2018). Most of the assessments support their conclusions based on series of catch/production, such as landing statistics. Catch biomass (biomass landed) and catch composition (species landed) are the more frequent parameters in the ecological evaluations. Nevertheless, catch-per-unit-of-effort and size distribution of fish landed are also frequently used indicators. More than 45 papers use fish landings and/or catch-per-unit-of-effort as indicators to support their analysis (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

Additional indicators were used for the assessment of economic and social aspects. Indicators for economic evaluation were revenue and market prices (Blythe, Murray, & Flaherty, 2013), relevance of foreign markets for exportations, and added costs and values (Baker-Médard & Faber, 2020). Indicators for social evaluation were level of dependence for livelihoods, employment, number of people involved (Belhabib *et al.*, 2015), influence of indigenous and local knowledge and the persistence/resilience of these last two (Bulengela *et al.*, 2019; Gaspare, Bryceson, & Kulindwa, 2015). In some cases, the persistence of cultural traits, like traditional knowledge, was seen as an indicator of social sustainability (Mirera *et al.*, 2013).

LATIN AMERICA

This review evidenced the limitations imposed by the lack of continuous monitoring to provide fisheries and biological data to evaluate sustainable use. Only a few studies included more detailed population analyses and measured conventional stock parameters, such as maximum sustainable yield, natural mortality, fishing mortality, among others (Aburto & Stotz, 2013; Baigún, Minotti, & Oldani, 2013; Catarino, Kahn, & Freitas, 2019; Cavieses Núñez, Ojeda Ruiz De La Penã, Flores Irigollen, Rodríguez Rodríguez, & Jardim, 2018; Duarte *et al.*, 2018a; Martínez-Candelas *et al.*, 2020; Mesquita, Cruz, Hallwass, & Isaac, 2019). The reviewed studies applied a varied set of indicators, often in combination, including total catches or landings (58), catch-per-unit-of-effort (22), and size of exploited fishing resources (37). Catch composition and its variation through time, measures of fishing effort, such as number of fishers, vessels and the distribution of effort in space and time, economic indicators (revenues and costs), and overall abundance trends estimated from indigenous and local knowledge were also used as indicators of sustainable use (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

A few studies calculated and compared sustainability indicators based on ecological, economic and social data (Cissé *et al.*, 2014; Robotham *et al.*, 2019; Torres-Guevara *et al.*, 2016). However, most of the reported trends are based on total catches only. The lack of effort or catch-per-unit-of-effort data makes it more difficult to properly assess the sustainability of these fisheries. Furthermore, while some species are preferred, most of these fisheries are multi-species and multi-gear (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). This imposes further challenges to sustainability assessments, as exploited species may differ regarding their resilience to fishing pressure and stock status. These challenges were addressed by most of the reviewed studies through two main, non-mutually exclusive, approaches. First, to rely on a variety of the indicators described above and second, to include fishers' knowledge about catches, trends, details of fishing effort in combination with fisheries data, biological surveys or modelling. Indeed, indigenous and local knowledge was included in the majority (69) of studies reviewed (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

Many studies stressed the important economic role of both coastal and inland small-scale fisheries in the studied regions, but relatively few studies included economic indicators (profits, revenues), analyzed market chains, or evaluated the economic sustainability of the studied fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Economic considerations were mentioned by 42% of the 78 studies on coastal small-scale fisheries and by 45% of the 29 studies on inland small-scale fisheries, sometimes linked to the analysis of catch trends and ecological sustainability.

NORTH AMERICA

The indicators adopted in the reviewed studies include catch (landings data), population and stock parameters, environmental or ecological indicators, productivity susceptibility analysis and various modelling approaches (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Even considering that both countries have a well-developed fisheries science and management with strong financial and technical capacity, the majority of the reviewed studies (17) include fishers' knowledge or indigenous and local knowledge, usually in combination with the above-mentioned fisheries and ecological indicators (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Moreover, fishers' knowledge has been included in these studies on various forms or manifestations, from traditional knowledge of indigenous people, usually from the Artic (Ambrose *et al.*, 2014; Ban *et al.*, 2017; Eckert *et al.*, 2018; Roux *et al.*, 2019) to local knowledge held by recreational fishers or commercial harvesters (Frezza & Clem, 2015; Kroloff *et al.*, 2019; Murray, Neis, Palmer, *et al.*, 2008; O'Regan, 2015).

ASIA-PACIFIC

The reviewed studies employed a wide range of indicators, most commonly catches (landings data), catch-per-unit-of-effort, fishing effort, abundance (density) and size of exploited fishing resources, besides socioeconomic indicators (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Almost two thirds (66) of the reviewed studies included indigenous and local knowledge-based indicators to inform fish abundance trends, catches, catch-per-unit-of-effort, sizes, fishing effort, perceptions on management or socioeconomic status, thus indicating the relevance of indigenous and local knowledge and collaboration with fishers for research on these small-scale fisheries.

3.3.1.4.2 The role of indigenous and local knowledge in small-scale fisheries

Despite the review provided here, it is also widely acknowledged that most small-scale fisheries remain unreported and unmonitored, resulting in the lack of longer time series data to evaluate their sustainability. This is especially the case in tropical countries and the Arctic, where small-scale fisheries are widespread. These data gaps can be overcome through collaborative research to record and analyze fishers' local ecological knowledge, a form of indigenous and local knowledge based on an experiential understanding of one's environment coupled with communal and historical use. Fishers' local ecological knowledge contributes to estimates on temporal trends in abundance of fisheries resources, and can extend the time series available for the analysis to periods before scientific monitoring (Giglio, Luiz, & Gerhardinger, 2015; Hallwass *et al.*, 2020; Jahan, Ahsan, & Farque, 2017; Maia *et al.*, 2018; Stocks, Foster, Bat, Ha, & Vincent, 2019a) or data (Sáenz–Arroyo, Roberts, Torre, & Cariño-Olvera, 2005) were available. Indeed, in many cases worldwide fishers' knowledge is the only available knowledge source.

In the last 20 years, several studies have recorded fisher indigenous and local knowledge and local ecological knowledge through using qualitative methods, such as interviews with fishers, to reconstruct temporal trends in fisheries resources. This was the case in 56 of the studies reviewed here. Through these studies data were collected from an aggregated total of 13,565 fishers (through interviews), on approximately 454 fish species in 32 countries worldwide **(Table 3.3)**. All the studies further quantitatively analyzed fishers' local ecological knowledge to identify trends in abundance, size and composition of fisheries resources through a series of indicators such as estimated abundance categories (declined, same, increased), catch per unit of effort, amounts of regular, poor and best catches, and size (length or weight) of largest ever caught **(Table 3.3)**.

The time span covered by these studies varies from 5 to 10 years (Daw, Robinson, & Graham, 2011; Liao *et al.*, 2019; Lima, Begossi, Hallwass, & Silvano, 2016; O'Donnell, Molloy, & Vincent, 2012) to several decades, with some going back to the 1950s and 1960s (Ainsworth, 2011; Lavides *et al.*, 2016; Lozano-Montes, Pitcher, & Haggan, 2008). The influence of time on fishing parameters has been analyzed either as a continuous variable (for example, year of the best catch) or as an interval categorical variable (for example, discrete years or decades according to fishers' age groups, specific events, etc.) **(Table 3.3)**.

Most of the studies reported declining trends in abundance, catch-per-unit-of-effort or size of fishing resources **(Table 3.3)**. Reported declines were usually focused on threatened species, some of which had been intensely exploited, such as reef fishes from the genus *Epinephelus* and *Mycteroperca* (groupers) (Bender, Floeter, & Hanazaki, 2013; Bender *et al.*, 2014; Bunce, Rodwell, Gibb, & Mee, 2008; Castellanos-Galindo *et al.*, 2018; Giglio *et al.*, 2015; Ribeiro, Damasio, & Silvano, 2021a; Zapelini, Bender, Giglio, & Schiavetti, 2019), the large catfish *(Pangasius sanitwongsei)* in the Mekong River (Gray, Phommachak, Vannachomchan, & Guegan, 2017), seahorses (*Hippocampus* spp.) (Stocks, Foster, Bat, Ha, & Vincent, 2019b), the angel shark *(Squatina squatina)* in the Mediterranean (Fortibuoni, Borme, Franceschini, Giovanardi, & Raicevich, 2016), sawfish species (*Pristis* spp.) in coastal ecosystems (Jabado *et al.*, 2017; Leeney & Poncelet, 2015), and the paddlefish *(Psephurus gladius)* in Yangtze River (Turvey *et al.*, 2010), among others **(Table 3.3)**.

A phenomenon sometimes related to studies based on fishers' memories to reconstruct past events is known as shifting baseline syndrome, i.e., environmental changes may be recognized only by older fishers and underestimated or not recognized by younger ones (Papworth, Rist, Coad, & Milner-Gulland, 2009; Pauly, 1995). Shifting baseline has been observed by many studies worldwide, which reported an influence of age on fishers' perceptions about changes in the abundance of fisheries resources (Bender *et al.*, 2013, 2014; Katikiro, 2014; Lozano-Montes *et al.*, 2008; Maia *et al.*, 2018; Turvey *et al.*, 2010; Ulman & Pauly, 2016). However, further studies show that this is not always the case, and both older and younger fishers may hold similar perceptions (Barbosa-Filho *et al.*, 2020; Hallwass, Lopes, Juras, & Silvano, 2013; Ribeiro *et al.*, 2021; Thurstan, Buckley, Ortiz, & Pandolfi, 2016b). Furthermore, fishers also report stable catches or sizes of at least some fish species (Ribeiro *et al.*, 2021; Silvano & Hallwass, 2020).

Limitations related to the application of fishers' local ecological knowledge to estimate abundance trends include heavy reliance on fishers' memories, which at time may be inaccurate or biased due to memory illusion or shifting baseline syndrome (Daw *et al.*, 2011; O'Donnell, Molloy, & Vincent, 2012; Papworth *et al.*, 2009). However, it should be noted that the ways in which local ecological knowledge and indigenous and local knowledge data are collected include methods for minimizing bias such as data triangulation

Table 3 3 **Study cases applying fishers' local or indigenous ecological knowledge for quantitative analyses of temporal trends on small-scale fisheries.**

N: number of interviewed fishers; **Trend:** time trends (C: continuous; I: interval (categories)); **Abundance:** overall trends in abundance estimated by fishers (D: declined; S: stable, IC: increased); **CPUE:** catch per unit of effort; **Catches:** include estimates of either regular or best catches; **Size:** usually the largest individual ever caught, in length or weight; **Composition:** relative abundance and number of species in the catch; **Scientific data:** besides data from fishers' knowledge (AG: agreement between fishers' knowledge and scientific data; DA: disagreement; PA: partial agreement); (*) Taxonomic level: species groups.

Country	Ecosystem	N	Trend	Abundance	CPUE	Catches	Size	Composition	# Species	Taxon	Scientific data	Source
AFRICA												
Guinea	Coastal	178	C / I			D / S	D	Changed	06	Fish	No	[1]
Guinea-Bissau	Coastal	274	I	D					01	Fish (sawfish)	No	[2]
Mauritius Islands	Coastal	093	I			D	D	Changed	25	Fish	No	[3]
Red Sea (Eritrea, Sudan, Yemen)	Coastal	423	C		D	D			Several	Non specified	No	[4]
Seychelles	Coastal	040	I		D	D			Several	Fish	**Yes / DA**	[5]
Tanzania	Coastal	350	I			D	D	Changed	17	Fish, shrimp, squid, octopus(*)	No	[6]
ASIA												
Bangladesh	Freshwater	200	I			D			01	Fish	No	[7]
China	Coastal	400	I	D		D			02	Horseshoe, crabs	**Yes / AG**	[8]
China	Freshwater	599	C			D			03	Fish	**Yes / AG**	[9]
India	Freshwater	100	I	D					58	Fish, shrimp	No	[10]
Lao	Freshwater	120	I	D / S					08	Fish	No	[11]
UAE	Coastal	082	I	D					01	Fish (sawfish)	No	[12]
Vietnam	Coastal	077	C		D		S		06	Fish	No	[13]

Country	Ecosystem	N	Trend	Abundance	CPUE	Catches	Size	Composition	# Species	Taxon	Scientific data	Source
EUROPE AND CENTRAL ASIA												
Adriatic (Italy, Slovenia, Croatia)	Coastal	052	C / I	D			D		01	Fish (shark)	**Yes / AG**	[14]
Italy	Coastal	032	C / I	D / S / IC				Changed	59	Fish	No	[15]
Mediterranean (Spain, Italy, Greece)	Coastal	091	I	D / S / IC	D		D / S / IC		42	Fish, invertebrates (shrimp, lobster, mollusks)	No	[16]
Poland	Coastal	031	I	D			D		01	Fish	**Yes / AG**	[17]
Scotland	Coastal	062	I	IC	IC	IC			01	Fish	**Yes / AG**	[18]
Spain	Coastal	064	C			D	D	Changed	06	Fish	**Yes / AG**	[19]
Turkey	Coastal	176	C	D	D				Several	Non specified	**Yes / AG**	[20]
Turkey	Coastal	155	I	D					01	Shellfish	**Yes / AG**	[21]
NORTH AMERICA												
Canada	Coastal	020	I	D	D		D		1	Sea cucumber	No	[22]
Canada	Coastal	042	C	D / IC					16	Fish	**Yes / AG**	[23]
Canada	Coastal	038	C / I	D	D	D / S			1	Crab	**Yes / AG**	[24]
Canada	Coastal	042	I	D			D		1	Fish	**Yes / AG**	[25]
Mexico	Coastal	108	C			D	D		1	Fish	**Yes / DA**	[26]
Mexico	Coastal	127	C			D			2	Shellfish	**Yes / AG**	[27]
Mexico	Coastal	049	I			D			3	Fish	**Yes / AG**	[28]
Mexico	Coastal	081	I	D					22	Fish, shrimp, lobster, mollusks(*)	**Yes / AG**	[29]

Country	Ecosystem	N	Trend	Abundance	CPUE	Catches	Size	Composition	# Species	Taxon	Scientific data	Source
PACIFIC												
Australia	Coastal	0141	C			S			05	Fish, shrimp	Yes / PA	[33]
Indonesia	Coastal	0186	I	D				Changed	16	Fish (shark)	Yes / AG	[34]
Philippines	Coastal	2655	I		D	D		Changed	05	Fish	**No**	[35]
Philippines	Coastal	3446	I	D	D			S	Several	Fish	**No**	[36]
Philippines	Coastal	0025	C		S				01	Fish	Yes / PA	[37]
Tonga	Coastal	0029	I	IC					Several	Fish	Yes / DA	[38]
SOUTH AMERICA												
Brazil	Coastal	0081	C / I		D / IC	D / IC	D / S	Changed	08	Fish, crab, shrimp	No	[39]
Brazil	Freshwater	0203	C / I		D			Changed	15	Fish	No	[40]
Brazil	Coastal	0082	I		S			Changed	22	Fish	**Yes / DA**	[41]
Brazil	Freshwater	0041	I			D / IC	D / S	Changed	16	Fish	**Yes / PA**	[42]
Brazil	Coastal	0222	I	D			S		01	Fish	No	[43]
Brazil	Coastal	0240	C	D					01	Fish	No	[44]
Brazil	Coastal	0079	I				D		01	Fish (shark)	No	[45]
Brazil	Coastal	0034	C			D			04	Fish	No	[46]
Brazil	Coastal	0359	I	D					04	Fish	No	[47]
Brazil	Coastal	102	C / I			D	D		02	Fish	No	[48]
Brazil	Coastal	053	C				D / S		09	Fish	No	[49]
Brazil	Coastal	210	I	D / S		D	D		08	Fish	No	[50]
Brazil	Coastal	214	C			D	D		09	Fish	**Yes / AG**	[51]
Brazil	Coastal	022	C	D					01	Fish	**Yes / AG**	[52]
Brazil	Freshwater	182	I	D					01	Fish	**Yes / AG**	[53]

Country	Ecosystem	N	Trend	Abundance	CPUE	Catches	Size	Composition	# Species	Taxon	Scientific data	Source
SOUTH AMERICA												
Brazil	Freshwater	300	I	D / IC					14	Fish, shrimp	**Yes / AG**	[54]
Chile	Coastal	123	C / I			D	D	Changed	03	Fish	**Yes / AG**	[55]
Colombia	Coastal	046	C	D		S			01	Fish	**Yes / DA**	[56]

Sources: **[1]** (Maia *et al.*, 2018); **[2]** (Leeney & Poncelet, 2015); **[3]** (Bunce *et al.*, 2008); **[4]** (Tesfamichael, Pitcher, & Pauly, 2014); **[5]** (Tim M Daw *et al.*, 2011); **[6]** (Katikiro, 2014); **[7]** (Jahan *et al.*, 2017); **[8]** (Liao *et al.*, 2019); **[9]** (Turvey *et al.*, 2010); **[10]** (S. Dey *et al.*, 2019); **[11]** (T. N. E. Gray *et al.*, 2017); **[12]** (Jabado *et al.*, 2017); **[13]** (Stocks *et al.*, 2019); **[14]** (Fortibuoni *et al.*, 2016); **[15]** (Ernesto Azzurro *et al.*, 2011); **[16]**(Damalas *et al.*, 2015); **[17]** (Figus *et al.*, 2017); **[18]** (P. Macdonald *et al.*, 2014); **[19]** (Coll *et al.*, 2014); **[20]** (Ulman & Pauly, 2016); **[21]** (Öndes, Kaiser, & Güçlüsoy, 2020); **[22]** (O'Regan, 2015); **[23]** (Boudreau & Worm, 2010); **[24]** (Ban *et al.*, 2017); **[25]** (Eckert *et al.*, 2018); **[26]** (Sáenz–Arroyo *et al.*, 2005); **[27]** (Sáenz-Arroyo & Revollo-Fernández, 2016); **[28]** (Lozano-Montes *et al.*, 2008); **[29]** (Ainsworth, 2011); **[30]** (Rehage *et al.*, 2019); **[31]** (Frezza & Clem, 2015); **[32]** (Beaudreau & Levin, 2014); **[33]** (Thurstan *et al.*, 2016a); **[34]** (Jaiteh *et al.*, 2017); **[35]** (Lavides *et al.*, 2016); **[36]** (Muallil, Mamauag, Cababaro, *et al.*, 2014); **[37]** (O'Donnell *et al.*, 2012); **[38]** (Webster *et al.*, 2017); **[39]** (Santos Thykjaer, dos Santos Rodrigues, Haimovici, & Cardoso, 2019); **[40]** (G. Hallwass *et al.*, 2019); **[41]** (Damasio *et al.*, 2015); **[42]** (Strieder Philippsen *et al.*, 2017); **[43]** (Barbosa-Filho *et al.*, 2020); **[44]** (de Souza Junior, Nunes, & Silvano, 2020); **[45]** (Giglio & Bornatowski, 2016); **[46]** (I. M. Martins, Medeiros, Di Domenico, & Hanazaki, 2018); **[47]** (Jimenez *et al.*, 2019); **[48]** (Giglio *et al.*, 2015); **[49]** (Bender *et al.*, 2013); **[50]** (C. Zapelini *et al.*, 2019); **[51]** (Bender *et al.*, 2014); **[52]** (Cleverson Zapelini, Giglio, Carvalho, Bender, & Gerhardinger, 2017); **[53]** (Leandro Castello, Arantes, Mcgrath, Stewart, & Sousa, 2015); **[54]** (Gustavo Hallwass *et al.*, 2013); **[55]** (Godoy *et al.*, 2010); **[56]** (Castellanos-Galindo *et al.*, 2018).

amongst community members, data comparisons with archival and spatial data, and sampling techniques intended to identify the most robust knowledge holders. It is also quite common to search for points of comparison between indigenous and local knowledge/ local ecological knowledge and scientific knowledge. For example, more than half (29) of the reviewed studies included conventional scientific databases, such as biological sampling, fish catches, or governmental monitoring, which were compared with data gathered from fishers **(Table 3.3)**. Although disagreements or partial agreements were observed in eight studies, most studies (21) showed high levels of agreement between trends based on local ecological knowledge and those based on scientific data **(Table 3.3)**. This further reinforces the usefulness and reliability of fishers' local ecological knowledge to evaluate temporal trends in fisheries.

Other studies integrated fishers' local ecological knowledge and conventional scientific data in models to show fisheries trends (Ainsworth, 2011; Ban *et al.*, 2017). A few studies also analyzed and observed temporal changes in the composition of fishing resources **(Table 3.3)**, usually indicating a shift from the exploitation of more valuable large fish to less valuable smaller fish (Coll *et al.*, 2014; Godoy, Gelcich, Vasquez, & Castilla, 2010; G. Hallwass *et al.*, 2019; Jaiteh, Hordyk, Braccini, Warren, & Loneragan, 2017; Strieder Philippsen, Minte-Vera, Okada, Carvalho, & Angelini, 2017) or the disappearance of some species altogether (Damasio, Lopes, Guariento, & Carvalho, 2015; Katikiro, 2014; Lavides *et al.*, 2016). These temporal changes in catch composition **(Table 3.3)** suggest that fisheries may have experienced 'ecological filters' in some freshwater and marine ecosystems, indicating genetic selection through specific forms of harvesting activities. The extent to which species diversity or specific species characteristics are affected in this way is uncertain.

Some of the reviewed studies have also provided useful information based on fishers' local ecological knowledge related to drivers or consequences of observed trends, including protected areas (Hallwass *et al.*, 2020), environmental impacts including dams or pollution (S. Dey, Choudhary, Dey, Deshpande, & Kelkar, 2019; Frezza & Clem, 2015; Gustavo Hallwass, Lopes, Juras, & Silvano, 2013; Jahan, Ahsan, & Farque, 2017; Strieder Philippsen *et al.*, 2017), climate change (Ernesto Azzurro, Moschella, & Maynou, 2011; Eckert *et al.*, 2018), distribution and ecology of invasive species (Araujo Catelani, Petry, Mayer Pelicice, & Azevedo Matias Silvano, 2021; Ernesto Azzurro & Cerri, 2021; Boughedir *et al.*, 2015; van Putten *et al.*, 2016), or trophic cascades associated with fishing (Boudreau & Worm, 2010; Ulman & Pauly, 2016).

Literature based on fishers' local ecological knowledge provides relevant and new data about many ecological parameters of fisheries including reproduction (season, sizes, sites), migratory behavior, spatial distribution, conditions, and trophic relationships (Aswani & Hamilton, 2004; Begossi, Salivonchyk, Lopes, & Silvano, 2016; Begossi *et al.*, 2011, 2019; Figus *et al.*, 2017; Gaspare *et al.*, 2015; Gerhardinger, Marenzi, Bertoncini, Medeiros, & Hostim-Silva, 2006; Hamilton, Giningele, Aswani, & Ecochard, 2012; Johannes, Freeman, & Hamilton, 2000; Le Fur, Guilavogui, & Teitelbaum, 2011; Leite & Gasalla, 2013; Lopes, Verba, Begossi, & Pennino, 2019; Mclean & Forrester, 2018; Nunes, Cardoso, Soeth, Silvano, & Fávaro, 2021; Nunes, Hallwass, & Silvano, 2019; Silva *et al.*, 2019b; Silvano & Begossi, 2012; Silvano, MacCord, Lima, & Begossi, 2006). Fishers' knowledge has also contributed to participatory spatial planning to map bycatch potential of endangered species, such as sea turtles by artisanal fisheries in the coast of Mexico (Cuevas, Guzmán-Hernández, Uribe-Martínez, Raymundo-Sánchez, & Herrera-Pavon, 2018) or to assess bycatch rates and mortality of the Ganges River dolphins *(Platanista gangetica gangetica)* (Dewhurst-Richman *et al.*, 2020). These ecological data provided by fishers could also be useful to assess sustainability of small-scale fisheries and improve their management.

A promising way forward to better integrate fishers' local ecological knowledge and provide needed data about poorly known small-scale fisheries includes collaborations with fishers. This could include participatory monitoring that facilitates fisher involvement in abundance surveys and recording catch, size and information on reproduction of fisheries resources, and occurrence of bycatch (Begossi, Salivonchyk, & Silvano, 2016; Cuevas *et al.*, 2018; Dias, Cinti, Parma, & Seixas, 2020; Keppeler, Hallwass, Santos, da Silva, & Silvano, 2020; Keppeler, Hallwass, & Silvano, 2017; Obura, Wells, Church, & Horrill, 2002; O'Donnell *et al.*, 2012; Schemmel *et al.*, 2016; Silvano, 2020; Silvano & Hallwass, 2020; Webster *et al.*, 2017).

3.3.1.4.3 Pelagic fisheries for forage fish

Small pelagic fish populations, also called forage fish, such as sardine, capelin, anchovy, herring and mackerel, provide about 25% of the total annual production of capture fisheries worldwide (FAO, 2020d). These resources contribute significantly to the well-being of coastal communities around the world, particularly in developing countries. Small pelagic fish are plankton feeders and represent the main prey items for several predators (piscivorous fish including sharks, mammals and birds), and play a key role in marine ecosystems by sustaining numerous higher trophic level species, many of which are commercially targeted (Alder, Campbell, Karpouzi, Kaschner, & Pauly, 2008; Bakun, Babcock, Lluch-Cota, Santora, & Salvadeo, 2010; Essington *et al.*, 2015; Smith *et al.*, 2011). Fisheries for small pelagic fish have a high economic value because of their use for human consumption and for the production of fish meal and fish oil. These fisheries are not only critically important in terms of future global food security but are also pivotal to the economies of small-scale fisheries communities (Pikitch *et al.*, 2014). It has been estimated that fisheries supported by forage fish are actually more than twice as valuable as forage fisheries themselves, providing a strong economic argument for their conservation (Pikitch, 2015).

Populations of small pelagic fish exhibit extreme fluctuations in abundance and geographic distribution due to the impact of environmental factors, which are often amplified by anthropogenic influences (Essington *et al.*, 2015; Izquierdo-Peña, Lluch-Cota, Hernandez-Rivas, & Martínez-Rincón, 2019; Stephenson & Smedbol, 2019). The exploitation of many stocks of pelagic fishes has exhibited a pattern of sharply increasing catches followed by an even more rapid decline **(Figure 3.23)**, leading in several cases to closure of the fishery (Stephenson & Smedbol, 2019). Nonetheless, Froehlich *et al.* (2018) calculated the maximum sustainable yield for 401 stocks that comprise 99% of global forage fish catch, and estimated that the average small pelagic fish catch could increase by 30% from 2012 levels, which would correspond to raising the average (post-1980) small pelagic fish limit by 1.8 million tons per year.

3.3.1.4.4 Pelagic fisheries for billfishes, tuna and tuna-like species

Fisheries targeting tuna and tuna-like species and billfishes are of great socioeconomic importance due to high economic value and extensive international trade and are therefore highlighted in the sustainable use assessment. Tuna accounts for over 9% of total marine fisheries catch, is the fourth most valuable globally traded fishery product, and is about 8% of the 129 billion United States dollars value of internationally traded fishery products (FAO, 2014d, 2018d). Fisheries targeting these species provide substantial economic revenue, employment and food security to fishing and coastal states (Bell & Secretariat of the Pacific Community, 2011; FAO, 2018d; Gillett, 2009).

Tunas and billfishes have been an important food source since ancient times, and are target species of fisheries worldwide (Majkowski, 2007; Miyake, Guillotreau, & Sun, 2010). In the 19th century, most tuna fisheries were coastal, conducted by locally-based fleets (Majkowski, 2005, 2007). Industrial tuna fisheries began in the 1940s. Over the next few decades, fishing grounds quickly expanded as did the number of countries with large-scale coastal and distant-water tuna fleets. About 82% of world tuna is consumed as canned product, and 18% as fresh product (including as sashimi) (Miyake *et al.*, 2010). Japan consumes an estimated 78% of the fresh tuna (Miyake *et al.*, 2010). Demand for both canned and fresh tuna has increased rapidly, with reported landings of principal market tunas increasing from about 700 thousand tons in 1960 to almost 4.8 million tons in 2014 (SPC, 2015) **(Figure 3.24)**.

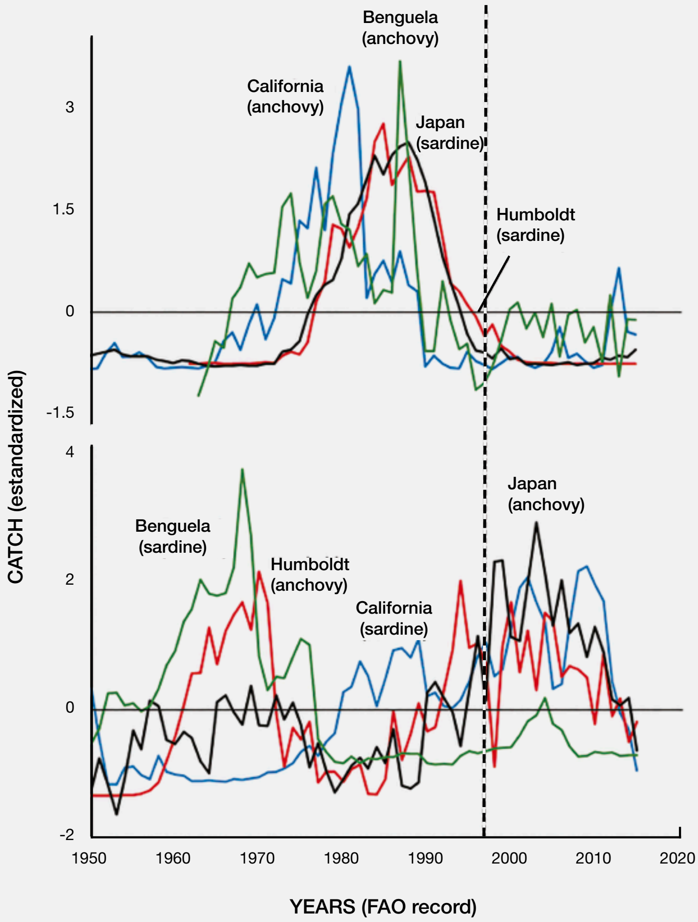

Figure 3 23 **Standardized catch time series for sardines and anchovies from the four largest small pelagics fisheries: Japan, Humboldt, Benguela, and California ecosystems.**

Data from the Food and Agriculture Organization of the United Nations' fishstat data base. Source: (Izquierdo-Peña *et al.*, 2019)

Since 2006, over half of principal market tunas have come from the western and central Pacific Ocean (SPC, 2015). Several Pacific Island countries and territories obtain a large proportion of their gross domestic product through revenue from tuna fisheries, as high as 63% of total government revenue in some cases (Aqorau, 2009; Bell *et al.*, 2015; FFA, 2015; Gillett, 2009). This includes licensing, fees, and granting access to foreign purse seine and longline tuna fisheries to fish in their exclusive economic zones. Capture and processing practices generate additional revenue and substantial employment in the Pacific Islands (Bell *et al.*, 2015; FFA, 2015; Gillett, 2009). In 2014, the Pacific sslands forum fisheries agency (15 Pacific small islands developing states, Australia and New Zealand) obtained an estimated 556 million United States dollars of their combined gross domestic product from the tuna fisheries, and employed over 22,000 people in processing and various other tuna-practice related positions (FFA, 2015). Some locally-based tuna fisheries supply largely low-value fishes (smaller tunas, incidental tuna-like species) to local markets in Pacific Island countries and territories, contributing to local food security and tourism industries (Bell *et al.*, 2015; Gillett, 2009).

Single-stock assessment models are the most common approach used by fisheries management authorities to assess the sustainability of stocks of principal market species of tuna, tuna-like species and billfishes. The four regional fisheries management organizations for tropical tunas have recently adopted and implemented single-stock harvest strategies. The main elements of harvest strategies are outlined in the following literature: (Sainsbury, 2000; WCPFC, 2014).

The status of most but not all stocks of principal market tunas and billfishes is relatively certain (ISSF, 2020; Juan-Jordá, Mosqueira, Freire, & Dulvy, 2013; Pons *et al.*,

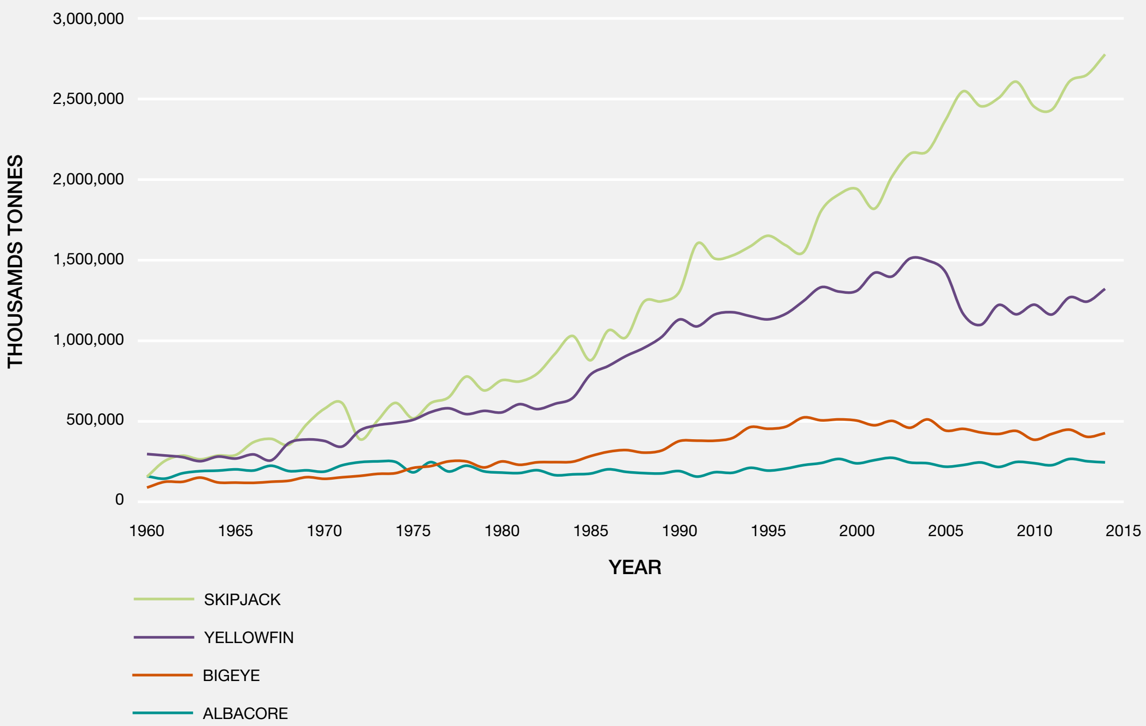

Figure 3 24 **Global reported landings of principal market species of tunas by region, 1960–2014.**

Source: (Gilman, Allain, Collette, Hampton, & Lehodey, 2016; SPC, 2015) © 2016 International Union for Conservation of Nature and Natural Resources, CC-BY.

2017). Direct mortality caused by pelagic marine fisheries is the main driver of reductions in the size and abundance of pelagic apex predators, including target stocks and incidentally caught species. Many target species are considered to be above limit thresholds and near targets. However, as discussed earlier in this chapter, the fisheries that catch these principal market species also intentionally or accidentally capture species that are highly vulnerable to anthropogenic mortality sources. There is extremely high uncertainty of the status of stocks and populations of these other species.

Fisheries that target tuna and tuna-like species, billfishes and other relatively fecund species can have large impacts on incidentally caught species that, due to their lower reproduction rates and other life history traits, are relatively vulnerable to increased mortality. This includes seabirds, sea turtles, marine mammals, elasmobranchs and some teleosts (Branch, Lobo, & Purcell, 2013; E. L. Gilman, 2011; M. A. Hall, Alverson, & Metuzals, 2000). Pelagic fisheries selectively remove individuals based on certain traits (e.g., behavioral traits for boldness; life-history traits for size-at-age; physiological traits for visual acuity; morphological traits for mouth dimensions), reducing intraspecific genetic diversity and altering fitness and evolutionary processes (Heino, Díaz Pauli, & Dieckmann, 2015; Hollins *et al.*, 2018). Fishing gear can alter and damage habitat (Dagorn, Holland, Restrepo, & Moreno, 2013; Escalle, Brouwer, Phillips, Pilling, & PNA, 2017)). Thus, fisheries targeting large, highly migratory pelagic predators of high trophic levels (total lenght > 4.0) indirectly modify trophic food web structure and processes and functionally-linked systems (J. A. Estes *et al.*, 2011; Pace, Cole, Carpenter, & Kitchell, 1999; Polovina, Abecassis, Howell, & Woodworth, 2009; J. Stevens, 2000; Ward & Myers, 2005). At this latter broad level, there is limited understanding of what magnitudes of interacting natural (e.g., large scale climate variability) and anthropogenic pressures (including from fishing) cause pelagic ecosystems to reach a tipping point where they undergo a protracted or permanent regime shift, and how altered components of the state of pelagic ecosystems affect functionally-linked systems (**Box 3.3**; (Ortuño Crespo & Dunn, 2017; Pace *et al.*, 1999).

Of the 23 stocks of the seven principal market tuna species, 9 have biomass levels that are below a level estimated to produce maximum sustainable yields or similar thresholds. The fishing mortality rate exceeds a maximum sustainable yield-based or similar reference point, indicating that the stock is not rebuilding its biomass, or both (ISSF, 2016).

Box 3 3 Ecosystem effects resulting from combined natural and anthropogenic impacts and their influence on the fisheries.

Although populated and exploited since the Neolithic, the Black Sea has undergone dramatic ecosystem changes in the last half century, mainly related to anthropogenic impacts such as uncontrolled fishing, cultural eutrophication and invasions by alien species. Fisheries collapses, harmful algal and jellyfish blooms, benthic community loss, and upper shelf hypoxia have had dire consequences for ecosystems and human livelihood depending on them. Recent research studies (G. Daskalov, 2003; Daskalov *et al.*, 2017; Oguz & Gilbert, 2007) have demonstrated that these major changes resulted from synergistic effects of climate forcing, trophic interactions and anthropogenic pressures (overfishing, eutrophication and introduction of invasive species).

Historical trends in fishing and environmental change in the Black Sea

Following the development of the fisheries, the pelagic top-predators have declined by the early 1970s in the Black Sea. For instance, the large population of dolphins diminished about tenfold through overexploitation (Özturk, 1996; Sirotenko, Danilevskiy, & Shlyakhov, 1979). Before 1970, the fishery targeted mainly large, valuable migratory species, such as bonito, mackerel, bluefin tuna and swordfish. All of these important fisheries collapsed mainly due to heavy and unregulated fishing (Daskalov, Demirel, Ulman, Georgieva, & Zengin, 2020; Daskalov, Prodanov, & Zengin, 2008). In the early 1970s, the stocks of planktivorous fishes (sprat, anchovy and horse mackerel) increased considerably and became a target for the industrial fishery (Barange *et al.*, 2009). Their increase in biomass and catch promoted the expansion of powerful trawl and purse seine fishing fleets and a steady increase in fishing effort (Gucu, 1997). The highest catch and fishing mortality were recorded in the late 1980s, but biomasses of exploited populations were declining due to recruitment failures in the previous years. Sharp reductions in biomass and catch in the early 1990s were described as stock collapses (Daskalov *et al.*, 2008). After 1990, the fishing effort decreased and a slow recovery of small pelagic fishes occurred during the 2000s (Daskalov *et al.*, 2017). Starting in the 1970s several human activities further induced a deterioration of the environmental conditions. Intensive bottom trawling on the shelf provoked dispersal of sediment, which severely decreased water transparency, and its re-sedimentation buried demersal life under thick silt layer (Samyshev & Rubinstein, 1988). Increased nutrient loading from rivers and coastal sources (Zaitsev & Mamaev, 1998) favoured frequent plankton blooms, equally contributing decreasing transparency and ventilation leading to benthic life kills. The degradation of massive phytoplankton blooms by aerobic bacteria that pump oxygen from the water further promoted hypoxia, especially near the bottom. By the 1990s, biological invasion of the ctenophore *Mnemiopsis leidyi* (brought in ship ballast water) has contributed to depletion of zooplankton and collapses of small pelagic fisheries (Knowler, 2005).

Driving factors and mechanisms of trophic cascades and regime shifts

Ecosystem shifts cascading down from top-predators to primary producers and affecting water quality were registered along the 1970s and 1990s (Daskalov *et al.*, 2008). The first shift followed the depletion of top predators from the 1950–1970, after which the ecosystem stabilized at low abundance of top predators, high abundance of planktivores, low zooplankton biomass and high phytoplankton biomasses during the 1970s and 1980s. The second shift was associated with the collapse of planktivorous fish and outburst of *M. leidyi* in the early 1990s, which resulted in a second system-wide trophic cascade, with similar alternating effects on zoo- and phytoplankton, and on water chemistry. Overfishing was recognised as the structuring factor affecting not only fish stocks, but the whole ecosystem and held responsible for the system shifts to unhealthy states (Daskalov *et al.*, 2008). Overfishing also contributed to hypoxia by cascading increase of phytoplankton and subsequently bacteria activity. Regional and global climate change, eutrophication, and invasive species were also reported to synergistically contribute to ecosystem shifts (Daskalov *et al.*, 2017; Oguz & Gilbert, 2007).

Effects of trophic cascades and regime shifts on fisheries

The cascading shifts have affected the whole food web from top-predators to primary producers, with repercussions on water chemistry (Daskalov *et al.*, 2008). The environmental degradation has naturally affected fish stocks and fisheries relying on them (Daskalov *et al.*, 2008; Zaitsev & Mamaev, 1998). The effect of 1970s trophic cascade on fisheries catches has been positive as small pelagic stocks boomed after being released from predation. The 1990s shift however entrained small pelagic stock and fisheries collapses and substantial socio-economic losses (Knowler, 2005). Although recovery of previous states is unlikely, some components of the ecosystem have been subject to partial recoveries (Daskalov *et al.*, 2017). The overall state on the marine environment has improved with the reduction of the nutrient load, partial control over *M. leidyi*, and more intense turnover rates related to warmer sea water. Following reduction in the fishing pressure, stocks and catches of small pelagic species recovered to intermediate levels, but large valuable species such as turbot, bonito and bluefish remain scarce according to historical abundances. Current single-species based management practices seem insufficient to deal with consequences of ecosystem regime shifts. At present the existing management bodies at national and international levels fail to implement ecosystem-based management. Recovery of resilient ecosystems should mean restoring all important components (including top-predators) into a desirable state with reduced anthropogenic impacts, normalized species interactions, buffered trophic cascades, increased biodiversity and improved environmental quality. This ecosystem state would provide strategic benefits, such as a clean marine environment, abundant and diverse fish stocks and sustainable economic activities (e.g., fishing, tourism), to a range of stakeholders and society as a whole.

Most tuna stocks are either under-exploited or fully-exploited, dominated by skipjack, albacore and yellowfin tunas. As discussed above, while the use of some of these principal market species is considered sustainable when assessed against certain metrics such as the FAO's definition of overexploited (3.3.1), vulnerable species bycatch accompanies the fishing activity. As political attention to problematic bycatch in marine capture fisheries has increased over recent decades, more resources have been allocated to assess the status of incidentally captured stocks and populations that are of relatively high risk, including, for example, silky and oceanic whitetip sharks, false killer whales, leatherback and loggerhead sea turtles, and several pelagic seabirds including albatrosses and large petrels. These assessments have included semi-quantitative ecological risk assessments using productivity-susceptibility analysis that informs the relative risk of affected stocks and populations, and quantitative, model-based and data-intensive stock assessments and population models that provide information on the absolute risks to affected stocks and populations.

The International Union for Conservation of Nature Red List global species-level categorizations do not provide information on the status of individual populations/stocks. Of the 61 species belonging to Suborder Scombroidei, species assessed against the International Union for Conservation of Nature Red List criteria, 13% were listed as Threatened and 7% as Near Threatened (Collette *et al.*, 2011; IUCN, 2014). Of the Scombroidei, Pacific bluefin, Southern bluefin, Atlantic bluefin and bigeye tuna were categorized as Threatened. The characteristics that these four species of threatened tunas have in common are long generational lengths, longer-lived and later maturity. When combined these traits results in longer time to recover from population declines (Collette *et al.*, 2011). These threatened tuna species also have higher economic values per unit of weight relative to the other market tunas (Miyake *et al.*, 2010).

While there were some early concerns over their application to exploited fishes this largely reflects a misunderstanding of how the criteria work (Mace & Hudson, 1999; Reynolds & Mace, 1999). The International Union for Conservation of Nature Red List assessments are global in scale whereas fisheries assessments are regional in scale and hence these different assessment processes are used for different purposes. However residual concerns about the applicability of the International Union for Conservation of Nature criteria have been refuted by extensive empirical evidence that consistently show strong alignment and harmony with fisheries management reference points, based on simulations using data from the global population dynamics database (Connors, Cooper, Peterman, & Dulvy, 2014) and multiple global meta-analyses of all fisheries stock assessments (e.g. Davies & Baum, 2012; d'Eon-Eggertson, Dulvy, & Peterman, 2015; P. G. Fernandes *et al.*, 2017; Porszt, Peterman, Dulvy, Cooper, & Irvine, 2012). The greatest concerns were raised for the highly fecund broad cast-spawning fishes, yet the International Union for Conservation of Nature Red List categories and criteria have been shown to highly aligned with fisheries assessment. As a result, marine fishes assessed by the International Union for Conservation of Nature as being Endangered or Critically Endangered are consistently fished beyond target and limit reference points (Dulvy, Jennings, Goodwin, Grant, & Reynolds, 2005; Simpfendorfer & Dulvy, 2017). For species that are not subject to fisheries assessments, the International Union for Conservation of Nature assessments offer valuable information on the need for fisheries management (ICES, 2018).

3.3.1.4.5 Whaling

Aquatic mammals are an important hunting target species for subsistence, culture and identity of some indigenous and local communities (IWC, 2021; S. L. Newell & Doubleday, 2020) **(Box 3.4)**. Across South America and West Africa hunted aquatic mammals includes 33 small cetaceans and all three manatee species (Cosentino & Fisher, 2016; Porter & Lai, 2017). The vast majority of whales hunted for aboriginal subsistence in the United Kingdom of Denmark, Norway and Iceland (**Figure 3.25A**, (International Whaling Commission, 2021)) are common minkes. Besides, Greenland (United Kingdom of Denmark) has been conducting aboriginal subsistence whaling targeting fin, bowhead and humpback whales as well as commercial whaling targeting narwhal and other small cetaceans. Faroe Islands (United Kingdom of Denmark) has been conducting the drive fishery targeting pilot whales. Norway and Iceland have been conducting commercial whaling on fin whales. In these countries local hunters often sell whale meat to foreign tourists or in European Union markets (Eklund T., 2017). Indigenous communities in the Russian Federation mostly hunt the gray whale (IWC, 2019a) and in the United States of America, the bowhead whale (IWC, 2019b). In India, Pakistan and Sri Lanka cetaceans are also hunted (often illegally) for use as bait in other fisheries (Porter & Lai, 2017).

Aquatic wild species can also be utilized on a commercial basis **(Figure 3.25)**. Since 1982, the International Whaling Commission which regulates commercial whaling has maintained a "zero quota" on commercial whaling (with the exception of catches set by countries under objection or reservation) because of historical overexploitation and the challenge of managing whaling sustainably. The organization currently has 88 members. Japan suspended commercial whaling in 1988 and began whaling for scientific research in 1987 to gather population data in accordance with the paragraph 10e of the Schedule of the International Convention for the Regulation of Whaling (Cosentino &

Box 3 4 Small-scale indigenous whaling in the North.

Many northern Indigenous peoples continue traditional whale hunting, a practice dating back centuries or more (Stoker & Krupnik, 1993). Whaling provides substantial quantities of food, is a central part of community activities and culture, and a source of fulfillment and identity (Sakakibara, 2020). Collaborative hunts and sharing of the products promote social cohesion, an essential component of thriving in a challenging environment (Huntington *et al.*, 2021). In some places whale products are sold in local markets, which occasionally creates conflicts among users (Sejersen, 2001), but rarely leading to excessive exploitation. The legacy of large-scale commercial whaling continues to affect some whale populations in the Arctic, but most stocks appear to have recovered and concerns about unsustainable takes at present are limited (Givens & Heide-Jørgensen, 2021; NAMMCO, 2018).

The bowhead whale (*Balaena mysticetus*); (Huntington *et al.*, 2021; Suydam & George, 2021) is hunted primarily by Iñupiaq and Yupik whalers in Alaska under a quota of 67 whales per year established by the International Whaling Commission based on population status and also cultural need. An annual hunt is conducted by Inuit in Nunavut of about one whale per year, with the hunt rotating among communities. The bowhead is also occasionally hunted in Chukotka, Russia, and in Greenland. The beluga whale *(Delphinapterus leucas)* is hunted in Greenland, Canada, Alaska, and Chukotka by Inuit, Inuvialuit, Gwichin, Iñupiat, Yupik, Yup'ik, and Chukchi. Worldwide, over 1000 beluga are taken per year on average, and the hunt is regarded as sustainable in nearly all locations (Hobbs *et al.*, 2019; NAMMCO, 2018). The narwhal *(Monodon monoceros)* is hunted in Canada and Greenland by Inuit (Lee, 2017). The worldwide annual harvest is similar to that for beluga whales and is considered sustainable for most populations currently hunted (Hobbs *et al.*, 2019; NAMMCO, 2018). Chukchi and Yupik whalers in Chukotka hunt about 125 gray whales per year (*Eschrichtius robustus*; (IWC, 2019a)) under an Illegal Whaling Commission quota. The harvest is considered sustainable. In 1999, Makah whalers in the American state of Washington resumed a cultural tradition of gray whale hunting that had been interrupted by colonization and its disruptions, but since 2002 domestic regulations have prevented the hunt from taking place (IWC, 2019b). In Greenland (IWC, n.d.), hunters take approximately 150 minke whales *(Balaenoptera acutorostrata)*, 11 fin whales *(Balaena physalus)*, and 7 humpback whales (*Megaptera novaeangliae*) per year. All of these Greenland large whale harvests are under an Illegal Whaling Commission quota and are considered sustainable. In addition to larger cetaceans, some dolphins and porpoises are taken in Arctic communities. Although not indigenous, Faroe Islanders in the North Atlantic hunt long-finned pilot whales *(Globicephala melas)* each year (Statbank, 2020), a small-scale traditional harvest dating back centuries, which has averaged around 650 whales per year over the last decade.

Fisher, 2016). In accordance with the provisions of the International Convention for the Regulation of Whaling (Article 8), all meat taken from whales caught for scientific whaling was processed and sold in stores and restaurants, and the proceeds obtained from the sales were used for the research activities in the following years in accordance with the direction by the Government of Japan. The International Court of Justice, using various criteria, ruled that Japan's whaling was not "for purposes of scientific research" as required by Article VIII of the International Convention for the Regulation of Whaling, and ordered Japan to immediately cease its JARPA II whaling program (JARPA II: second phase of Japan's whale research program under special permit in the Antarctic) (Clapham, 2015).

In 2019, Japan withdrew from the International Convention for the Regulation of Whaling, in line with Japan's basic policy of promoting sustainable use of aquatic living resources based on scientific evidence, and resumed commercial whaling after 31 years of suspension (Holm, 2019). Norway and Iceland are members of the International Whaling Commission, but have continued to commercially hunt whales either under objection to the moratorium decision or under reservation to it (IWC, 2021). The Russian Federation has also objected to the moratorium, but has not resumed whaling. Countries members of the Illegal Whaling Commission that take whales are obliged to provide statistical, scientific and other pertinent information to the International Whaling Commission. While the Western North Pacific stock of common minke and Bryde's whales are confirmed by the Illegal Whaling Commission Scientific Committee to be relatively abundant, abundance estimate of North Pacific stock of sei whale is still under examination by the Illegal Whaling Commission Scientific Committee although it has been substantially recovered. Thus, sei whales as a whole are still classified as endangered by the International Union for Conservation of Nature.

In 2018, despite a substantial number of opposition, the International Whaling Commission adopted a resolution which reaffirms "that the moratorium on commercial whaling, which has been in effect since 1986, has contributed to the recovery of some cetacean populations, and aware of the cumulative effects of multiple, existing and emerging threats to cetacean populations such as entanglement, bycatch, underwater noise, ship strikes, marine debris and climate change" and "agrees that the role of the International Whaling Commission in the 21st century includes inter-alia its responsibility to ensure the recovery of cetacean populations to their pre-industrial levels, and in this context reaffirms the importance in maintaining the moratorium on commercial whaling" (**Figure 3.25 A, B** and **C**).

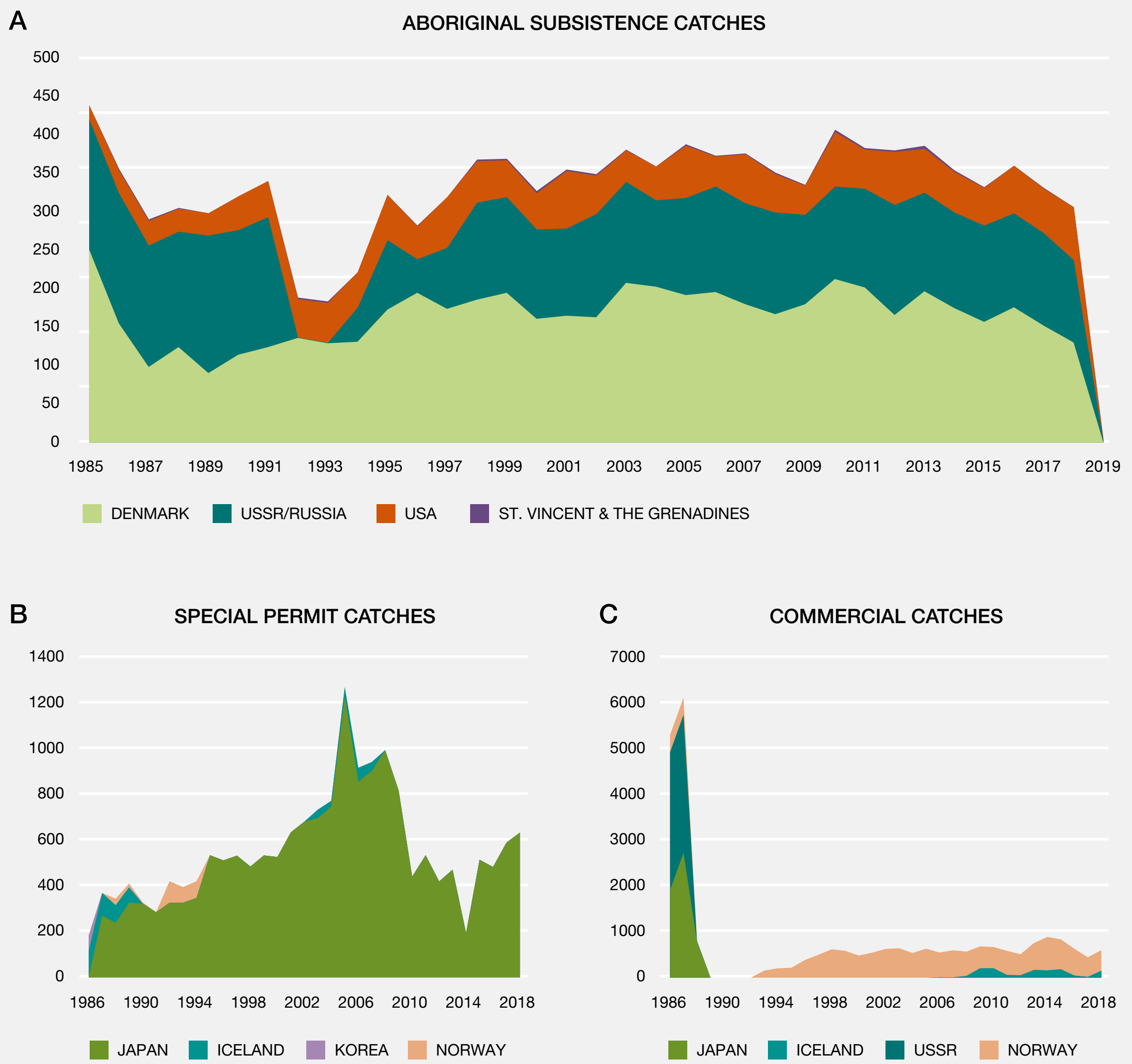

Figure 3 25 **Global catches of whales according to the International Whaling Commission, 1985–2018.**

(A) Aboriginal subsistence catches **(B)** special permit catches **(C)** commercial catches taken under objection or reservation. CC-BY-NC. See data management report for the figure at https://doi.org/10.5281/zenodo.6453071.

3.3.1.4.6 Industrial demersal fisheries in coastal areas

The status of demersal fisheries in temperate countries is well documented in the RAM Legacy Stock Assessment Database (Christopher Costello *et al.*, 2016; RAM Legacy Stock Assessment Database, 2018; Ricard *et al.*, 2012), where approximately 53% of global reported catch is counted. Those consist of three dominant taxonomic groups, gadids (cod, haddock, pollock and hake), pleuronectids (flatfish), and sebastids (rockfish). While many of these fisheries underwent a historical phase of overexploitation, recent evidence suggests that many of these fisheries have been managed since the 1990s and 2000s in ways that reduced fishing mortality rates (Christopher Costello & Ovando, 2019). In many cases these measures improved stock status (Hilborn & Ovando, 2014; B. Worm *et al.*, 2006) and increased biomass to the point that some authors now focus on underfishing of some key stocks (Hilborn, 2019). The **Figure 3.26** shows the trend in abundance and fishing mortality for these species in temperate areas (Europe, North America, Japan, Chile, New Zealand and Australia). Stock abundance tends to be above the level that would produce long-term maximum sustainable yield and fishing pressure is lower. This has resulted in increasing general stock abundance **(Figure 3.26)**.

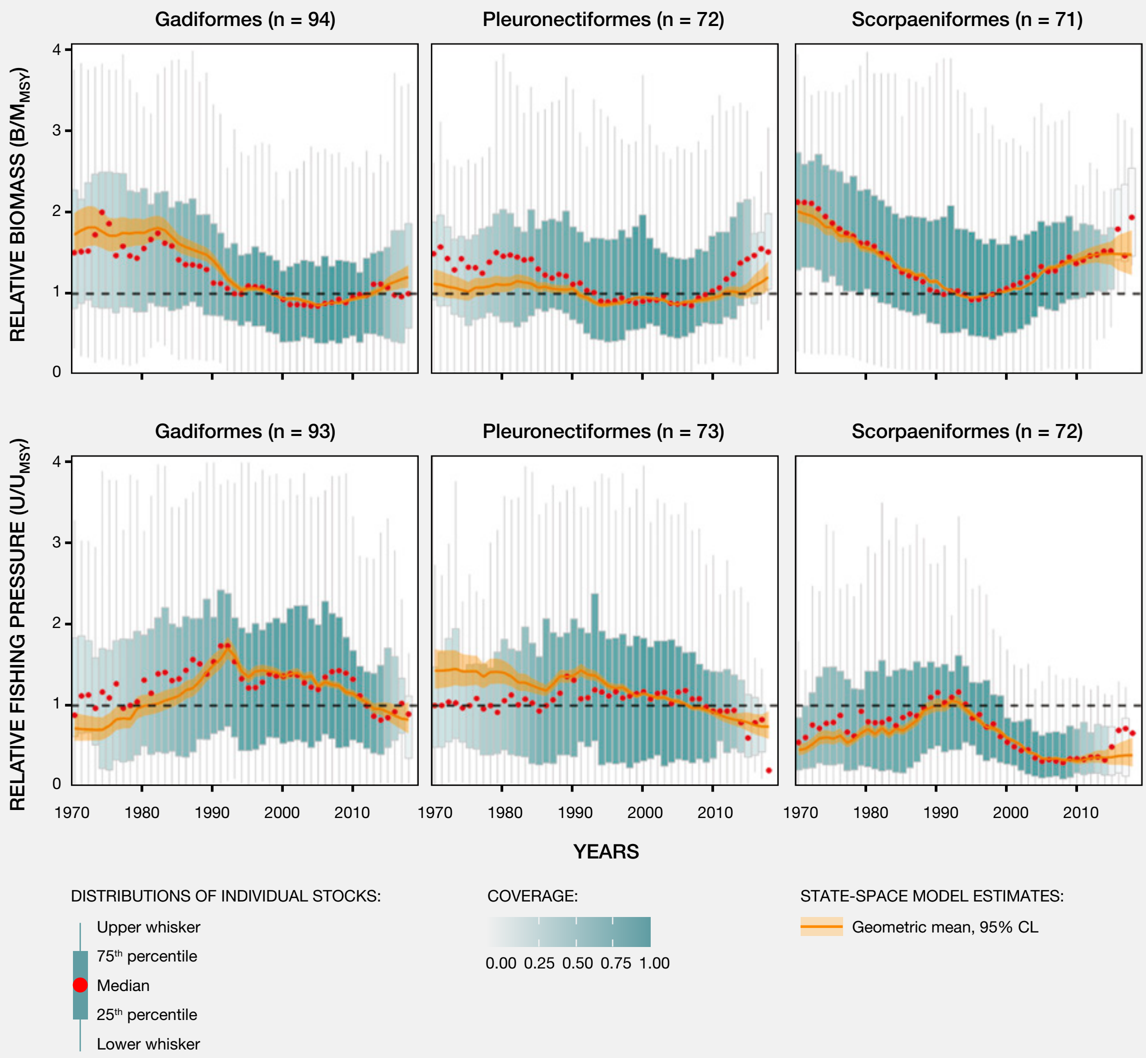

Figure 3 26 **Stock abundance trends.**

These figures describe the trend in ratios of B/Bmsy (Biomass relative to the biomass that produces Maximum Sustainable Yield), U/Umsy (Fishing pressure or mortality relative to the fraction of the population harvested), and catch/(mean catch) across assessed stocks in the taxonomic group. Source: (Hilborn *et al.*, 2021) under license CC-BY_NC-ND 4.0.

The status of demersal fisheries in the rest of the world is much less documented. A quarter of the remaining global reported catch has undergone some form of data-limited stock assessment (FAO, 2016b) while 22% remains unassessed, with little information about population status or risk of over-fishing (Christopher Costello & Ovando, 2019). These data limited stocks make up an increasing proportion of globally reported catch over time, from 20% to 47% in the last 60 years (Vasconcellos & Cochrane, 2005). From two areas for which information is available, the Mediterranean and Western Africa, the evidence is that these stocks are very heavily exploited and almost certainly over-fished and subject to over-fishing (Hilborn *et al.*, 2020).

The demersal species from the regions not well covered in the RAM Legacy Stock Assessment database, along with the small pelagic fisheries of the same regions, constitute the dominant component of the unassessed fish stocks of the world.

Most of those demersal stocks belong to coastal fisheries which contribute much, if not most, of global catches, but quantitative estimates of the extent of their contribution depend on how coastal fisheries are defined, especially in relation to small scale fisheries. Palomares and Pauly (Palomares & Pauly, 2019) used the “Sea Around Us” reconstructed catch database (Zeller *et al.*, 2016) to

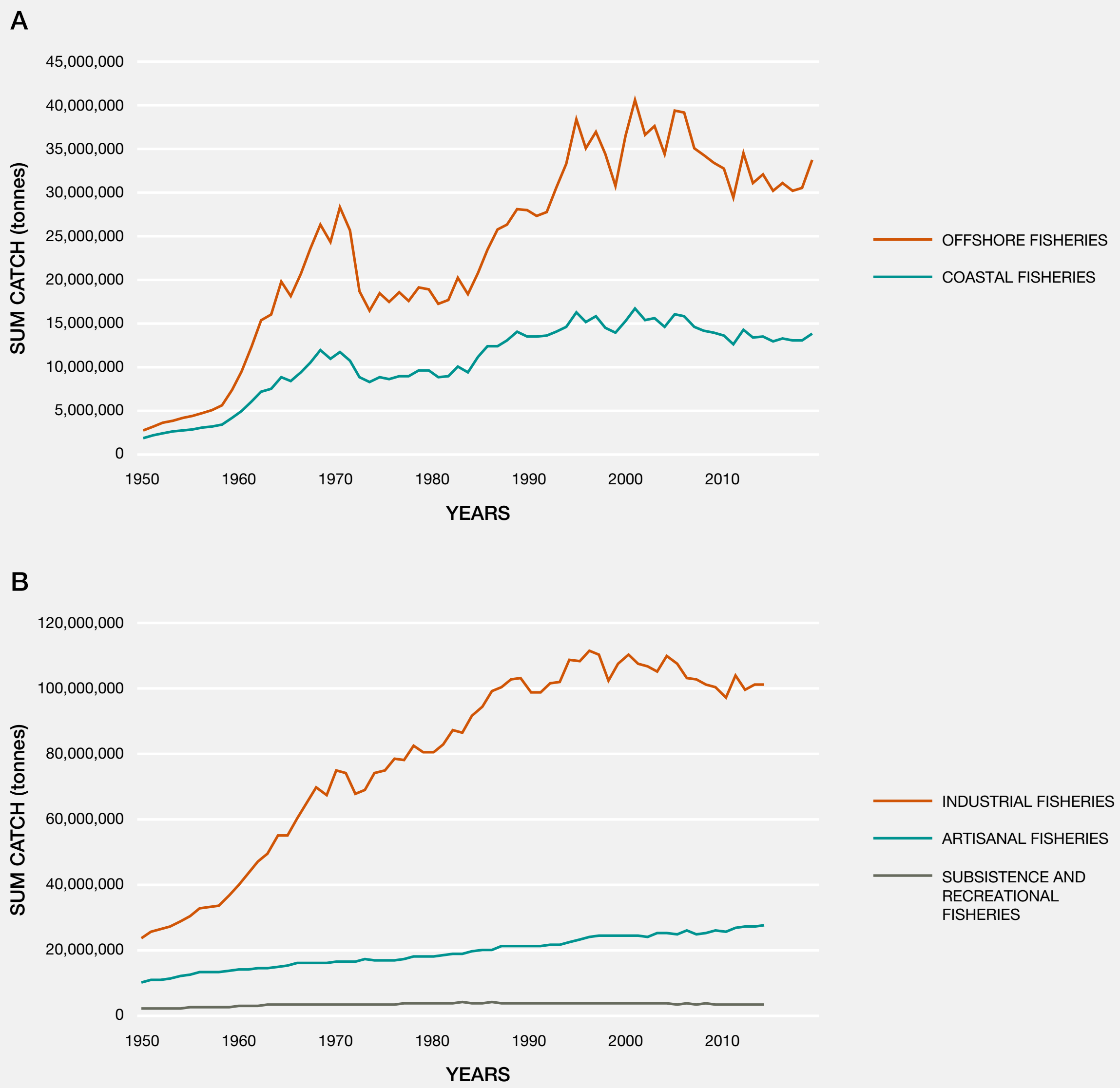

Figure 3 27 **Catches from 1950–2014 of (A) the world's marine fisheries (B) coastal fisheries.**

Areas <=50 km from inhabited coastlines or to a depth of <=200 m. Based on (Palomares & Pauly, 2019) under license number 5278770226780. CC-BY NC.

estimate the catch in an area at most 50 km from inhabited coastlines or down to a depth of 200 m **(Figure 3.27)**, considered to be the area in which small scale fisheries (artisanal, subsistence, and recreational) are located. Coastal fisheries made up an average of 55% of global marine fisheries in the 5-year period from 2010 to 2014, while small-scale fisheries in the same period contributed 36% of the marine catches consumed directly by people **(Figure 3.28)**.

Lower-income countries lack the capacity to industrially harvest fish populations off their shores, and thus frequently host foreign fishing fleets through fishing access agreements or joint venture operations (Belhabib *et al.*, 2015; Kaczynski & Fluharty, 2002). The higher capacity and improved technology of higher-income nations has enabled these countries to build and operate distant water fishing fleets, and often to subsidize those fleets heavily (Sala, Aburto-Oropeza, Reza, Paredes, & López-Lemus, 2004; Dirk Zeller & Pauly, 2019). Describing fishing patterns of those industrial fleets in comprehensive and quantitative terms is challenging due to the lack of open access to detailed records on the behavior of fishing vessels. However, McCauley *et al.*, (McCauley *et al.*, 2018) produced fishing patterns of industrial fishing vessels (>24m) based on high-resolution fishing vessel activity information derived from automatic

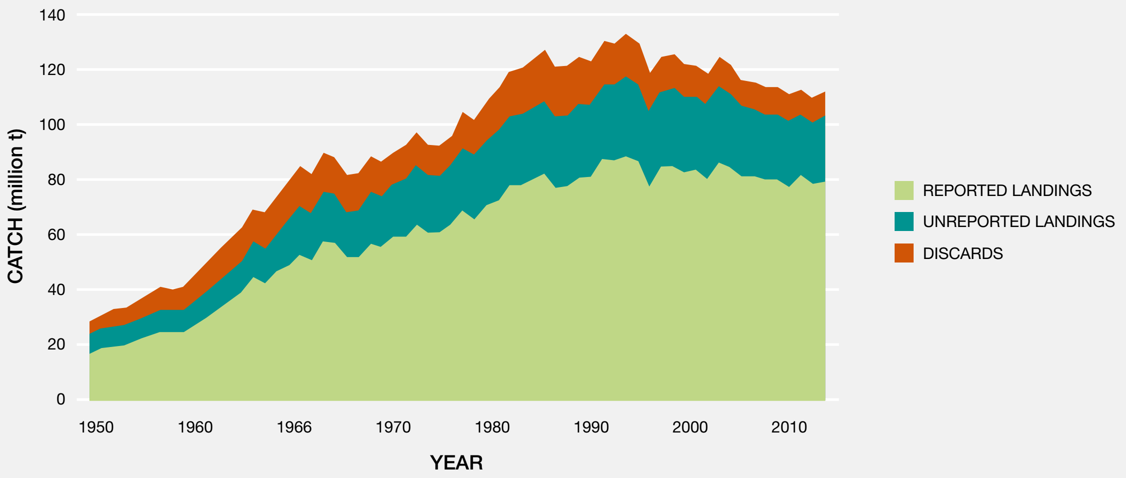

Figure 3 28 **Global catch data as reported to the Food and Agriculture Organization of the United Nations by fishing countries.**

Reported catch: black line) (1950–2016). Source:(Dirk Zeller, Cashion, Palomares, & Pauly, 2018) under license CC-BY NC.

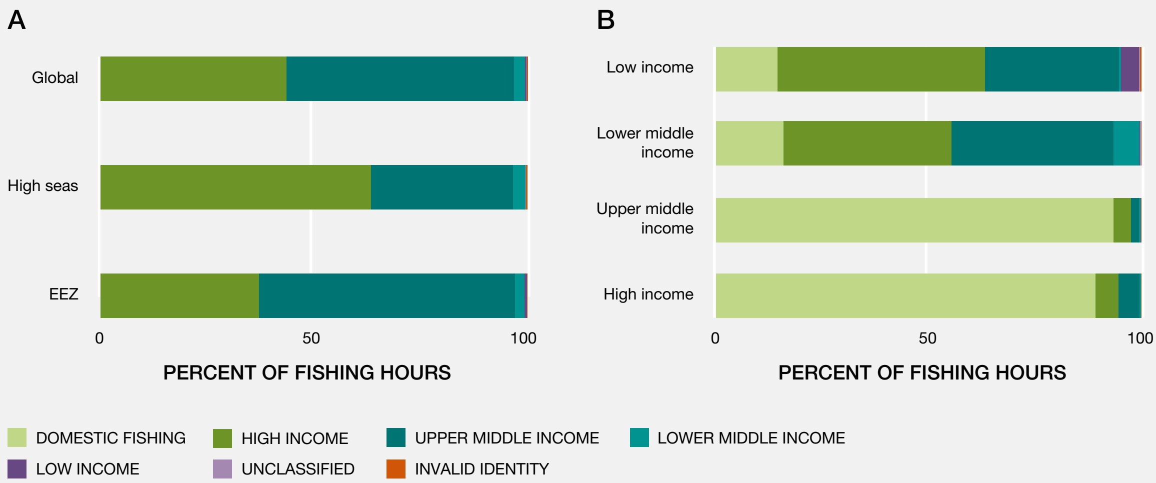

Figure 3 29 **Distribution of industrial fishing effort by vessels flagged to nations from different income classes as measured using automatic identification systems data and convolutional neural network models.**

(A) The percent of fishing effort (measured in fishing hours) detected globally on the high seas and in all exclusive economic zones for vessels flagged to nations from four different World Bank income groups. **(B)** The percent of automatic identification systems-detected industrial fishing effort in all exclusive economic zones, grouped by the World Bank income groups of the exclusive economic zones. Here, the category Domestic fishing is included, which refers to instances when a fishing country was fishing in its own exclusive economic zone. Other categories represent foreign fishing effort conducted within an exclusive economic zone by a nation flagged to one of the four World Bank income classes. "Invalid identity" refers to vessels with a Maritime Mobile Service Identity (MMSI) number that did not accurately refer to an individual country. "Unclassified" refers to fishing entities that were fishing in an exclusive economic zone but did not have a World Bank income group. All data presented here are summarized from the year 2016. Source: (McCauley *et al.*, 2018) under license CC BY 4.0.

identification systems data (**Figures 3.29** and **3.30**). Such patterns address one of the fundamental issues of fisheries sustainability, namely direct and collateral impacts by fishing gear on habitats, target and non-target species (Amoroso *et al.*, 2018, 2018; Lewison *et al.*, 2004a; Palomares & Pauly, 2019), directly related to the amount of gear deployed rather than to the amount of target yield extracted coming from catch data (Stewart *et al.*, 2010).

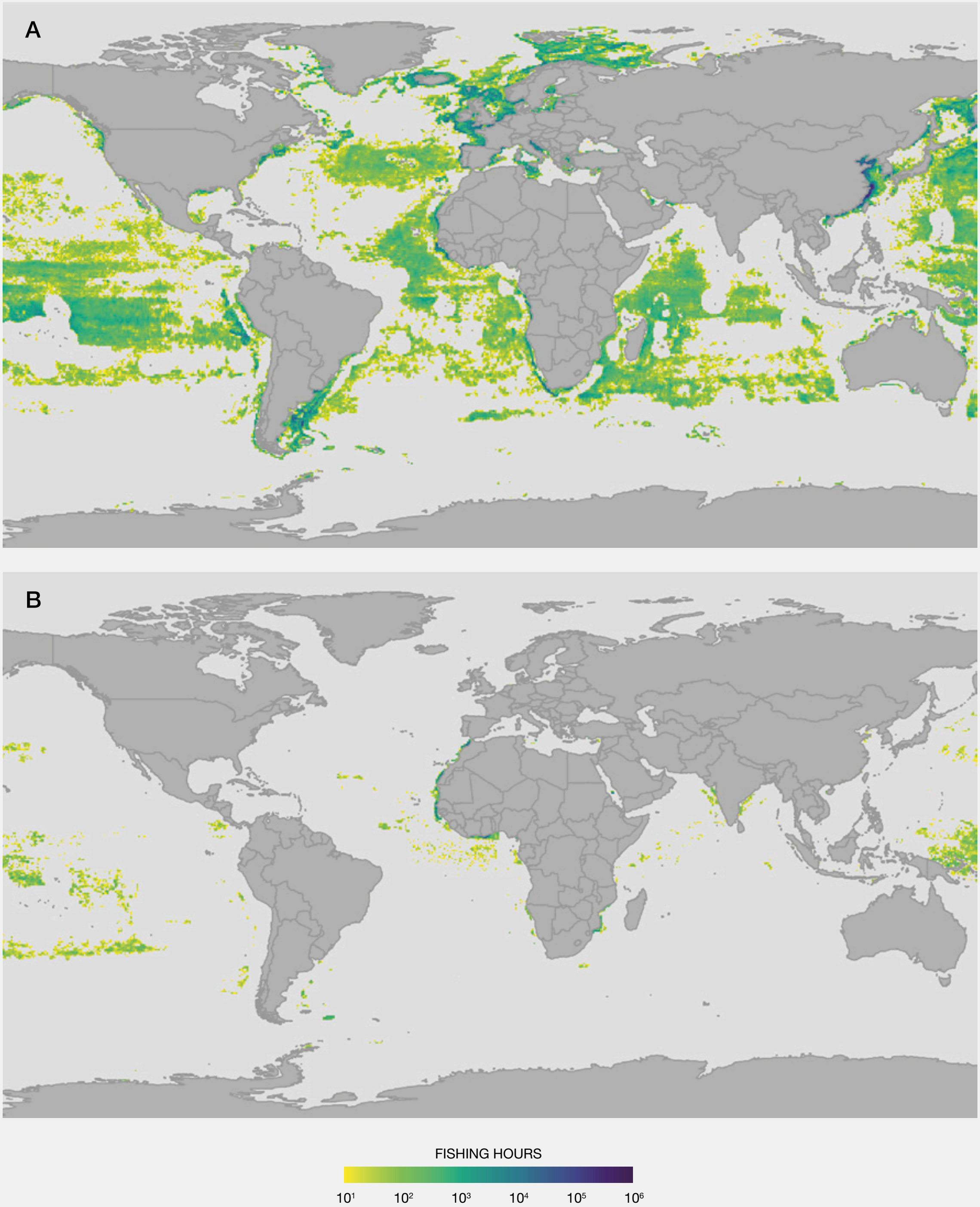

Figure 3 30 **Density distribution of global industrial fishing effort, derived using automatic identification systems data.**

(A) Vessels flagged to higher-income countries and **(B)** vessels flagged to lower-income countries. Industrial fishing effort is estimated using convolutional neural network models and plotted as the log10 number of fishing hours. *This map is directly copied from its original source (McCauley et al., 2018) and was not modified by the assessment authors. The map is copyrighted under license CC BY 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.*

The density distribution of global industrial fishing effort reveals global dominance of industrial fishing by wealthy nations (www.worldbank.org; using 2016 classifications). Vessels flagged to higher-income nations are responsible for 97% of the trackable industrial fishing on the high seas and 78% of such effort within the national waters of lower-income countries (McCauley *et al.*, 2018).

While legal, these arrangements raise many challenges regarding their sustainability and equity. For instance, the expected benefits of these partnerships, such as revenues and investments in local infrastructure and technologies, have not always materialized (Antonova, 2016; Crona *et al.*, 2016). Distant water fleets are also involved in illegal, unreported and unregulated fishing (Pauly *et al.*, 2014), which are considered as a serious threat to fisheries and fisheries-dependent communities, marine ecosystems and societies at large (Hutniczak, Delpeuch, & Leroy, 2019). Agnew *et al.* (2009) estimated that 11–26 million tons (from exclusive economic zones and high seas), or roughly one-quarter of the world catch of fish goes to illegal, unreported and unregulated fishing every year. The same authors found a correspondence between their regional estimates of illegal and unreported fishing and the number of depleted stocks in those regions. As exemplified in the case study in **Box 3.5**, the relationship between industrial fisheries, small scale fisheries, population status, food security, and livelihoods is a complex one indeed.

Box 3 5 Bottom trawling: assessing seabed habitat and biota impacts.

The recognition that sustainability of fisheries not only involves maintaining target stocks at productive levels, but also minimizing wider ecosystem impacts of fishing has turned increasing attention to the evaluation of the environmental footprint of different fishing methods. In particular, the use of bottom-contact mobile gears as a means of catching fish has sparked heated debates in fishery and conservation sciences. On the one hand, bottom trawling contributes close to 20 million tons of fish and invertebrates per year to the global food supply and provides food and livelihoods for millions of people as well as significant export revenues to many countries (Amoroso *et al.*, 2018). On the other hand, bottom trawling impacts seabed habitats, damaging biogenic structures and altering sediment composition and its biogeochemical dynamics, kills benthic organisms and alters ecosystem functions (Clark *et al.*, 2016; De Borger, Tiano, Braeckman, Rijnsdorp, & Soetaert, 2021; Hiddink *et al.*, 2017; O'Neill & Ivanović, 2016; Pusceddu *et al.*, 2014) (Pusceddu *et al.* 2014, Clark *et al.* 2016, O'Neill and Ivanović 2016; Hiddink *et al.* 2017, De Borger *et al.* 2021). Concerns about environmental impacts of bottom trawling have fueled strong public campaigns and resulted to its ban in some countries and regions. Less extreme approaches for reducing the negative impacts of trawling have been pursued, including changes in gear design and fishing operations, prevention of further expansion of trawled area, ocean zoning, bycatch and habitat quotas and the closure of large areas to protect sensitive habitats (McConnaughey *et al.*, 2020; Williams *et al.*, 2020). United Nations General Assembly Resolutions 61/105 (2007) and 64/72 (2010) required Regional Fisheries Management Organizations to identify vulnerable marine ecosystems on the seabed within their jurisdictions and ensure that fisheries did not cause serious adverse impacts to them. Of particular concern has been the expansion of trawling into deeper areas, leading for example to the ban on bottom trawling in deep waters (below 800 m) and in areas with vulnerable marine ecosystems (below 400 m) adopted by the European Union in 2016.

Assessments of the global and regional seabed impacts of bottom trawling require information on the distribution and intensity of trawling, the direct impact of the gear on the swept habitats and communities, and their capacity to recover from trawling disturbances (Mazor *et al.*, 2021; McConnaughey *et al.*, 2020; Pitcher *et al.*, 2017). A study using high-resolution satellite vessel monitoring system and logbook data on 24 continental shelves and slopes to 1,000-m depth (covering 7.8 million-km^2 in total) showed that 14% of the overall study area was trawled and 86% was not trawled (Amoroso *et al.*, 2018). However, the seabed proportion impacted by trawling varied markedly among and within regions, from less than 1% in southern Chile to a maximum of 80% in the Adriatic Sea and from areas (within region) trawled several times per year and others only disturbed sporadically. Trawling activity was aggregated; the most intensively trawled areas accounting for 90% of activity comprised 77% of footprint on average trawled (R. Amoroso *et al.*, 2018). In most heavily trawled areas of Europe a large fraction of the area (e.g., North Sea, West Iberia and Skagerrak and Kattegat) was trawled at least once per year, while more than half of the seabed was not trawled during the 2-6-year study period in 20 of 24 regions examined. Trawling footprints were also smaller in regions where fishing rates met sustainability benchmarks trawled (Amoroso *et al.*, 2018).

To evaluate biotic impacts, the frequency of trawling events further needs to be compared to the rate of recovery of the different types of organisms inhabiting seabeds. Recent meta-analyses of more than three decades of published results for sedimentary habitats have shown that the immediate mortality of animals in the path of the trawl is correlated with the penetration depth of the gear in the sediment, which vary with the type of gear (Hiddink *et al.*, 2017; Sciberras *et al.*, 2018). The most commonly used trawl gear (otter trawls) kills 6% of the biomass per pass, whereas the most destructive gear (hydraulic dredges) kills 41% of the seabed biota present. Estimated recovery rates after trawling ranged from 1.9 to 6.4 years on average, depending on the type of sediment, trawl gear and benthic species longevity (with longer-lived animals showing larger depletion effects in comparative studies (Hiddink *et al.*, 2019, 2017)). Repeated trawling would thus induce a

Box 3 5

shift toward species with faster life histories in communities exposed to frequent trawl events (Hiddink *et al.*, 2017; Jennings & Cotter, 1999). A reduction in median longevity of the community of close to 20% on average was estimated for the relatively heavily trawled North Sea (McConnaughey *et al.*, 2020). Selective effects linked to chronic trawling are likely to be much stronger for long-lived sessile epifauna, such as sponges and corals (Hiddink *et al.*, 2017).

By combining known distribution of trawl intensity from Amoroso *et al.* (Amoroso *et al.*, 2018) with predicted abundance distributions of different benthos groups for 13 diverse regions of the globe, Mazor *et al.* (2021) found that expected benthic community status ranged between 86% and 100% of untrawled status (mean 99%), with more than three-quarters of benthic groups predicted to be at 95% or more of their benchmarks. Mean benthos status was lowest in regions of Europe and Africa and for taxonomic classes Bivalvia and Gastropoda. Communities prevalent in sedimentary habitats of the continental shelves could thus sustain moderate levels of trawling, provided that target fishing mortalities are maintained within accepted sustainability benchmarks. Biogenic habitats, such as coral reefs, maerl beds and sea mounts habitats (not covered by (Hiddink *et al.*, 2017)) are nonetheless expected to be the much more sensitive to trawling impacts due to their long recovery times. The limited data available for long-lived habitat-forming species indicate that post-trawling recovery may take decades (Kaiser, Hormbrey, Booth, Hinz, & Hiddink, 2018; Williams *et al.*, 2010) and be unachievable within acceptable timeframes; spatial closures are therefore essential (Clark *et al.*, 2016).

The studies discussed above highlight the importance for policy analysis and implementation of collecting local data on the intensity and distribution of trawling, and the distribution of sediment types and vulnerable marine habitats. These data are needed to identify local best practices and most effective approaches to reduce habitat impacts of fishing, and to allow quantification of trade-offs between fish production for food and the environmental costs associated with different fishing methods and marine policies.

3.3.1.5. Uses of wild caught aquatic organisms

Regarding fishing practices, the following uses are well-documented in the literature and available data sources: food and feed (3.3.1.5.1), medicine and hygiene (3.3.1.5.2), recreational fishing (3.3.1.5.3), decorative and aesthetic (3.3.1.5.4), and ceremony and cultural uses (3.3.1.5.5). The following uses are not relevant to this practice or were not documented: energy, education and learning, and materials and shelter. With regards to non-lethal uses of wild aquatic organisms, a review of catch and release recreational fishing (3.3.1.6.1) and ornamental and aquarium fisheries (3.3.1.6.2) are included.

3.3.1.5.1 Food and Feed

Fish and seafood products are important for human diet, providing about 3.1 billion people with almost 20 percent of their average daily animal protein intake (Sunderland *et al.*, 2019). Human consumption of fish in 2018 totaled 96.4 M tons (FAO, 2020d). Of the landed catch of industrial fisheries, about 80% is used for direct human consumption, and close to 100% of the retained catch of small-scale fisheries is eaten by people (FAO, 2018d). It is important to note that some of these estimates include wild fish and farmed fish from aquaculture. For different indicators available at a global scale, especially fish consumption, much of the available literature does not clearly distinguish between farmed and wild caught fish. Further, in several data sets the information on both wild and farmed fish is so intricately mixed up that it is impossible to distinguish between the two. Indeed, this lack of clarity makes proper assessment of the sustainable use of wild fish species extremely challenging and presents a serious issue for accurate reporting and tracking. This issue is discussed in more detail in the knowledge gaps section (3.5). Thus, despite the focus of this assessment on wild species, assessment experts consistently evaluated the various material they reviewed in relation to two options: (i) select not to use available data and literature on farmed fish and exclude the state of the knowledge on this topic or (ic) include available data on farmed fish in combination with wild fish.

Since 1973, the global consumption of fish has doubled, due to increased demand in developed and developing countries (Delgado, International Food Policy Research Institute, & WorldFish Center, 2003; FAO, 2018d). Consumption grew from approximately 9.0 kg per capita in 1961 to 20.2 kg per capita in 2015, at an average rate of about 1.5 percent per year (FAO, 2018d). A higher rate of 2.4 percent is observed in developing countries for the same period. The growth of world per capita fish consumption from 18 kg in 2008 to 20 kg in 2013 was due to an increase in per capita consumption of freshwater & diadromous fish (migrate between freshwater and saltwater, example: salmon, eel, etc.), crustaceans and shell molluscs, whereas that of marine fish and cephalopods declined (Cai & Leung, 2017).

The importance of global fish production for nutrition and food security varies geographically across regions, countries, and communities dependent on fish at rates far above the global average **(Box 3.6)**. Some of the most fish-dependent populations are located in countries in which the contribution of fish is relatively low at the national level

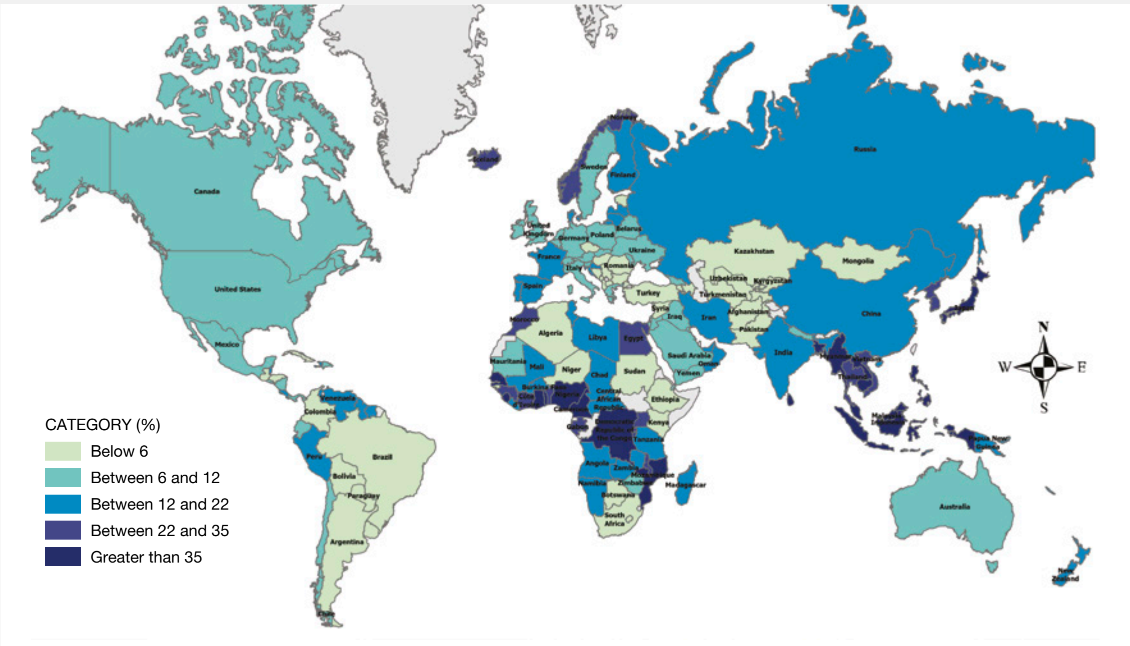

Figure 3 31 **Fish dependency around the world.**

This map is directly copied from its original source (Bennett et al., 2018) and was not modified by the assessment authors. The map is copyrighted under license CC BY 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

Box 3 6 Dried fish in Asian countries.

Dried fish is an important part of small-scale fisheries (FAO, 2018c; Kawarazuka & Béné, 2010) and includes fish that has been cured, dried, salted, brined, fermented, or smoked fish (see Supplementary material Table S3.1). These are often small and low market value fish from capture fisheries. Approximately 12% of fisheries are prepared and preserved, and 12% are cured. In some countries dried fish consumption is significantly higher (FAO, 2018c).

The voluntary guidelines for securing sustainable small-scale fisheries considers fishing and fish processing as important drivers of food security and poverty eradication (FAO, 2015). In Asia and Africa wide varieties of species are dried (Ruddle & Ishige, 2010), including many small pelagic species (Doe, 2017, see Supplementary material Table S3.1). In Bangladesh, dried fish are eaten more frequently than any other type of fish. The contribution of dried products to total fish consumption is disproportionately important for low-income consumers (Belton & Thilsted, 2014). Although dry fish is not cheap, the quantity needed for a meal is less and therefore economical and may explain popularity in rural areas (Samaranayaka, Perera, & Warnasuriya, 2013).

Dried fish contribute to food and nutrition security in both coastal and arid mountainous regions of low-income countries as they are a concentrated source of animal protein, rich in calcium and other micronutrients and fats, easily transportable and have a long self-life (Belton, Hossain, & Thilsted, 2018; Thilsted, James, Toppe, Subasinghe, & Karunasagar, 2014). For example, in Malawi, a serving of 24 g of small dried fish twice a day provides an intake of calcium, zinc and iron which is 327%, 152% and 22% higher, respectively than a daily diet without fish (R. S. Gibson & Hotz, 2001; Kawarazuka & Béné, 2010). Since low end processing activities are mostly done by women (Samanta, Bhaumik, & Patra, 2016), their control over family income directly affects household food security and nutritional outcomes (Kawarazuka & Béné, 2010). Women have been involved in the dried fish sector in developed countries and regions as well. Historically, and for centuries (until the 1960s) dried fish processing was a major activity in places such as Newfoundland and other Eastern North American locales and was undertaken significantly by women (Doe, 2017; Neis, 1999). Men were engaged in the pursuit and capture of fish; women in the spreading, turning and drying of fish. This produced food and income security for workers in this profession.

Box 3 6

Subsistence and artisanal fisherfolk communities in Asia mostly belong to socially and economically marginalized groups (Hapke, 2001), with those engaged in dried fish activity even more marginalized among fisher communities. Hence, the importance of wild marine species in life and livelihoods of the poorest of the poor is immense. At the same time the fisher communities draw life satisfaction by engaging in fishing activities they find challenging and skillfully providing them with a different identity (Nayak, Dias, & Pradhan, 2021).

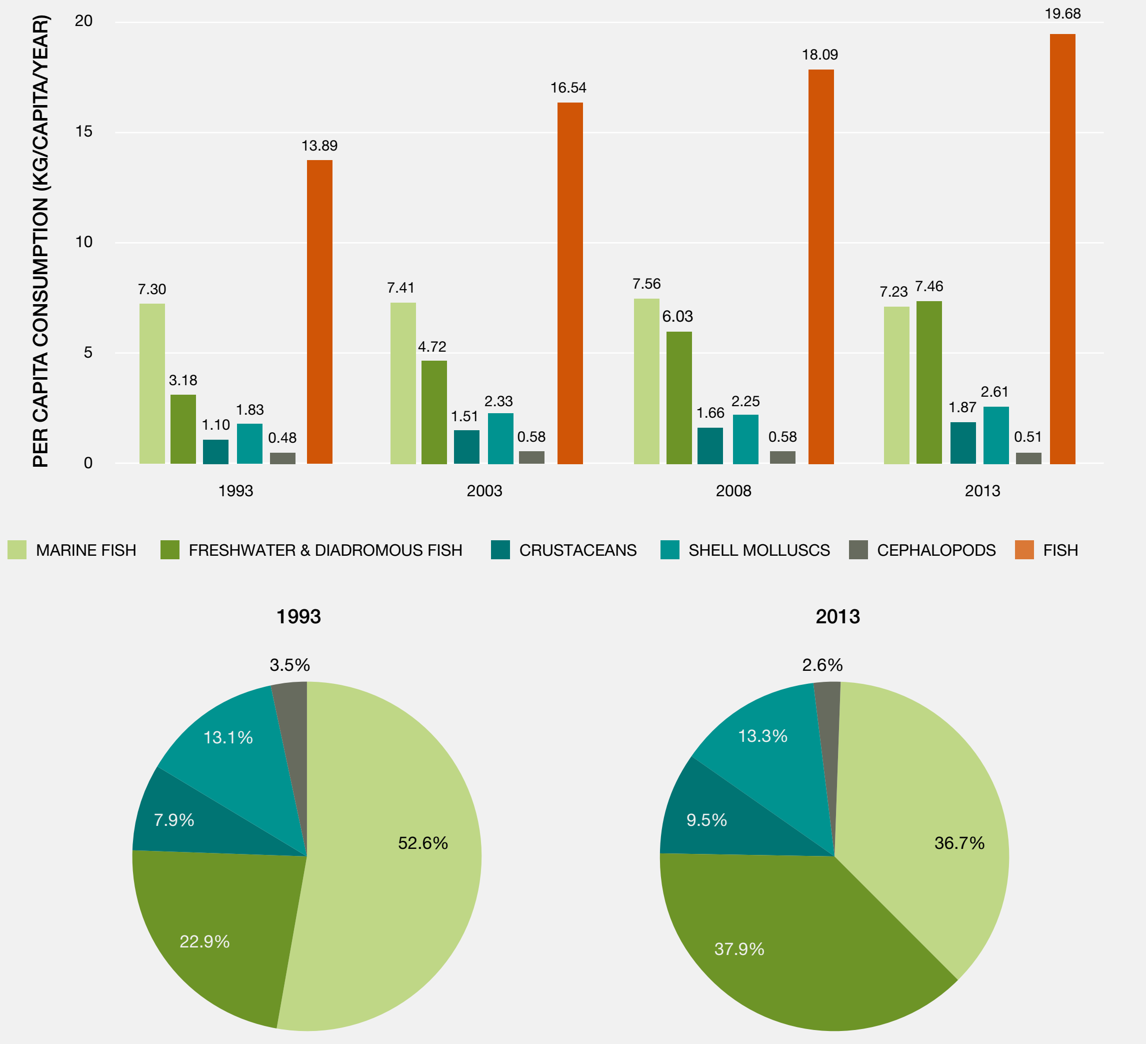

Figure 3 32 **Species composition of world per capita fish consumption.**

Source: (Cai & Leung, 2017) © FAO, 2017. CC-BY NC.

(Bennett *et al.*, 2018). At sub-national scales, individual communities can be almost entirely dependent on seafood for protein. Fish is crucial for coastal indigenous groups, who on average consume fish at a rate that is 15 times higher than the global average **(Figure 3.31)**.

Marine fish used to be the largest species group in world fish consumption, but its share declined from 53% in 1993 to 37% in 2013. Marine fish are still the dominant species consumed in many countries. Indeed, in 2013 marine fish accounted for more than half of fish consumption in more than 170 countries. Over the same period freshwater & diadromous fish consumption grew rapidly, increasing from 3.2 kg in 1993 to 7.5 kg in 2013 (A. Bennett *et al.*, 2018). Crustaceans accounted for nearly 10% of world fish consumption in 2013, increasing from 8% in 1993. Shell molluscs accounted for 13% of world fish consumption in 2013; nearly the same as in 1993. Cephalopods accounted for 2.6% in 2013; down from 3.5% in 1993 (Cai & Leung, 2017) **(Figure 3.32)**.

Hatchery-based aquaculture relies on the use of wild fish as feed. The share of fed species in total aquaculture production accounts for the majority (69.5%) of "food fish" production from aquaculture (Clavelle, Lester, Gentry, & Froehlich, 2019; FAO, 2018d). Capture-based mariculture depends on wild-caught juveniles for "seed," which are then raised and fattened in captivity (Boyd *et al.*, 2020; Ottolenghi *et al.*, 2004). This practice, sometimes referred to as "ranching," is widespread and an important source of production for many species, including tuna, shrimp, lobster, grouper and eels (Lorenzen, Leber, & Blankenship, 2010). However, no current estimates of the extent of capture-based mariculture exist.

Production of fed species depends on feeds containing high concentrations of proteins and lipids traditionally sourced from fishmeal and oil rendered from wild-caught forage fish, such as herring, sardines and menhaden (Tacon, Hasan, & Metian, 2011; Tacon & Metian, 2008b, 2008a, 2015). The total annual production of fish meal was 4.5 million tons, and the total annual production of fish oils was 0.9 million tons in 2016, of which 69% and 75%, respectively, were used in aquafeeds (Hua *et al.*, 2019). An additional 23% and 5% of this fish meal is used in pig and chicken feeds. The aquaculture industry is making important gains in improving feed conversion ratios, reducing the inclusion of fishmeal in feed and developing substitutes (FAO, 2016b; Klinger & Naylor, 2012; R. L. Naylor *et al.*, 2009). Nonetheless, the use of wild fish for feed by the aquaculture sector is increasing as a result of overall growth, intensification of farming practices, and from the rising share of higher trophic level species in total production menhaden (Tacon, Hasan, & Metian, 2011; Tacon & Metian, 2008b, 2008a, 2015) **(Figure 3.33A)**.

Forage fish have been captured and reduced into fishmeal and oil for decades (reduction fisheries), supporting production of terrestrially farmed species, such as pigs and poultry. Aquaculture did not become the dominant user of rendered forage fish until the 2000s, well after global catches of forage fish had plateaued (Shepherd & Jackson, 2013). These pelagic species now help support over 70% of aquaculture production (FAO, 2016b; Tacon & Metian, 2015) acting as feed for carnivorous species (for example, salmon, tuna) and increasingly non-obligate carnivores (for example, carps, shrimp) alike (Tacon & Metian, 2008b, 2015). The added demand from the rapid growth of aquaculture resulted in terrestrial husbandry substituting forage fish with alternative feed sources, reducing fishmeal and oil use by pigs and poultry to roughly 25% of total forage fish use **(Figure 3.33B)**.

To date, two factors have helped avoid resource limitations of forage fish affecting aquaculture growth. First, forage fish have become an increasingly smaller fraction of fish feed inputs over the decades, driven in part by price **(Figure 3.33C)**. Most aquaculture (and agricultural) feed is now largely crop-based (for example, soy), and this trend continues to increase **(Figure 3.33D)**. Additionally, some countries use trimmings (fish by-products) from aquaculture and fisheries, as well as other aquatic species, as forage fish alternatives **(Figure 3.33D)**. Second, aquaculture of selected species is continuously becoming more efficient, as measured by feed conversion ratios. Together, these factors contribute to lower fish-in-fish-out ratios (weight of forage fish used relative to fed cultured species produced).

The issue of fishmeal and oil use from aquaculture is continuing to raise diverging views and the sustainability of such practices remains dispersed in the literature (Natale, Hofherr, Fiore, & Virtanen, 2013). Cashion *et al.* (2017) underscore the concerns around directing ~20 million tons of wild fish every year towards feeding farmed fish, pigs and chickens instead of humans (Belton & Thilsted, 2014). Importantly, 90% of fish destined for uses other than direct human consumption are food-grade or prime food-grade fish (Cashion *et al.*, 2017). Tacon & Metian (2013) indicate that feed use of small pelagic fish competes with its use for food especially in developing countries. Much of the literature warns against aquaculture's reliance on forage fish, citing the fully exploited, over-exploited or recovering status of many forage fisheries (Rosamond L. Naylor *et al.*, 2000), though the current global amount being extracted appears below maximum sustainable levels (Froehlich *et al.*, 2018; Hilborn & Costello, 2018).

Switching from feed fish to direct human food would depend upon affordability and development of low-cost conserved products. A regional approach is needed to assess the consequences of using more feed fish for human consumption. While there are possible benefits of switching at least part of the catches of forage fish to food in South American countries, in Asia this is a less clearly understood, since cheap fish and trash fish contribute to the development of small-scale aquaculture, which reportedly has positive effects on livelihood and human consumption. In sub-Saharan Africa the effects would be limited since feed fisheries are an exception and aquaculture is not yet widespread or dependent on compound feed (Hasan & Halwart, 2009).

Nonetheless, the use of wild fish for feed by the aquaculture sector is increasing as a result of overall growth, intensification of farming practices, and the rising share of fed, higher trophic level species in total production (Tacon *et al.*, 2011; Tacon & Metian, 2008b, 2008a, 2009, 2015). Furthermore, fishmeal and oil are also used in terrestrial livestock feed, and their demand is increasing for pet food, and human food and medicine. Given current trends in aquaculture and demand for seafood and terrestrial meat, estimates suggest that ecological limits of forage fish could be reached as soon as 2037, or even sooner if precautionary measures do not further limit access to the wild resource (e.g., Atlantic herring, Clupea harengus, Clupeidae) (Froehlich *et al.*, 2018).

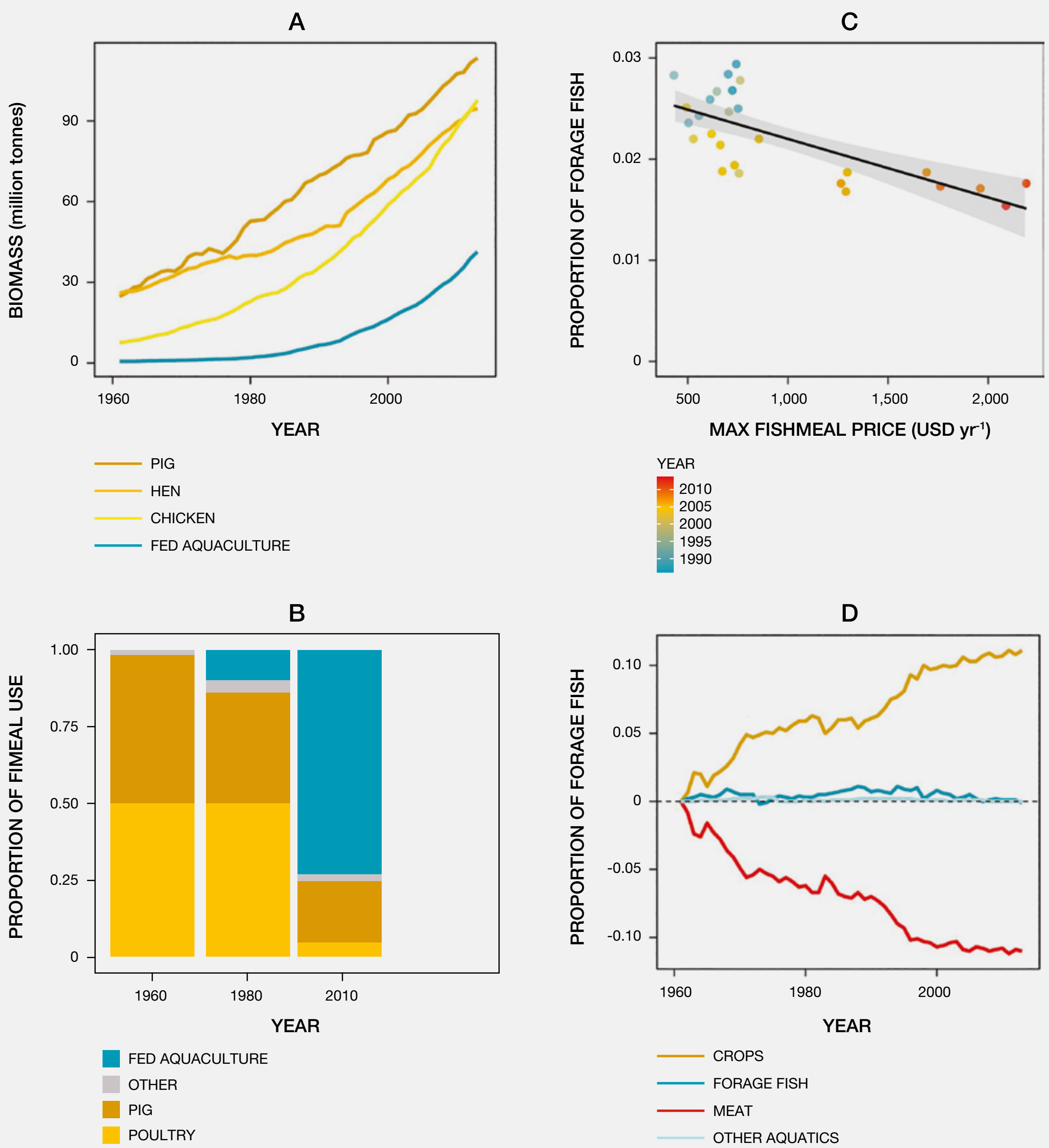

Figure 3 33 **Animal production (livestock, poultry and fed aquaculture species) and forage fish use trends.**

(A) Time-series of biomass of primary farmed animal groups (poultry and pig, fed aquaculture) that consume forage fish. **(B)** Proportion of fishmeal use by the primary consumer groups over time. **(C)** Proportion (mean ± 95% confidence interval) of forage fish in global feed relative to maximum fishmeal price per year (see color scale). **(D)** Difference in proportion of inclusion in total animal feed over time compared to 1961 for crops, forage fish (also depicted in panel C), other aquatic inputs and terrestrial meat-sourced contributions (by-products) in livestock and aquaculture feed, combined. Source: (Froehlich *et al.*, 2018) © 2018, Springer Nature under license CC BY-NC-SA 4.0.

Small Scale Fisheries contributing to Food and feed uses

This section was written following the methods used for the systematic review described in 3.3.1.3. (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

EUROPE AND CENTRAL ASIA

Small-scale fishing is still the most important component of commercial fishing in the European Union with special relevance in Southern Europe (Lloret *et al.*, 2018). It is a highly diversified fishery, involving fishing systems of many forms and sizes, and targeting a wide range of taxonomic groups. Small-scale fisheries in Europe are responsible for a catch equivalent to one large-scale fishery when it comes to human consumption (Leleu *et al.*, 2014). Traditional European small-scale fisheries are more than 2,000 years old (C. Antunes *et al.*, 2015), and data on some fisheries can be found as far back as 400 years (Marcos *et al.*, 2015). Stocks of small pelagic fish species and of larger demersal fish species have been exploited since the Middle Ages and are still important today (Almeida *et al.*, 2014; Bastari *et al.*, 2017; Battaglia *et al.*, 2017; Braga, Azeiteiro, Oliveira, & Pardal, 2017b). A number of local fish species exploited by European small-scale fisheries are famous worldwide, such as trout (Shephard *et al.*, 2019), cod (Dinesen *et al.*, 2019), anchovies and sardines (Sartor *et al.*, 2019).

As indicated by 47 out of the 63 papers reviewed, small-scale fisheries systems are often unsustainable, although varying levels of sustainability were observed in 30% of the papers (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). This applies equally to inland, coastal and marine/oceanic fishing. A number of studies described multi-faceted fishing systems, where some stocks were sustainably exploited while others were not. In 74% of the papers, focusing on broader analysis, and using long and consistent series of data (a set comprising 19 papers), unsustainability elements were still observed.

Approximately 10% of the reviewed papers report cases of partial sustainability and 16% report sustainable cases of small-scale fishing (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). The cases of sustainable fishing reported are mainly supported by enabling factors that reflect the adoption of sound management decisions and measures. These are systems that successfully controlled the fishing effort (Fourt *et al.*, 2020), and enforced the regulation of zones of use and no-use (no-take), determined by officially protected marine areas or estuaries (Antunes *et al.*, 2015; Guidetti & Claudet, 2010; Marengo *et al.*, 2015; Morales-Nin *et al.*, 2017).

The reported cases of unsustainability of small-scale fishing for food and feed are due to a larger and more diverse array of inter-related causes. Fishing pressure above the capacity of the stocks was mentioned by 41% of the papers. This leads to overfishing (either of the targeted species or of their prey species), catches above the maximum sustainable yield, or to the reduction in catch-per-unit-of-effort (Azzurro *et al.*, 2019; Corral & Manrique de Lara, 2017; Duncan *et al.*, 2016; Figus *et al.*, 2017; Lloret *et al.*, 2018; Quetglas *et al.*, 2016).

Overfishing may be a consequence of bad management practices, which was the second most frequently reported cause in the literature, mentioned in 22% of the reviewed papers. This includes ineffective control of fishing effort, incongruence between different management measures adopted simultaneously (Baeta *et al.*, 2018), adoption of dubious measures (Corral & Manrique de Lara, 2017), slow implementation of management measures (Colloca *et al.*, 2017), bad communication with the local fishers (Morales-Nin *et al.*, 2017), adoption of weak governance systems (Pita *et al.*, 2019) and competition between fishing modalities (Battaglia *et al.*, 2017; Carvalho *et al.*, 2017; Das & Afonso, 2017; Lloret *et al.*, 2018; Öndes, Kaiser, & Güçlüsoy, 2020). Environmental disturbances (14% of the papers) leading to the reduction of stocks, either by pollution, inadequate use of fishing gears or climate change were mentioned (Azzurro *et al.*, 2019; Braga *et al.*, 2018; Dinesen *et al.*, 2019; Pita *et al.*, 2019). Excessive discards or bycatch were also mentioned by a smaller number of papers (Öndes, Kaiser, & Güçlüsoy, 2020).

AFRICA

It is well established that most of the non-artisanal small-scale fishing in Africa is unsustainable (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). This general statement applies equally to inland, coastal and marine/oceanic fishing.

Small species dominate the African fishing practice for both food and feed that involves the inland and coastal fisheries driven by tradition, species displacement, and substitution (Jamu *et al.*, 2011). A transition from large piscivorous species to small omnivorous species took place during the last half century, when larger fish were almost extinguished from the catch as a result of increasing numbers of fishers, fishing fleets and gear efficiency. A limited number of high value species continue to be targeted, often for export and for higher prices in international markets. There are many cases in the literature reporting on local problems with foreign industrial fleets competing with small-scale fleets, and both affect the artisanal fishing systems. Consequently, these systems show many indicators of unsustainability, such as declining stocks, catches, average size of fishes, catch-per-unit-of-effort, and so on (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Many official fish landing data series available are underestimated, and important attempts for reconstruction are taking place. Researchers have tried to uncover records of unregulated artisanal catches to produce realistic series of data. These reconstructed series also show the same declining trends.

In comparison with commercial fleet fisheries, artisanal fisheries present more diverse scenarios and different trends (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Some artisanal fishery systems show signs of reduction of catch volume and size over the decades due to excessive fishing pressures (Dyhia Belhabib *et al.*, 2018; Tuda & Wolff, 2015), mainly because fishing pressure has stayed high. Control of fishing pressure is, sometimes, an inherent trait of a system. Systems based on indigenous and local knowledge use the available habitats and fishing grounds (Mirera *et al.*, 2013) to distribute fishing pressure among a large number of species, or to focus the pressure on specific cohorts or in specific times (Musembi *et al.*, 2019). All of these are effective measures of controlling effort and off-take.

LATIN AMERICA

In Latin America, almost all studies (99) analyze the use of fisheries resources as food, either for subsistence, commerce or both. Overall, 15% of these studies report sustainable use, 48% report unsustainable use (exploited populations declining and other sustainability problems), and 37% indicated partially sustainable use (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Considering 76 studies of coastal small-scale fisheries (including oceanic islands, bays and estuaries), about 13% (10 studies) mention sustainable use, while 53% indicate unsustainable fishing (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Among 23 studies on inland or freshwater small-scale fisheries, 22% indicate sustainable and 30% unsustainable uses, whereas the remaining majority of studies point to partially sustainable use, suggesting less data availability for inland fisheries compared to coastal cases (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Sustainable coastal small-scale fisheries examples include co-management systems through territorial rights granted to fishing communities and well-established rules to exploit mainly shellfish, oysters and lobsters in Chile and Mexico (Álvarez *et al.*, 2018; Castilla, Espinosa, Yamashiro, Melo, & Gelcich, 2016; De la Cruz-González *et al.*, 2018; Defeo *et al.*, 2016; Gelcich *et al.*, 2017, 2010). Some of these co-management systems were effective in supporting recovery of resources after a fishery collapse, such as the shellfish *Concholepas concholepas* in Chile (Castilla *et al.*, 2016; Defeo *et al.*, 2016; Gelcich *et al.*, 2010), *Atrina maura, A. tuberculosa, Pinna rugosa*, oyster *(Crassostrea iridescens)*, lobster and fish in Mexico (Álvarez *et al.*, 2018; De la Cruz-González *et al.*, 2018; (Palacios-Abrantes, Herrera-Correal, Rodríguez, Brunkow, & Molina, 2018).

In association with small-scale fisheries, a management strategy called "Territorial Users' Rights Fisheries management" (TURF) has been implemented with varying success in Chile (Defeo *et al.*, 2016; Gelcich *et al.*, 2010). For example, population and catches of the clam *(Mesodesma donacium)* declined over time after the establishment of a territorial users' rights fisheries system, causing the collapse of the clam fishery. However, this was at least in part due to management restrictions preventing fishers from moving fishing grounds to cope with natural variability of clam abundance (Aburto & Stotz, 2013). A study across 500 km of the Chilean coast indicates effects of displacement caused by Territorial Users' Rights Fisheries, which intensify fishing efforts and thereby reduce shellfish abundance in open access areas which have been reduced in size compared to surrounding areas which have entered into government management. This creates conflict and resource shortages for fishers not engaged Territorial Users' Rights Fisheries management (Garmendia *et al.*, 2021).

Other cases of sustainable coastal small-scale fisheries include two fish species *(Paralabrax nebulifer, Caulolatilus princeps)* that have been fished sustainably mostly because they are only occasionally fished, when preferable resources are unavailable in Baja California Sur, Mexico (Cavieses Núñez *et al.*, 2018). The sustainability of the important fishery of octopus *(Octopus maya)* in Yucatan (Mexico) is unresolved (Duarte, Hernández-Flores, Salas, & Seijo, 2018b; Raya & Berdugo, 2019). From one hand, the regulations, including fishing season, applied over 30 years and the interaction of fishing gear (baits) with the reproductive behavior of parental care without feeding performed by females, of may have contributed to maintain stocks of this octopus, even in face of intense fishing pressure (Duarte *et al.*, 2018a). However, an increased market demand and search for profit maximization may have pushed fishers to adopt a combination of legal and illegal, furtive, and undeclared fishing tacticts (including diving), which may undermine sustainability and threatens the long-term viability of the octopus' fishery in the Yucatan Peninsula (Raya & Berdugo, 2019). Most of the studies identifying partially sustainable coastal small-scale fisheries include those lacking temporal series of data to estimate species declines, showing distinct trends among exploited species (i.e., some declining, others stable or increasing) or other indicators (e.g., catch volume and size), besides some studies indicating shifts in composition of fished species (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Several studies on coastal finfish fisheries fall in this partially sustainable category in Brazil (Barbosa-Filho *et al.*, 2020; Damasio *et al.*, 2015; Lima *et al.*, 2016; Silvano, Nora, Andreoli, Lopes, & Begossi, 2017), Mexico (Erisman *et al.*, 2010; Rife *et al.*, 2013) and Colombia (López-Angarita *et al.*, 2018), besides the fishery for king crab *(Lithodes santolla)* in Chile (Bozzeda, Marín, & Nahuelhual, 2019). Some of these partially sustainable cases involve a temporal shift in the exploited fishing resources, in the form of a decline (or even disappearance) in catches of large, slow growing and high valued fish, such as reef predators, coupled with an increase in catches of smaller, fast growing and usually less valued fishery resources, such as shrimp, reef herbivores, or pelagic fish, as indicated in Brazil (Damasio *et al.*, 2015; Ribeiro, Damasio, & Silvano, 2021; Zapelini, Bender, Giglio, & Schiavetti, 2019), Ecuador (Schiller, Alava, Grove, Reck, & Pauly, 2015), Costa Rica (Sánchez-Jiménez, Fujitani, MacMillan, Schlüter, & Wolff, 2019) and Mexico (Erisman *et al.*, 2010; Rubio-Cisneros, Aburto-Oropeza, & Ezcurra, 2016; Rubio-Cisneros *et al.*, 2017). This pattern was also observed in fisheries of elasmobranchs (sharks and rays) in Mexico, where catch of large and threatened species has declined, whereas smaller and more resilient species have increased and tend to have sustained an intense fishing pressure (Ramírez-Amaro & Galván-Magaña, 2019; Saldaña-Ruiz, Sosa-Nishizaki, & Cartamil, 2017).

Although benthic invertebrates have been usually among the more sustainable fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651), there are some cases of overexploitation and even fisheries collapses of high valued and easy to catch invertebrates, such as the abalones (*Haliotis* spp.) or sea cucumbers (*Isostichopus badionotus*, among other species), in Chile (Sáenz-Arroyo & Revollo-Fernández, 2016), Ecuador (Schiller, Alava, Grove, Reck, & Pauly, 2015) and Mexico (Gamboa-Álvarez *et al.*, 2020). The size and density of the shellfish Queen conch *(Lobatus gigas)* had declined over a 15-year period in Belize, raising concerns of recruitment or overfishing, but deep water and protected areas may provide a refuge from fishing pressure (Tewfik, Babcock, Appeldoorn, & Gibson, 2019).

Only a few studies were considered to be partially sustainable or unsustainable because of side effects from some fishing practices that would cause habitat damage or by-catch, for example, trawling to catch shrimp (Martins *et al.*, 2018; Rosa *et al.*, 2011; Sánchez-Jiménez *et al.*, 2019), pufferfish (Eduardo *et al.*, 2020) or jellyfish (Brotz *et al.*, 2017). This may be partially due to two factors that may have reduced the number of articles on trawling in this review: first, some or most of these trawling fisheries may be considered to be large-scale to have made it into the small-scale fisheries review. Second, some studies were perhaps not retrieved in a review using search words as 'sustainable, sustainability, success and increasing'.

The sustainable cases of inland small-scale fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651) are mostly related to the successful co-management of the large and valuable commercial fish pirarucu *(Arapaima gigas)* in the Brazilian Amazon (Campos-Silva & Peres, 2016; Castello *et al.*, 2009; Petersen, Brum, Rossoni, Silveira, & Castello, 2016), (see also **Box 6.5** on community-based fishery of pirarucu in the Amazon in Chapter 6). Other mechanisms that could lead to sustainable fisheries are the exploitation of fish resilient to either fishing pressure or environmental change (e.g., dams). For example, the fishing of *Plagioscion squamosissimus*, especially in communities within extractive reserves or other kinds of protected areas, as observed in several rivers in the Brazilian Amazon (Gustavo Hallwass, Luís Henrique Tomazoni da Silva, Paula Nagl, Mariana Clauzet, & Alpina Begossi, 2020; Gustavo Hallwass *et al.*, 2011;Hallwass *et al.*, 2020; Gustavo Hallwass & Silvano, 2016; Keppeler *et al.*, 2017; Mesquita *et al.*, 2019; Silvano *et al.*, 2014).

Small-scale fisheries have cultural and socioeconomic relevance to indigenous Tacana people in the Beni River, Bolivian Amazon, where a participatory survey indicated that this fishery, which exploits 43 species for food and income, has been ecologically and economically sustainable as catches and sizes of exploited fish remained unchanged for a period of seven years, providing a regular source of revenues to local communities (Salinas *et al.*, 2017). Similarly, a study conducted 20 years ago indicates that the large frugivorous fish *Colossoma macropomum* in the Bolivian Amazon supports a sustainable fishery partly due to its linkages with a small population and a well-preserved floodplain forest habitat (Reinert & Winter, 2002). Unsustainable cases include migratory fish, such as *Prochilodus* species among others, which have suffered intense fishing pressure, sometimes aggravated by environmental impacts (e.g., dams in rivers in Brazil) (Catarino *et al.*, 2019; Santos, Pinto-Coelho, Fonseca, Simões, & Zanchi, 2018; Philippsen *et al.*, 2017) and Argentina (Baigún *et al.*, 2013). Another unsustainable pattern in the Brazilian Amazon refers to the decrease in catches and size of some of the larger and most valuable commercial fishes, such as *Colossoma macropomum* and large catfish (Pimelodidae), among others (Castello, McGrath, & Beck, 2011; Garcez Costa Sousa & de Carvalho Freitas, 2011; Hallwass *et al.*, 2019; Tregidgo, Barlow, Pompeu, de Almeida Rocha, & Parry, 2017). Even the pirarucu *(Arapaima gigas)* that increased in co-managed small-scale fisheries is considered to be unsustainably exploited in non-managed Amazonian rivers, where the abundance of this fish has reportedly reduced (Leandro Castello *et al.*, 2015; G. Hallwass *et al.*, 2019), mainly due to widespread illegal fishing (Cavole, Arantes, & Castello, 2015).

An interesting exception of this pattern is the fishing of some large and migratory catfish (*Brachyplatystoma* spp.) in the Brazilian Amazon, as catches of some of these species have increased in some rivers either due to successful regulations, improved fishing technologies (larger nets, motorized boats) or to market opportunities (Cruz *et al.*, 2020; Gustavo Hallwass *et al.*, 2020; G. Hallwass *et al.*, 2019). However, these catfish fisheries are difficult to manage due to the long migrations (more than 1,000 km) that these fish perform along the main Amazon River and its tributaries (Barthem *et al.*, 2017; Nunes *et al.*, 2019; Petrere, Barthem, Córdoba, & Gómez, 2004), which make these fishes especially susceptible to impacts caused by dams (Santos *et al.*, 2018) and may thus require basin wide or even transboundary international management approaches(Doria *et al.*, 2020; Goulding *et al.*, 2019).

NORTH AMERICA

In North America, most of the reviewed studies focus fish and invertebrates as food (15) were from the Artic and Alaska (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651), whereas fewer studies address recreational (3), or both uses (4). Among the studies on use of fishing resources as food, only one reported a sustainable lobster fishery in California (United States of America), where a collaborative approach improved the ecological assessment and feedback with human dimensions of the system (Kay *et al.*, 2012). Similarly, a study including fishers' knowledge indicated that the depletion of Atlantic cod caused an increase in the population of lobsters, thus improving the sustainability of lobster fisheries (Boudreau & Worm, 2010). Another study indicated that Pacific salmon species have been increasing in recent years (1990s and early 2000s) in the Beaufort Sea (Carothers, Sformo, Cotton, George, & Westley, 2019). Some problems affecting the sustainability of coastal small-scale fisheries are the potential serial depletion and regional overfishing of the rock crab fishery in California (Fitzgerald, Wilson, & Lenihan, 2018), severe declines in the abundance and catches of the Dungeness crab *(Cancer magister)* in Canada (Ban *et al.*, 2017), and overfishing and declines of stocks of salmon in Alaska (H. L. Harrison & Loring, 2016; Loring, Harrison, & Gerlach, 2014) and sea cucumber in Canada (O'Regan, 2015). One study that combines traditional and scientific ecological knowledge showed that two exploited shellfish species were also impacted by local and regional environmental factors (Ambrose *et al.*, 2014). However, other studies have shown that the involvement of indigenous peoples and local communities were critical to the reversion of a declining trend in local populations of lake sturgeons *(Acipenser fulvescens)* in Wisconsin and the Great Lakes region (United States of America), a very relevant social and economic traditional small-scale fishery (Kline, Bruch, & Binkowski, 2012; Runstrom, Bruch, Reiter, & Cox, 2002). The previous population decline of this species was due to unsustainable practices, such as overfishing and habitat loss or transformation, trends also observed in other parts of the world, including the large-scale fishing of sturgeons (Tavakoli *et al.*, 2021). In the Great Lakes region, the local community-built co-management rules across the last six decades for the sturgeon fishery, including fishing festivals and competitions (Kline *et al.*, 2012), and this fishery is also important for the Menominee Nation (an indigenous tribe in upper Midwestern in the United States of America). Together with local authorities and researchers, the local community build a successful restoration program to reintroduce lake sturgeon larvae to areas where they could no longer be found (Runstrom *et al.*, 2002).

ASIA-PACIFIC

In Asia-Pacific, the majority of studies (77) address the use of fishing resources as food, either as subsistence, commercial or to support livelihoods. Only 6 studies report sustainable use of fishing resources for food in coastal small-scale fisheries, including reef fish and invertebrates in the American Samoa (Craig *et al.*, 2008), Solomon Islands (Cohen *et al.*, 2013), the Torres Strait Islands in Australia (Busilacchi, Russ, Williams, Begg, & Sutton, 2013), besides fisheries of shrimp in Indonesia (Anna, 2017), abalone (*Haliotis* spp.) in Australia (Mayfield *et al.*, 2012) and co-managed finfish fisheries in Bangladesh (Mazumder *et al.*, 2016). The analysis of a long time series of 3,000 years involving both indigenous and local knowledge from fishers and archaeological data indicates no major changes in catch composition of fish and invertebrates exploited in the American Samoa, where catches are at lower levels than the estimated stock sizes of reef fish and fishing yields (kg/ha) correspond to those of less fished Pacific Islands (Craig *et al.*, 2008). This sustainable pattern may be related to a relatively small population of fishers who fish primarily for subsistence and, even considering that sales increased over time, other economic opportunities may have reduced reliance on fishing and hence fishing pressure (Craig *et al.*, 2008).

The observed fisheries' sustainability in the Torres Strait Islands could also be partially related to more subsistence-oriented fisheries (Busilacchi *et al.*, 2013). Similarly, in French Polynesia catches of reef fish have been stable for nine years, even after major natural disturbances including a cyclone. This could be partially due to government subsidy that reduced poverty among fishers, who are mostly part time (Rassweiler *et al.*, 2020). Nevertheless, these are exceptions among the Pacific Island countries, where most cases of sustainable or potentially sustainable fisheries are usually linked to some form of co-management or customary management system, such as periodic harvest closures (Cohen & Alexander, 2013;Cohen *et al.*, 2013; Cohen & Foale, 2013). Although promising, these co-management systems have shown variable results depending on the life history of exploited species, the size of managed area and the regime of opening and closing the area to fishing, which regulates the fishing pressure (Cohen & Foale, 2013b). Therefore, some of these co-management systems improved fisheries yields for fast-growing exploited species in a context of moderate or low fishing intensity. Others have shown a decline of larger and slow growing species (reef fish), usually associated with smaller closed areas or more intense fishing promoted by shorter closed intervals (less than one year) and longer opening periods (Cohen & Foale, 2013; Goetze, Langlois, Claudet, Januchowski-Hartley, & Jupiter, 2016; Hamilton, Hughes, Brown, Leve, & Kama, 2019; Rhodes *et al.*, 2008; Yang & Pomeroy, 2017).

Even the more sustainable reef fisheries observed in American Samoa and French Polynesia show a lack of larger piscivorous reef fish, suggesting these larger predators may have been intensively fished in the past (Craig *et al.*, 2008; Rassweiler *et al.*, 2020). In some Pacific Island countries, fisheries for small pelagic fish could be a sustainable alternative for food production, as these fish seem to be more resilient to fishing pressure compared to larger reef fish, as observed in the Solomon Islands (Roeger, Foale, & Sheaves, 2016) and Timor Leste, where fishing aggregation devices and co-management has helped to improve sustainability of coastal and reef fisheries (Tilley, Hunnam, *et al.*, 2019; Tilley, Wilkinson, *et al.*, 2019).

There are examples of co-management measures that helped to recover the abundance and hence to improve sustainability of fisheries resources, such as shellfish in Fiji (Thaman, Thaman, Balawa, & Veitayaki, 2017) and reef fish in Hawaii (Friedlander, Shackeroff, & Kittinger, 2013; Friedlander *et al.*, 2014). However, some studies also indicated declines in catches of Hawaiian fisheries for octopus and reef fish (Delaney *et al.*, 2017; Kittinger *et al.*, 2015). An analysis of bioeconomic modelling, which included stock parameters in addition to data on catch, effort, revenues and costs, indicated that shrimp fisheries could be sustainable in Indonesia by showing increased catches over a period of 27 years and surplus stocks (Anna, 2017). However, potential side effects or impacts from shrimp fisheries, such as by-catch or habitat damage, were not included in this study (Anna, 2017), which could compromise the overall sustainability of this fishery. A moratorium of one year imposed on large scale fisheries for tuna in Indonesia had mixed effects on catches of the small-scale pole and line tuna fisheries, but fishers considered that the moratorium was positive and increased their catches, indicating the potential conflicts and competition between large- and small-scale fisheries (Khan, Gray, Mill, & Polunin, 2018).

Some cases of unsustainable coastal small-scale fisheries include sharks in Indonesia (Ainsworth, Pitcher, & Rotinsulu, 2008; Ferse *et al.*, 2014; Jaiteh *et al.*, 2017) and China (Lam & Sadovy De Mitcheson, 2011a), and sawfish in Bangladesh (Hossain *et al.*, 2015). In China, a comprehensive study including market surveys and interviews with fishers in Hong Kong and mainland southern China indicates an overall depletion of sharks in the South China sea, where shark fisheries collapsed between 1970s and 1990s, (Lam & Sadovy De Mitcheson, 2011b). Notwithstanding management measures implemented by the Chinese government, a recent study analyzing landings' data and fishing effort from China for the period of 1955–2019, shows variable decadal trends with an overall adverse effect from increased fishing intensity on piscivorous fishes, including sharks and rays (Liu *et al.*, 2021). Effects from overfishing can interact synergistically with effects from climate change (Liu *et al.*, 2021). Moreover, China, especially Hong Kong, is the world largest market for shark fins, thus driving exploitation and trade of sharks worldwide, usually at unsustainable levels (Eriksson & Clarke, 2015; Fields *et al.*, 2018). However, shark fisheries can be at least partially sustainable in the Great Barrier Reef (Australia), where susceptibility to fisheries vary among species and their life histories, as smaller species are caught mainly as adults (less vulnerable), whereas larger ones are regularly caught as juveniles, and thus more vulnerable to fishing (Harry *et al.*, 2011). Furthermore, in Eastern Indonesia the whale shark *(Rhincodon typus)* is not commercially exploited due to customary beliefs among Bajao people that prohibit harvesting this fish, low market values of shark meat and skin, and a lack of technology to harvest such a large fish. No catch data is provided for other regions of Indonesia where this shark could be commercially fished (Stacey, Karam, Meekan, Pickering, & Ninef, 2012).

Unsustainable patterns have been also observed in several countries for fisheries of sea cucumbers (Holoturidae), which usually shows a typical cycle of boom and bust typically ending in sharp declines (Eriksson *et al.*, 2018; Hair *et al.*, 2016; Prescott *et al.*, 2017). The large reef fish that form predictable spawning or feeding aggregations, such as groupers or large herbivores, may be negatively affected by unsustainable practices, such as night spearfishing and catches of juveniles, as these slow growing fish are vulnerable to intense fishing during aggregation periods, even in regions under co-management systems (Hamilton *et al.*, 2019; Hamilton *et al.*, 2012; Rhodes *et al.*, 2008; Robinson, Cinner, & Graham, 2014).

Unsustainable nearshore coastal and reef fisheries have been observed in Southeast Asian countries located in biodiversity hotspots, such as Indonesia and Philippines, among others (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Multiple factors, including increased population, poverty, lack of economic alternatives other than fishing, pressure from domestic and international markets, open access and illegal fishing by using destructive practices (bombs, cyanide) lead to unsustainable levels of fishing effort and overall declines in catches of many fishing resources, such as reef and coastal fish, sharks, rays, sea cucumbers and lobsters in these biodiversity rich countries (Acebes, Barr, Pereda, & Santos, 2016; Ainsworth *et al.*, 2008; Ferse *et al.*, 2014; Jaiteh *et al.*, 2017; Khasanah, Nurdin, Sadovy de Mitcheson, & Jompa, 2020; Macusi *et al.*, 2019; Muallil, Mamauag, Cababaro, *et al.*, 2014; Muallil, Mamauag, Cabral, Celeste-Dizon, & Aliño, 2014; Prescott *et al.*, 2017; Selgrath *et al.*, 2018a, 2018b).

None of the 10 studies addressing use of fish or invertebrates for food in coastal and inland small-scale fisheries in Asia Pacific indicate sustainable fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). These fisheries are usually considered unsustainable due to multiple and interacting effects of overfishing, lack of proper management, illegal or destructive fishing practices, coupled with habitat alteration by river dams, deforestation, pollution and increased water temperature, as observed in Bangladesh (Ahmed, Rahman, Bunting, & Brugere, 2013; Jahan, Ahsan, & Farque, 2017), Laos (Gray *et al.*, 2017; Millar *et al.*, 2019) and India (Dey *et al.*, 2019; Keskar, Raghavan, Kumkar, Padhye, & Dahanukar, 2017). Nevertheless, an increase in low value fish has been observed in Cambodia (Enomoto *et al.*, 2011) and co-management initiatives including fishers' indigenous and local knowledge could be strategic and promising for recovery of fish stocks in the Mekong River Basin (Baird & Flaherty, 2005) and through community-based freshwater reserves in Thailand (Koning, Perales, Fluet-Chouinard, & McIntyre, 2020). The widespread small-scale coastal fisheries in Japan have a long history of a strong bottom-up, co-management system of governance, actively including local fishers through the fishery cooperative associations, which cooperate with scientists and government to regulate fishing activity and allocate fishing grounds among coastal fishers, among other management activities (Ganseforth, 2021; Makino, Matsuda, & Sakurai, 2009; Matsuda, Makino, & Sakurai, 2009; Teh, Teh, Abe, Ishimura, & Roman, 2020). This co-management system can contribute to the sustainability of small-scale fisheries and to marine conservation in Japan, to the extent that local communities can implement fishery regulations to cope with declining fishing resources. This may include protected areas, gear modifications and restrictions on fishing effort (number of boats), as observed in the Shiretoko World Natural Heritage Site where the management plan considers fishers as part of the ecosystem (Makino *et al.*, 2009; Matsuda *et al.*, 2009). Nevertheless, the social and economic sustainability of the Japanese small-scale fisheries face some challenges, such as limited workforce due to an ageing population and lower incomes from fishing compared to other activities (Teh *et al.*, 2020), besides institutional changes that may reduce participation of local fishing association in fisheries management (Ganseforth, 2021).

3.3.1.5.2 Medicine and hygiene

Aquatic organisms provide diverse sources of bioactive compounds of interest for nutraceutical, pharmaceutical, and cosmeceutical industries **(Table 3.4)**. Fish, crustaceans and molluscs produce a variety of biologically active compounds that have been characterized by their antimicrobial, antiviral, anti-inflammatory, antioxidant, anti-cancer/antitumor, antihypertensive, anti-atherosclerotic, anticoagulant, and immunomodulatory properties and other medicinal functions (Chbel, Asmaa, Delgado, Aurelio Serrano, Soukri, Abdelaziz, & El Khalfi, Bouchra, 2021; Nisticò, 2017; Šimat *et al.*, 2020). Fish oil, chitin, peptides, polysaccharides, gelatin, pigments, polyphenols, vitamins and minerals are examples of the compounds that have been used as functional food ingredients (Venugopal, 2018) with health benefits. For a number of countries, especially in the tropics, nutrients such as zinc, calcium and iron available from marine fish are essential to the health of local populations, especially for children under five years old (Hicks *et al.*, 2019). Biological properties of fish have also been used to treat or prevent different kinds of health disorders.

The food industry introduced several components to improve the properties of foods (i.e., emulsifier, stabilizer, texture modifier, coating or thickening agent) or to enrich foods with functional components and allow their application in health-promoting foods for direct consumption (Šimat *et al.*, 2020). There are many papers promoting the benefits of biologically active components from wild caught animals, but little data were found on the number of wild animals caught and used in pharmaceuticals, nutraceuticals and hygiene products. Thus, the below review focuses on selected uses for which there is enough information to provide an overall assessment.

Fish oil as a source of omega-3 long chain polyunsaturated fatty acids

Fish oils contain high levels of omega-3 long chain polyunsaturated fatty acids (n-3 LC-PUFA), including those known as EPA and DHA (eicosapentaenoic acid [20:5n-3] and docosahexaenoic acid [22:6n-3]). Those components are well accepted as being essential for a healthy and balanced diet, and a large number of studies demonstrate the positive effects of food supplementation with fish oil on human health and the prevention of certain diseases (see (Ghasemi Fard, Wang, Sinclair, Elliott, & Turchini, 2019) for a review).

Table 3 4 **Major nutraceuticals and bioactive components from seafood.**

Source: (Venugopal, 2018) © 2018, Springer International Publishing A, license number 5153531358540. CC-BY-NC.

Finfish
Bioactive peptides
Biological calcium Cartenoids Ensymes includinf cold-adapted enzymes
Glycosaminoglycans inclusing chondroitin sulfate, dermatan sulfate and hyaluronic acid
Long-chain omega-3 polyunsaturated fatty acids (PUFAs)
Phosphopeptide from fish bone
Protein hormones such as calcitonin
Protein isolates including collagen and gelatin
Suqlene and squalamine
Shellfish (crustaceans and mollusks)
Bioactive peptides
Carotenoids
Chitn, chitosan and chitosan derivatives
Enzymes
Glucosamine
Long-chain omega-3 polyunsaturated fatty acids (PUFAs)
Mussel polysaccharides, lipids and other prodcuts
Protein isolates including collagen and gelatin

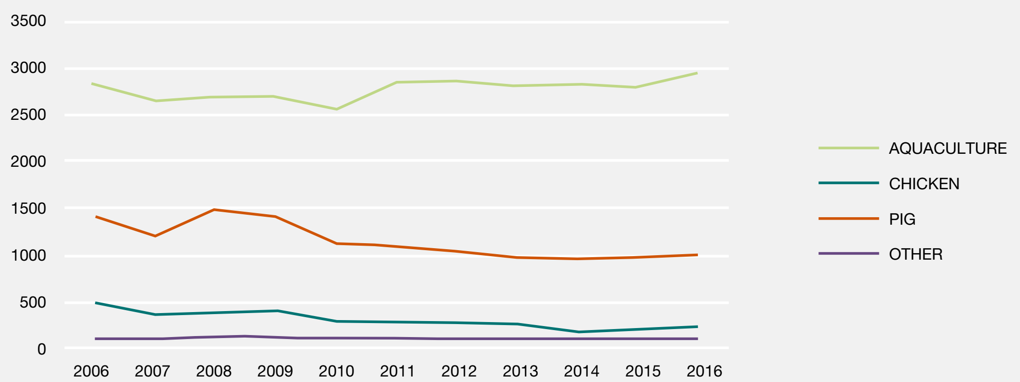

Figure 3 34 **World fish oil market use by sector 2006–2016 (000Mt).**

Source: (Seafish, 2018) under license CC-BY.

The vast majority of n-3 LC-PUFA is produced by marine micro-organisms, predominantly microalgae (Harwood & Guschina, 2009), whereas terrestrial wild plants do not produce EPA or DHA (eicosapentaenoic acid [20:5n-3] and docosahexaenoic acid [22:6n-3]). (Harwood, 1996). Therefore, the supply of these components for humans come from the ocean, and predominantly from capture fisheries (almost 90%), whether as food fish or via fish oil and fishmeal, with relatively small additional amounts estimated from seafood by-products and recycling, unfed aquaculture and traditional macroalgal sources (Tocher *et al.*, 2006).

The global supply of fish oil remains relatively stable (FAO, 2020d; J. Shepherd & Bachis, 2014), constrained largely by natural supply constraints in the fisheries (Misund, Oglend, & Pincinato, 2017) **(Figure 3.34)**. Supplements in the food industry use 20 to 25 percent of globally available fish oil

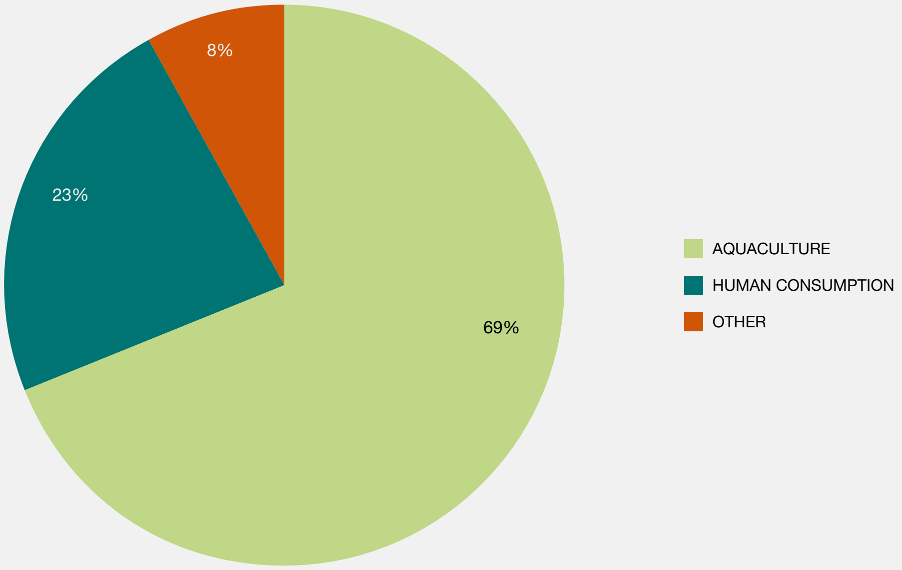

Figure 3 35 **Global fish oil use per destination in 2017 (volume in tonnes).**

Source: (EUMOFA, 2019) under license CC-BY.

(2017), up from only 5% in 1990 **(Figure 3.35)**. While Fish oil is currently the only economically viable source of n-3 LC-PUFA for feed purposes (Misund *et al.*, 2017), the growing demand from the human nutritional supplement industry has tightened the competition noticeably (J. Shepherd & Bachis, 2014). Based on the recommended dose for cardiac health, the total demand for n–3 LC-PUFA is over 1.25 million metric tonnes (mt) whereas total supply is optimistically estimated at just over 0.8 million mt indicating a shortfall of over 0.4 million mt (Tocher, 2015).

Squalene, squalane, and related compounds from shark's liver

Livers of deep-sea shark species contain high contents of squalene and other hydrocarbons like pristine, which are of interest for cosmetics and medical uses (Macdonald & Soll, 2020). Many shark species, particularly from the deep-sea >200 m, have relatively large livers (up to 20% of animal weight) (Abel & Grubbs, 2020; Vannuccini, 1999). The proportion of liver oil varies between species from 10 to 70% of liver weight (Nichols, Rayner, & Stevens, 2001), and 15 to 82% of liver oil is squalene (Bakes & Nichols, 1995; Deprez, Volkman, & Davenport, 1990). The preferred commercial source of squalene remains shark liver oil, although produced by different animals and plants, presumably due to availability and high yields relative to most plant-derived sources.

Squalene is a skin rejuvenating agent and together with its hydrogenated product squalane (produced from squalene), there is huge potential in nutraceutical, pharmaceutical, and cosmeceutical industries (Venugopal, 2018). Squalene is also used as an adjuvant in vaccines (Brito & O'Hagan, 2014) especially in influenza vaccines (Panatto *et al.*, 2020; Schultze *et al.*, 2008). Shark liver oil also contains Pristane, a natural saturated terpenoid alkane, and squalamine, an amino sterol antibiotic with antiviral, antitubercular, anti-angiogenic properties (Venugopal, 2018).

Recent data shows an increase in reported import and processed production of shark liver oil, with trade volumes reaching 752 tons as the largest reported volume in decades **(Figure 38)** (FAO, 2020d). A review of scientific and management literature by Macdonald and Soll (C. Macdonald & Soll, 2020) identified 133 shark species which are known to be involved in the liver oil trade. One-third of identified species are classified as threatened (vulnerable, endangered, or critically endangered) according to the International Union for Conservation of Nature Red List criteria **(Figure 3.36)**. Population trends for 56% of these species are unknown, and 34% are assessed as showing a decreasing trend **(Figure 3.37)**.

Deep-sea sharks offer larger volumes of liver oil compared to other shark species and are therefore of greater interest to the shark liver oil trade **(Figure 3.38)**. The knowledge on these species remains relatively poor due to low research priority added to the difficulties to conduct research in the deep sea (Kyne & Simpfendorfer, 2007; Neiva, Coelho, & Erzini, 2006; Verissimo, MacMillan, & Smith, 2011). Therefore, little is known about population structure, habitat use and reproduction of many of these species. Nevertheless, shark reproductive rates and recovery potential are known to decline when depth increases, and

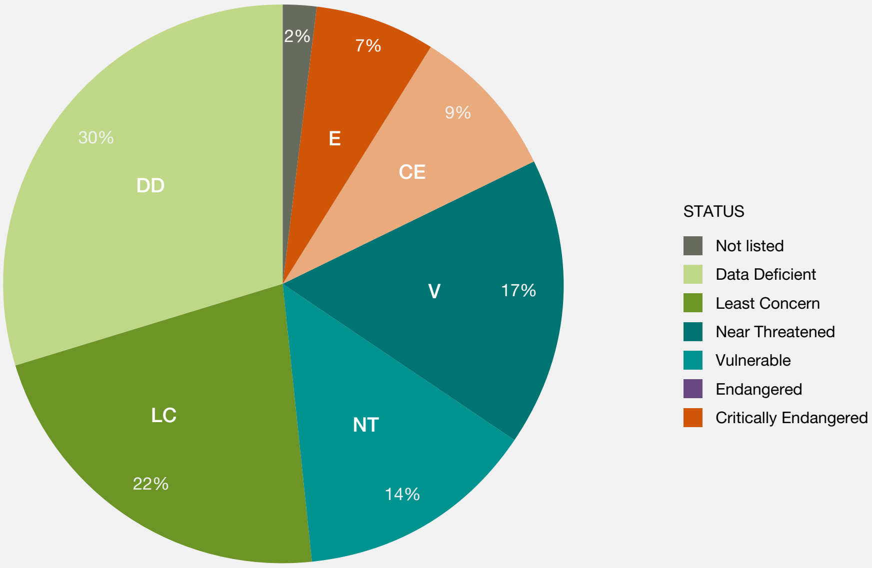

Figure 3 36 **The International Union for Conservation of Nature Red List conservation status of elasmobranch species reported in the liver oil trade.**

Source: (Macdonald & Soll, 2020) under license CC BY-NC-ND 4.0.

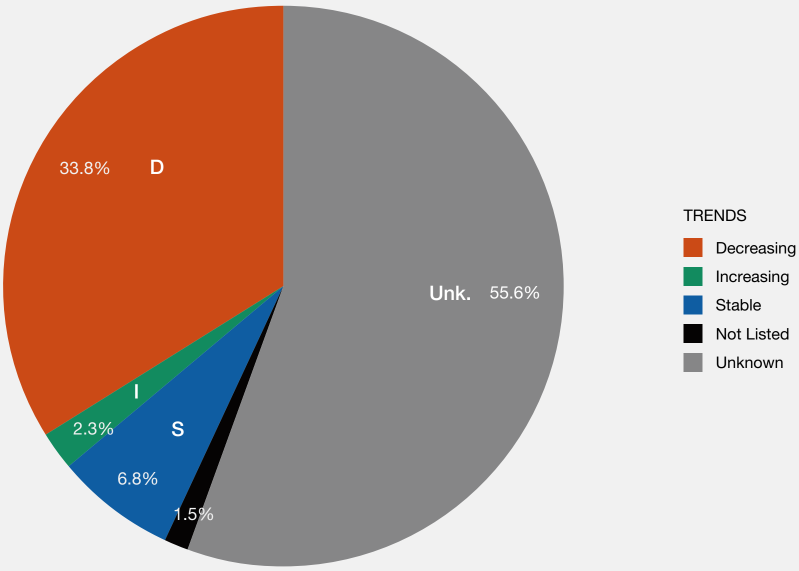

Figure 3 37 **The International Union for Conservation of Nature Red List conservation status of elasmobranch species reported in the liver oil trade.**

Source: (Macdonald & Soll, 2020) under license CC BY-NC-ND 4.0.

population depletion risks exist even when exploitation (targeted or incidental) rates are low (Simpfendorfer & Kyne, 2009). For these reasons, deep-sea sharks have been identified as a conservation priority (Dulvy *et al.*, 2014).

The cosmetics industry in Europe and the United States of America has decreased its use of shark-based squalene in recent years, under pressure from non-profit organizations and consumers. Independent tests conducted by the French organization "Bloom" determined that most cosmetics (>90% of products tested) sold in Europe or the United States of America no longer contain shark-derived ingredients, although shark-derived squalene is still commonly used in cosmetics

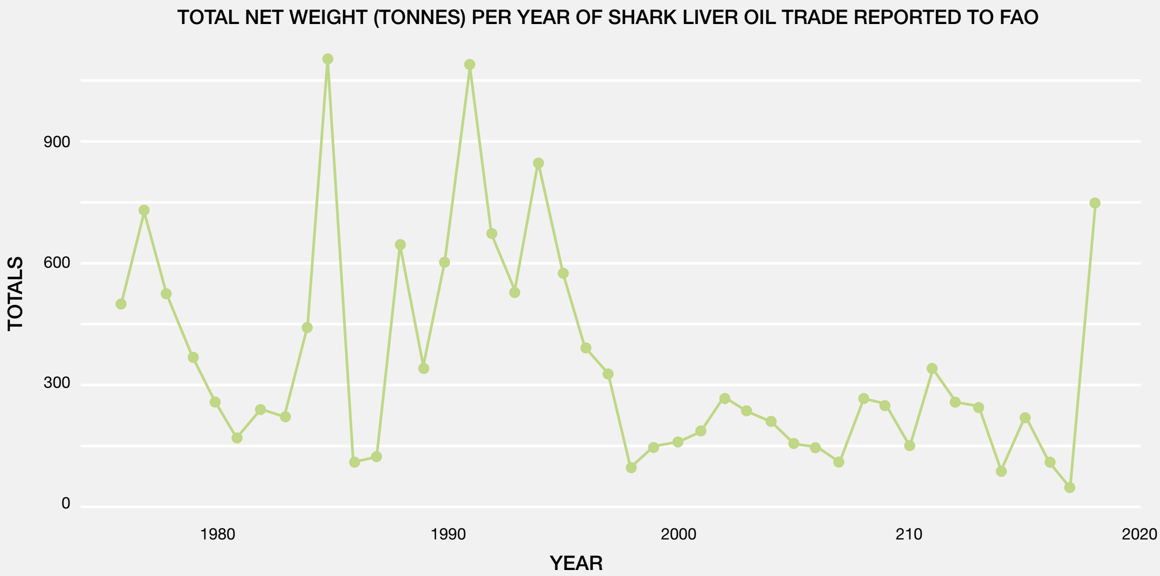

Figure 3 38 **The total reported net weight (tons) of annual trade in shark liver oil reported to the Food and Agriculture Organization of the United Nations.**

Source: (Macdonald & Soll, 2020) under license CC BY-NC-ND 4.0.

elsewhere (Ducos, Guillonneau, Le Manach, & Nouvian, 2015). The Covid-19 pandemic has reinvigorated the debate on using shark squalene-derived products in the production of potential SARS-CoV-2 vaccines (C. Macdonald & Soll, 2020).

Bioactive compounds from wild caught species and seafood processing by-products

Fish and shellfish, including crustaceans, are sources of a wide range of bioactive compounds **(Box 3.7)** that can be recovered from commercial fish processing waste (scales, shells, frames, backbones, viscera, head, liver, skin, belly flaps, dark muscle, roe, and others) and bycatch (unwanted fish and fish of poor economic value). A large corpus of grey literature promotes the use of such material for the production of nutrients, nutraceuticals and pharmaceuticals (Venugopal, 2018), however most processed fish by-products are reduced to fish meal, fish oil and fish silage (A. Jackson & Newton, 2016; Venugopal, 2018).

The potential of using these byproducts is important. Jackson and Newton (A. Jackson & Newton, 2016) estimate that the collection and processing of all byproducts not currently used for fish oil extraction would yield around 50,000 tons of EPA and DHA (eicosapentaenoic acid [20:5n-3] and docosahexaenoic acid [22:6n-3]) with around 80% coming from wild capture fisheries. This additional tonnage of EPA and DHA would increase the global supply by around 25%.

3.3.1.5.3 Recreational fisheries

Recreational fisheries are defined as the fishing of aquatic animals that do not constitute the individual's primary source of nutrition and are not sold or traded on any market (FAO, 2012b). Recreational fishing is one of the most popular leisure activities in inland waters and coastal zones worldwide, with about 11.5% of the world's population involved (Arlinghaus, Tillner, & Bork, 2015; Steven J. Cooke & Cowx, 2004; Kelleher *et al.*, 2012). In industrialized countries, this proportion can be much higher, exceeding 30% (e.g., Norway) (Arlinghaus *et al.*, 2015).

Benefits derived from recreational fisheries include substantial economic benefits in the form of expenditures and related infrastructure (Cisneros-Montemayor, Sumaila, Kaschner, & Pauly, 2010; Potts, Childs, Sauer, & Duarte, 2009), an increase in the stability of the employment buffer through increased year-round or seasonal tourism employment (Smith, Khoa, & Lorenzen, 2005), psycho-social benefits (Floyd, Nicholas, Lee, Lee, & Scott, 2006; Parkkila *et al.*, 2010), and recreational fisher involvement in conservation efforts such as habitat restoration, citizen science, and research (Copeland, Baker, Koehn, Morris, & Cowx, 2017; Tufts, Holden, & DeMille, 2015).

While commercial fisheries catch by country are documented since 1950 by the FAO, data for global marine recreational catches remains scarce. (Freire *et al.*, 2020) reported three published estimates, one of 0.5 million tons

Box 3 7 **The promising potential of cone snails.**

Molluscs have long been used in traditional medicine and scientists often rely on local knowledge to identify bioactive compounds with potential therapeutic applications (Benkendorff *et al.*, 2015). In this context, one of the most studied groups of organisms are the cone snails, renowned for their capacity to produce venoms used to capture their prey or deter predators (Dutertre *et al.*, 2014). Cone snails are only the tip of the iceberg: order Neogastropoda, has at least 15,000 recorded species, most of which are suspected to be venomous (Puillandre *et al.*, 2011).

Venoms produced by cone snails (termed "conotoxins") have been studied since the end of the 1970s, and constitute an inexhaustible reservoir of toxins, with more than 1,000 species and up to 200 unique toxins produced by each of them (Olivera, 2006). One toxin of cone snail has been approved to be used as an analgesic to treat chronic pain (PRIALT®). Several others are engaged at various steps of the process of drug approval, with applications such as epilepsy, cardioprotection and diabetes (Bjørn-Yoshimoto *et al.*, 2020).

Such promising applications make the cone snails (and relatives) an attractive group of organisms for pharmacological companies. However, the only source of toxins is natural populations (cone snails are highly difficult to reproduce in captivity (Perron, 1981). Researchers are now looking for sustainable solutions to preserve the biodiversity.

The Nagoya protocol regulates access to genetic resources to guarantee fair benefit sharing with local populations. This is the case, for example, with cone snails that mostly live in tropical shallow waters of emerging countries. Indeed, the highest diversity of cone snails is encountered in the Indo-Pacific (Puillandre *et al.*, 2014), specifically in the Southwest Pacific (e.g., Philippines, Indonesia, Papua New Guinea, New Caledonia), and the most studied species, such as *Conus textile* or *Conus geographus*, the latter being the only deadly species for humans, with a fatality rate of 50% (Kohn, 2018), live in these regions. There, cone snails are harvested for aesthetic reasons, and if local populations harvest common species to sell them to tourists, rare species are subject to an active international market reserved to specialists. Restrictions are applied regardless of intent. Strict application of the Nagoya protocol in a growing number of countries also affects scientific study of biodiversity. The impact of sampling in the field for scientific purpose has been claimed to be negligible compared to the impact of tourists and collectors (Duda *et al.*, 2004), the latter being itself considered to be negligible in regard to the impact of human-mediated environmental changes (Peters, O'Leary, Hawkins, & Roberts, 2016).

per year from FAO approximated recreational catches (marine and inland) based on a questionnaire answered by people in 30 mostly developed countries. A second estimate reached 10.9 million tons per year was derived from an extrapolation of Canadian recreational participation and catch rates, and included both marine and inland areas (Steven J. Cooke & Cowx, 2004). Freire *et al.* (2020) describe estimates of likely marine recreational catches for 1950–2014, based on independent reconstructions for 125 countries. Those estimates of marine recreational fisheries show that catches grew globally until the early 1980s, stabilized during the 1990s, and began increasing again thereafter, amounting to around 900,000 tons in 2014. Marine recreational catches account therefore for slightly less than 1% of total global marine catches **(Figure 3.39)**. Trends vary regionally, decreasing strongly in North America, slightly decreasing in Europe and Oceania, while increasing in Asia, South America and Africa. The derived taxonomic composition indicates that recent catches were dominated by Sparidae (12% of total catches), followed by Scombridae (10%), Carangidae (6%), Gadidae (5%), and Sciaenidae (4%). The importance of Elasmobranchii (sharks and rays) in recreational fisheries in some regions is of concern, given the life-history traits of these taxa. Preliminary catch reconstruction, despite high data uncertainty, should encourage efforts to improve national data reporting of recreational catches **(Figure 3.40)**.

In Europe, the majority of recreational and tourism fishing is carried out in the Mediterranean Sea (Antunes *et al.*, 2015; Cillari *et al.*, 2012; Lloret *et al.*, 2018; Marengo *et al.*, 2015; Mavruk, Saygu, Bengil, Alan, & Azzurro, 2018; Ulman *et al.*, 2015b; Ulman & Pauly, 2016), although some of these fishing practices take place in the Atlantic coast or its islands and archipelagos (Carvalho *et al.*, 2017; Das & Afonso, 2017). It is well established in the literature reviewed that the recreational small-scale fisheries performed in Europe is not sustainable, and only 30% of the studies reviewed show any level of sustainable exploitation of recreational small-scale fishing activities (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Unsustainability is assumed due to the lack of regulation of the recreational fishing activity in general.

The available information shows that the majority of this practice is not necessarily linked with the tourism industry (Cillari *et al.*, 2012). Instead, it is usually carried out by locals as cultural practices that maintain important connections between communities and nature. This allows for some territorial overlap, and consequently for some level of competition with other fishing practices, mainly the commercial fishing for food and feed (Carvalho *et al.*, 2017; Das & Afonso, 2017; Marengo *et al.*, 2015). Although the European regulation of fisheries in general tends to be

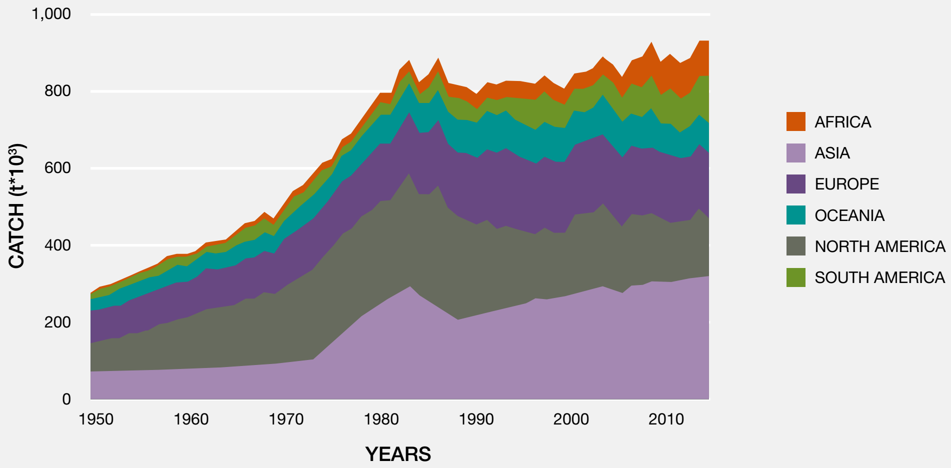

Figure 3 39 **Global marine catches from recreational fisheries by major geographic region for 1950–2014 for all countries with marine recreational fisheries.**

Source: (Freire *et al.*, 2020) under license CC BY 4.0.

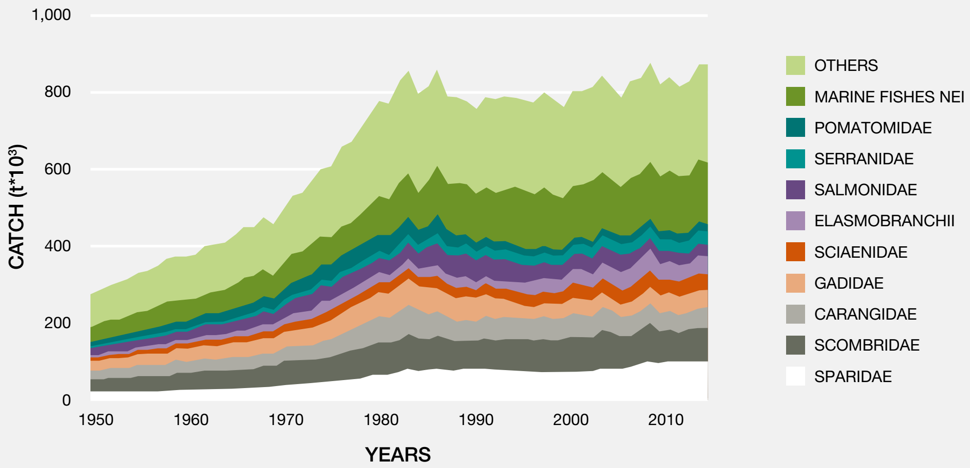

Figure 3 40 **Taxonomic composition of global recreational catches by the nine most represented families or higher groupings.**

'Marine fishes nei' (nei, not elsewhere included) comprises a large contribution of taxonomically unidentified catches; while 'Others' comprises all additional taxa with minor contributions pooled.
Source: (Freire *et al.*, 2020) under license CC BY 4.0

very widespread, most of the recreational fishing practices are not formal, and are therefore unregulated (Lloret *et al.*, 2018). On the other hand, sustainable recreational fishing practices in Europe are probably due to the use of more selective gears (Cillari *et al.*, 2012), and those that are carried out in marine protected areas or other specific areas designated by local management arrangements (Marengo *et al.*, 2015).

In Africa, despite the small number of studies on small-scale recreation and tourism fisheries, the reviewed scientific literature suggested that this type of fishing is unsustainable (Belhabib *et al.*, 2016; Leeney, 2016, 2017; Leeney & Poncelet, 2015; McCafferty *et al.*, 2012). This unsustainability is assumed due to strong fishing pressure, and lack of regulation and monitoring which means there is a relative lack of data available. The assessments cover most of the West Coast, encompassing many fish species and also a good part of the East Coast for the recreational fishing industry, mainly targeting the sawfish (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). This later fishing practice is experiencing a strong decline in the last decades and in some areas the sawfish is now rarely detected.

In Latin America only two studies evaluated recreational fisheries, but in both cases these fisheries co-occur with artisanal commercial fisheries that exploit fish for food and none were considered as being fully sustainable (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). The increase in recreational spear fishing caused an unsustainable decline on catches and sizes of three reef fish species in Chile (Godoy *et al.*, 2010). The tourism related to fishing, either in the form of tourists fishing for recreation or eating fish in hotels and restaurants, has increased over time and is an important economic activity in the Bahamas and other Caribbean Island countries (Smith & Zeller, 2016). However, the recreational catches related to tourism, about half of total catches in the Bahamas, have been unreported and poorly regulated, which is again assumed to compromise sustainability over time (Smith & Zeller, 2016).

In North America, most of the reviewed studies address the recreational coastal fisheries in the United States of America, especially in Florida (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Some of these studies on recreational fisheries of the bonefish *(Albula vulpes)* indicate an unsustainable pattern of decline in abundance and size of this fish species, which has suffered increased fishing effort and post-release mortality, leading to an overexploited catch-and-release fishery with negative population effects (Frezza & Clem, 2015; Rehage *et al.*, 2019; R. O. Santos, Rehage, Kroloff, Heinen & Adams, 2019). Another study showed anglers and guides are environmentally conscientious and self-aware of potential anthropogenic drivers of bonefish decline, which may have also been influenced by climate and water quality (Kroloff *et al.*, 2019). A study analyzing 22 fish species of the snapper-grouper reef fish complex in the Florida Keys reported that the majority of these species have been fished unsustainably, though overfishing appears most severe for those long-lived, slow-growing fish (Ault *et al.*, 2005). The only inland study that provided a comprehensive review of recreational and other fisheries in the region of Great Lakes and Mississippi River (United States of America and Canada). It describes internal threats such as overexploitation and bycatch/release mortality, as well as external threats such as inter-sectoral conflicts, environmental change (e.g., habitat alteration and fragmentation), water availability, and introduction of non-native species and pollution (Cooke & Murchie, 2015).

In Asia-Pacific, only four reviewed studies address recreational coastal or inland fisheries (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Although accounting for only a small fraction of the total reconstructed fisheries catches in 25 Pacific Island countries, recreational fisheries have economic relevance to local coastal communities, as these fisheries are related to tourism (Zeller *et al.*, 2015). The occurrence of whale sharks, which are not commercially exploited and are regularly sighted by fishers, indicates opportunities for the development of non-extractive tourism activities based on observation of whale sharks and promoting collaboration and use of fisher indigenous and local knowledge in Eastern Indonesia (Stacey *et al.*, 2012). The two cases of inland recreational fisheries indicate potentially overfished populations of crayfish *(Euastacus armatus)* in Australia (Zukowski, Curtis, & Watts, 2011) and more sustainable fisheries of migratory fish in the lower Mekong River basin (Mattson, 2006). Manta rays *(Manta alfredi)* have been exploited possibly at unsustainable levels for food and medicinal use in the Philippines (Acebes *et al.*, 2016).

Recreational fisheries are of concern as fishers concentrate their effort on specific areas, times, species and sizes, leading to greater impacts on targeted stocks. For instance, the nearshore zones more intensively exploited by marine recreational fishers are often critical habitats for multiple life stages of many fish (e.g., spawning, nursery), and immature life stages may be targeted in these areas (Steven J. Cooke & Cowx, 2004). Recreational fishers also selectively target larger and older "trophy" fish, often of keystone, top-predatory species, with life-history characteristics that make them vulnerable to exploitation (late age-at-maturity, low fecundity), which can lead to demographic or evolutionary effects on fish populations (Robert Arlinghaus & Cooke, 2009; Lewin, Arlinghaus, & Mehner, 2006; J Lloret *et al.*, 2020; Prato *et al.*, 2016) and community changes (e.g., successful invasion by non-native species) (FAO, 2012b). Recreational fishers can be regarded as keystone top-predators (Hilborn & Walters, 1992) with increasing efficiency, as knowledge (techniques, areas, seasons, species, etc.) is becoming more accessible and technology (GPS, sounders, braided lines, etc.) more affordable (Griffiths *et al.*, 2010).

Hence, recreational fisheries are now widely recognized as a significant component of marine capture fisheries and a potentially significant contributor to fish declines along with the commercial fleets (Agius Darmanin & Vella, 2019; Robert Arlinghaus & Cooke, 2009; Herfaut, Levrel, Thébaud, & Véron, 2013; Pawson, Glenn, & Padda, 2008). To achieve sustainable fisheries management, it appears essential to incorporate recreational fisheries stock assessments (Gordoa, Dedeu, & Boada, 2019).

3.3.1.5.4 Decorative and aesthetic

Some animal parts are used to make perfumes, mainly as a fixative substance that includes musk, ambergris, civet and castoreum. Of these four animal products, ambergris is jetsam coprolite which originates from the sperm whale (Macleod, Sinding, Olsen, Collins, & Rowland, 2020). It has been found rarely but this is in practice for centuries all over the world. It is difficult to estimate the sustainability of the ambergris gathering, as some samples have been present in the environment for about a thousand years (Rowland, Sutton, & Knowles, 2019).

The rest of this section was written following the methods used for the systematic review described in 3.3.1.3 (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

In Europe, only a fraction of the small-scale fisheries exploits aquatic animals for uses other than food. These organisms are usually benthic invertebrate species, which are not only fished for food and feed (Duncan *et al.*, 2016; Pita *et al.*, 2019), but also for a limited number of other uses. Some Porifera are traditionally used and sold as sponges for baths, for instance (Fourt *et al.*, 2020). The literature is unresolved on the sustainability of these practices. In recent decades, traditional gear was replaced by modern technologies, such as trawls (Pita *et al.*, 2019), which in combination with increased demand, led to overfishing (Fourt *et al.*, 2020). Some stocks collapsed, although when this happened is unclear. However, more recently strong control of the catch along with other introduced management measures have resulted in the sustainability of this fishing practice being slowly rebuilt (Fourt *et al.*, 2020). However, in most places the uncontrolled use of trawls is still a severe threat to the sustainability of megabenthic fauna, either for the exploited stocks or for other species of demersal fish, which are equally important for the European economy (Duncan *et al.*, 2016).

In Latin America, few studies address other uses than food, including ornamental fish to aquarium trade, decorative (handcrafts) or medicinal uses, and often these alternative uses can be made of the same organisms, some of which are also used as food (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). None of the 14 studies that focused on these alternative uses addressed the sustainability of the practices. Some studies indicated partially sustainable uses of medicinal or decorative fish species on the Brazilian coast, which may occur at a local scale (low fishing pressure), but may sometimes include threatened species or be linked to trawling and by-catch (Eduardo *et al.*, 2020; Pinto, Mourão, & Alves, 2015; Rosa *et al.*, 2011; C. A. B. Santos & Nóbrea Alves, 2016). The medicinal or decorative use of parts of sharks (mostly by finning) and sawfish are regarded as unsustainable, leading to declines in the exploited species (Barbosa-Filho *et al.*, 2019; Bonfil *et al.*, 2018). Fisheries exploiting jellyfish mostly for food, but including many occasional uses as food for livestock or aquaculture, bait, medicine or aesthetic (collagen) have developed at different stages in several South American countries (Brotz *et al.*, 2017). These fisheries may be considered as partially sustainable, or potentially sustainable, given limited data on landings, potential problems of bycatch and habitat damage (depending on fishing technique) and coastal pollution from jellyfish processing (Brotz *et al.*, 2017).

In North America, no uses other than food and recreation were observed among the reviewed studies in this region (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

In Asia-Pacific, only a few studies (8) from the reviewed coastal and inland small-scale fisheries mention uses other than food, such as ornamental or decorative (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). The use of marine shellfish shells as ornaments and handicrafts in Fiji is likely partially sustainable due to a recovery of exploited shellfish populations as a result of co-management (Thaman *et al.*, 2017).

3.3.1.5.5 Ceremony and cultural expression

For many small-scale fishing societies, successful fishing does not depend only on technical procedures, but rather on religious and cultural rituals and practices. Good fishing implies that propitiatory practices, such as fasting, specific diets (Teiwaki, 1988) or sex avoidance (Deb, Haque, & Thompson, 2015; Hoeppe, 2007), accompany the various stages of the technical process, including the manufacture of canoes used in fishing practice (Foale, Cohen, Januchowski-Hartley, Wenger, & Macintyre, 2011). Rituals may also be led by shamans (Ivanoff, 1992; Laugrand, 2015) or marabouts (Artaud, 2016). Thus, many taboos are meant to favour 'luck' or prevent the breach of rules and ward off the ontological imbalances resulting from a non-respect of the rules (Artaud, 2016, 2020). In fishing societies these rituals play an important part because marine species are perceived as 'partners' (Astuti, 1995; Bataille-Benguigui, 1981; D'Arcy, 2008) rather than simply as 'prey' or 'resources'. Bonds of seduction or alliances (Robert Earle Johannes, 1981; Zerner, 2003), fraternity (Grimble, 1989; Lewis, 1994), co-substantiality (Laugrand, 2015; N. Peterson & Rigsby, 2014) or consanguinity (Ivanoff, 1992) unite human and aquatic communities. Beyond these relationships, fishing rituals aim at strengthening the ties between people, social groups or clans. For instance, for the Tao people, fishing flying fish (Family Exocoetidae) is an opportunity to renew a set of cultural and identity principles and values (Berger, 2019; Fan, 2019; Gaffric, 2013). The same is true of whale hunting, which for several indigenous communities constitutes a means of regulating group relations or asserting their singularity within a State (see section 3.3.1.4.6) (Adamson, 2012; Deutsch, 2017). It is also the case for salmon fishing among the Ainu (Iwasaki-Goodman & Nomoto, 2001). Items from aquatic species, such as sea-shells, are used in some rituals, for instance in the candomblé, an Afro-Brazilian religion (Neto, Voeks, Dias, & Alves, 2012).

3.3.1.6 "Non-lethal" fishing practices and uses

3.3.1.6.1 Catch and release recreational fishing

Recreational fishing can involve a variety of gear types but catch-and-release fishing is most typically focused on fish caught by hook and line (FAO, 2012b). Therefore, this discussion is focused on angled fish.

With respect to recreational catch-and-release fishing, it is difficult to disentangle the socio-economic benefits of harvest *versus* release-oriented recreational fishing, which collectively generates over 100 billion United States dollars annually while creating opportunities for anglers to connect with nature and spend time with friends and family (Robert Arlinghaus & Cooke, 2009). Recreational fisheries certainly can and do involve harvest for personal consumption (Steven J Cooke *et al.*, 2018), but harvest rates vary markedly among regions, species, and angler typologies. To emphasize that variation, recreational harvest rates of species like muskellunge *(Esox masquinongy)* and bonefish (*Albula* spp) are around 1% while species like walleye *(Sander vitreus)* and Atlantic cod *(Gadus morhua)* have harvest rates that typically exceed 60% (Robert Arlinghaus *et al.*, 2007). In some cases, release of fish is dictated by regulations (e.g., closed seasons, bag limits, size limits) but it can also be voluntary. Where there are long term trend data available, there is evidence that fish release rates have crept up slowly over time (e.g., Brownscombe *et al.*, 2014).

The release of angled fish requires proper handling and not all fish survive (Cooke & Schramm, 2007). From a sustainability perspective, it is irrelevant whether fishing mortality arises from harvest (i.e., from an extractive fishery) or from release mortality (i.e., in a non-extractive fishery). Catch and release mortality rates are highly variable and can range from near total mortality to near total survival (recognizing that zero mortality is never attainable). Several syntheses suggest that the bulk of recreational fisheries exhibit release mortality rates that are less than 10% (Arlinghaus *et al.*, 2007; Bartholomew & Bohnsack, 2005; Muoneke & Childress, 1994). Although mortality rates are informative, alone they provide little information on the population-level consequences of release mortality (Kerns, Allen, & Harris, 2012). Information on fishing effort, life history characteristics, population status, and the role of other fisheries practices dictate whether catch and release mortality threatens the sustainability of fish populations. Mortality arising from catch and release is often cryptic and has been implicated in fisheries collapse (Post *et al.*, 2002; Schroeder & Love, 2002). There are many factors that determine whether an individual fish will survive a catch and release event. The single biggest driver of mortality is anatomical hooking location with fish hooked in the jaw region having comparatively low mortality relative to fish hooked more deeply in areas such as the gills or esophagus (Arlinghaus *et al.*, 2007).

Recreational catch and release fishing can have consequences for aquatic and coastal habitats. Issues include tackle loss (e.g., lead sinkers, hooks, line), littering, trampling of shoreline vegetation and in-water habitats (e.g., coral, gravel spawning sites), erosion, noise pollution, and hydrocarbon release from boats, and accidental or intentional release of exotic species (e.g., bait bucket transfers, stocking), among others (reviewed in Cooke & Cowx, 2006; Lewin *et al.*, 2006; McPhee *et al.*, 2002; Venohr *et al.*, 2018).

Many fishing guides and outfitters pride themselves on their operations being catch and release focused and use that in marketing. A number of non-governmental organizations focus on educating anglers on how to engage in responsible catch and release. Moreover, governments routinely apply harvest regulations as part of their fisheries management initiatives in an effort to create sustainable fisheries that benefit aquatic ecosystems and the humans that use them. Thus, catch and release activities and the associated tour operators contribute to creating responsible and sustainable recreational fisheries (Cooke *et al.*, 2019).

3.3.1.6.2 Ornamental or aquarium fish

Ornamental fish trade is a global, multibillion-dollar industry, involving over 125 countries (Evers *et al.*, 2019a) and worth billions of United States Dollars. Ornamental fisheries are divided into marine and freshwater fisheries. Some of the original representative sustainable gathering projects of ornamental fishes are losing their competitiveness due to the rise of off-site aquaculture.

The freshwater ornamental fish trade involves about 125 countries worldwide, is worth approximately 15-30 billion United States dollars (Evers, Pinnegar, & Taylor, 2019b; Penning *et al.*, 2009) and trading around 1.5 billion specimens per year (C. H. Stevens, Croft, Paull, & Tyler, 2017). Roughly 1,000 of the over 5,300 freshwater fish species traded are widely available in commercial numbers (Evers *et al.*, 2019b). A big difference is that around 90%

of freshwater ornamental fishes are farmed, usually in Asia or South America, but also in Israel, the United States of America and Europe. Although a smaller portion of freshwater ornamental fishes are still sourced from the wild, in comparison to marine ornamental fishes, it is still a challenge to determine the volume due to lack of reliable data.

The marine aquarium trade supplies public and private aquariums with a large diversity of organisms (Dey, 2016; Wabnitz, 2003). A review found that an estimated 15-30 million specimens of coral reef fishes are extracted each year from tropical coral reefs (Biondo & Burki, 2020). The review did not assess mortality rates (Stevens *et al.*, 2017), making proper harvest estimates more challenging since they cannot be based on trade data (Cohen, Valenti, & Calado, 2013; Militz, Kinch, Foale, & Southgate, 2016; Monticini, 2010; Olivier, 2001; C. H. Stevens *et al.*, 2017; Thornhill, 2012). Most marine ornamental species are being collected from the wild (Biondo, 2017, 2018; Biondo & Burki, 2019; V. Dey, 2016; Rhyne *et al.*, 2012; Rhyne, Tlusty, Szczebak, & Holmberg, 2017; Wabnitz, 2003) including species that are listed as endangered by the International Union for Conservation of Nature Red List, such as the Banggai cardinalfish *(Pterapogon kauderni)*. Of the approximately 4,000 marine ornamental fishes known to date (R. Froese & D. Pauly, 2019), about 2,500 species are in trade (Rhyne *et al.*, 2012, 2017). Of all these species only around 25 species (1%), can be bred in commercial numbers and about 300 have been bred successfully in research stages (Pouil, Tlusty, Rhyne, & Metian, 2020).

The International Union for Conservation of Nature Red List category is a starting point to warrant protection of a species, but many species of reef fishes are currently labelled 'not evaluated' and 'data deficient': 73.3% in 2014 and 44.8% in 2018, meaning that the conservation states for almost half of the species is still unknown (Biondo, 2018). Protection from international trade would come through the Convention on International Trade in Endangered Species but only few species are listed on its appendices (e.g., *Hippocampus* spp. *Cheilinus undulatus*, *Holacanthus clarionensis*) thus very little specific trade data is collected (https://cites.org/eng/app/appendices.php, (CITES, 2012).

It is estimated that over 50 countries are actively involved in the marine aquarium industry (Biondo & Burki, 2020; Rhyne *et al.*, 2012, 2017). However, this trade lacks sufficient monitoring, and the specific geographic origin of most specimens uncertain (Biondo & Burki, 2019, 2020; Biondo & Calado, 2021; Cohen *et al.*, 2013; Ploeg, 2007). The largest exporting markets are Indonesia, the Philippines and Sri Lanka (Rhyne *et al.*, 2012, 2017; Wabnitz, 2003). While some analyses have tried to estimate trading figures for large importing markets, such as the United States of America (Rhyne *et al.*, 2012, 2017), Australia (Trujillo-González & Militz, 2019), and Europe (Biondo, 2017, 2018; Biondo & Burki, 2019; Leal *et al.*, 2016), they all represent approximations and the figures presented are most likely underestimates. Japan is mentioned in the literature as a large importer, but with no recent trade figures available (Biondo, 2017, 2018; Biondo & Burki, 2019, 2020; Rhyne *et al.*, 2012, 2017; Wabnitz, 2003). Furthermore, there is no information at all for growing markets, such as those located in Southeast Asia, Africa, and South America (Biondo & Calado, 2021).

With regards to the literature focused on small scale fishing, in Latin America the nine studies addressing small-scale fisheries of ornamental fish for aquarium trade included only three studies in the Brazilian coast (Eduardo *et al.*, 2020; Monteiro-Neto *et al.*, 2003; Rosa *et al.*, 2011), while all others focus on freshwater fisheries in the Peruvian and Brazilian Amazon (Araújo *et al.*, 2020; Evers *et al.*, 2019a; Gerstner, Ortega, Sanchez, & Graham, 2006; Guzmán Maldonado *et al.*, 2017; Ladislau *et al.*, 2020; Moreau & Coomes, 2007). A study in the Brazilian coast shows an increasing trend in the number of fish (mainly native reef species) caught and traded, mostly for export, but there are no data on fishing effort or population status of exploited fish to check for the sustainability of such large trade (Monteiro-Neto *et al.*, 2003). Other studies in the Peruvian and Brazilian Amazon indicate that this activity may be unsustainable due to illegal fishing, rapid expansion of fishing effort, reduced fish abundance in more heavily fished regions compared to protected areas and synergic effects of intense exploitation, market pressure (increased sale prices) and habitat change caused by dams (Evers *et al.*, 2019a; Gerstner *et al.*, 2006; Guzmán Maldonado *et al.*, 2017). Studies addressing either coastal or inland ornamental small-scale fisheries expressed concerns on unreported and unknown fish mortality during collection and transportation (Monteiro-Neto *et al.*, 2003; Moreau & Coomes, 2007).

In Africa, only a small number of papers dealt with small-scale fisheries for ornamental trade, both in the coral reefs off the coast of Kenya. Some of the many species studied proved to be at low risk of overexploitation, mainly because there is large and disseminated use of very selective gears to capture the fish in this type of fishing. This selectivity allows the removal of mature, large (and colorful) individuals above the maturation size (Gomes, Erzini, & Mcclanahan, 2014). On the other hand, some other species are vulnerable to overfishing and other species are probably already overfished (Okemwa, Kaunda-Arara, Kimani, & Ogutu, 2016). This overfishing is due to low natural abundance and long-term intense fishing pressure. In those cases, more active management measures could mitigate threats to vulnerable species.

In Asia-Pacific, data from both fishers' knowledge and recordings of fish landings (logbooks) of seahorses

(Hippocampus comes), which are exploited as ornamental and medicinal fish in the Philippines, indicate that catch-per-unit-of-effort did not change over a period of nine years (O'Donnell *et al.*, 2012). Fishers' logbooks that included zero catches (fishing trips on which no seahorse was caught) showed the lowest catch-per-unit-of-effort values, and a previous study based on fishers' indigenous and local knowledge indicated declines of seahorse catches from 1970 to 2005 (O'Donnell, Pajaro, & Vincent, 2010). Some studies point to unsustainable rates of exploitation of sea horses (*Hippocampus* spp.) on the coast of Vietnam (Stocks *et al.*, 2019; Stocks, Foster, Bat, & Vincent, 2017). In India, nearly 50% of marine aquarium fish and corals, considered highly financially valuable species, have not been assessed for their extinction risk (Prakash *et al.*, 2017). The ornamental fisheries of corals (many species) and the coastal fish *(Pterapogon kauderni)* in Indonesia are considered to be unsustainable, due to intensive fishing pressure, habitat damage, or overestimated quotas beyond ecological capacity (Ferse *et al.*, 2012; Kolm & Berglund, 2003). A recent monitoring survey of Banggai Cardinalfish populations shows mixed trends from 2004 to 2018 among seven sites in Indonesia: recovery or partial recovery in three sites, stable in one, increase in one and decline in two sites, indicating potential effects from conservation measures in some sites and the relevance of microhabitats (sea urchins and sea anemones) to juveniles and adults of this reef fish (Wiadnyana *et al.*, 2020).

Morevoer, some marine protected areas, which were created to protect reef fish for ornamental aquarium trade in Hawaii, have increased abundance of some exploited species and thus possibly improved the sustainability of these commercially valuable ornamental fisheries (Friedlander *et al.*, 2014). The few studies on inland ornamental fisheries indicate potential unsustainable harvest, due mostly to intense fishing effort and weak regulations (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). The increase on fishing effort had caused overexploitation of wild caught populations of the clown loach or tiger botia fish *Chromobotia macracanthus* in Indonesia, which directed fishers to catch fish larvae to be reared in captivity (Evers *et al.*, 2019a). In India, thousands of individuals of threatened and endemic freshwater fish species have been regularly caught and sold for high values in the export market, stimulating an intense fishing pressure (Raghavan *et al.*, 2013).

The aquarium trade of ornamental fishes is usually considered as a profitable, rapidly developing, but somewhat unpredictable economic activity, which is subjected to sudden fluctuations in the international market and may involve high operational costs, either for coastal (Monteiro-Neto *et al.*, 2003) or inland fisheries (Araújo *et al.*, 2020; Moreau & Coomes, 2007). Trade includes many dealers with large differences in prices paid between fishers and final retailers (Rosa *et al.*, 2011). For example, the well-established aquarium trade in the Negro River (Brazilian Amazon), which exploits mainly the small cardinal tetra fish *Paracheirodon axelrodi* for the international market, has experienced problems related to the productive chain, such as competition with international producers, absence of local buyers, decrease on sales and lower profits, making some fishers abandon this activity (Evers *et al.*, 2019a; Ladislau *et al.*, 2020).

The global trade of marine ornamental fishes has always lagged behind in terms of transparency, as there is a multitude of stakeholders involved from the fishers at location of capture to the (many) intermediaries and traders, the exporters and importers and the intermediaries in the importing countries (Amos & Claussen, 2009). Some attempts have been made to increase transparency in the marine ornamental fish industry. The Global Marine Data Base (GMAD) was introduced in 2002 and collected importer and exporter data but with only 41 contributing companies and unfortunately, only for one year (Green, 2003). Another attempt was the Marine Aquarium Council label that was established in 1998 to ensure traceability, good practice, and sustainable schemes of ecologically and socially responsible fishing, but has been inactive since 2008 (Dee, Horii, & Thornhill, 2014).

3.3.2 Gathering

3.3.2.1 Introduction

Wild algae, fungi and plants provide food, income and nutritional diversity for an estimated one in five people around the world, in particular women, children, landless farmers and others in vulnerable situations (Sorrenti & Food and Agriculture Organization of the United Nations, 2017). The Plant List (http://www.theplantlist.org/) and the World Flora Online (WFO, http://www.worldfloraonline.org/) list around 360,000 species with accepted names (accessed January 2021). The world checklist of vascular plants includes approximately 350,000 accepted species. With regards to fungi, 148,000 species have been scientifically identified, but it is believed that more than 90% of species remain unknown to science (Antonelli *et al.*, 2020).

Gathering is defined in the sustainable use assessment as the removal of terrestrial and aquatic algae, fungi, and wild plants or parts thereof from their habitats. This definition includes leaves and fruits of trees. Whole tree or excessive branch removal of trees is discussed under logging (see Chapter 1 for complete definitions of all practices). Gathering may, but often does not, result in the death of the organism. All wild plants, fungi, and parts of plant and fungal bodies harvested in forests, savannas, and grasslands that are not wood harvested for timber are broadly categorized as algae, fungi and plants (Sorrenti & Food and Agriculture Organization of the United Nations, 2017).

Exploitation of wild algae, fungi and plants often involves the systematic removal of biological, units or parts of units, from a population, but the level of mortality in the exploited population depends on methods of extraction and the vital parts that are removed (Ticktin, 2004). Local communities and indigenous peoples harvest wild algae, fungi and plants for primary health care, basic livelihood needs, to provide social safety nets, and subsistence income. Traditional algae, fungi and plants gathering, for either subsistence or commercial purposes, is often considered a desirable, low-impact economic activity from wild habitats, compared to alternative forms of land use that involve structural disturbance such as selective logging (Plotkin, Famolare, Conservation International, & Asociación Nacional para la Conservación de la Naturaleza, 1992). Gathering is also an important cultural and recreational activity for many, pursued by individuals and family groups even where there is no pressing financial need (Emery, 2001).

A majority of wild algae, fungi and plants gathering was considered ecologically and economically sustainable in a recent review (de Mello, Gulinck, Van den Broeck, & Parra, 2020; Stanley, Voeks, & Short, 2012). Therefore, exploitation of wild algae, fungi and plants, as such, is usually assumed to be sustainable and is viewed as a best compromise between the requirements of biodiversity conservation and those of extractive communities under varying degrees of market integration. However, commercial harvesting of wild plants has increased in recent years, for food, the pharmaceutical and cosmetic industries, as well as for artisanal herbal teas, natural dyes, and decoration. Due to the wide variation in the nature of wild algae, fungi and plants and the way they are harvested and traded, the sustainability of intensive harvesting for trade is debatable (Isabel B. Schmidt, Mandle, Ticktin, & Gaoue, 2011).

The number of people who participate in gathering provides one measure of the significance of this practice to nature's contributions to people. Data on numbers of people who gather globally are incomplete and differences in methodologies vary such that direct comparison of results across studies is difficult. The challenge of assessing numbers of people who gather are compounded by inter-annual variation in gathering, by individuals and households in response to changing needs and opportunities, and as availability of individuals with the desired characteristics ebbs and flows (Lovrić *et al.*, 2020; Watson *et al.*, 2018). With those caveats, available data suggest globally, numbers of people who engage in gathering are likely higher than those for other extractive practices.

Gathering is one of the practices most closely associated with traditional lifeways, subsistence practices, and indigenous and local knowledge in both high and low-income countries worldwide. Which wild species are edible and how they are processed, are essential elements of local and traditional knowledge. Most ethnobiological studies on gathering wild species for food consumption have documented edible species, parts, or processing methods. It is widely agreed upon in the available scientific literature that older women are the primary holders and stewards of indigenous and local knowledge, and pass on their knowledge through mother-child nexus and community sharing. Children from indigenous peoples and local communities have specialized access to specific wild resources, ones which are generally of lesser importance for adults and complement their diet. As almost exclusive harvesters of these resources, children retain their own sphere of knowledge and know-how. They are often neglected in considerations of gathering stakedholders, in spite of being full social actors in these societies and being engaged in transmission and exchange networks (Dounias & Aumeeruddy-Thomas, 2017).

Regarding trade in wild algae, fungi and plants, the International Trade Centre estimated that approximately 440 different organic wild products were identified as of 2005. Nearly all of them are wild plants, seaweed and mushrooms; more than half (253/440) of them are medicinal and aromatic plants. A total of 223,754 tons (t) of organic wild harvested products were harvested in 2005. The largest gathering areas were reported in Africa and Europe, while the highest quantity was reported harvested in Asia from a relatively small area (International Trade Centre UNCTAD/WTO, 2007). There is a large amount of trade in wild algae, fungi and plants in the informal economy with little or no records. However, formal markets for resins, tannins, pine nuts, wild mushrooms and other wild algae, fungi and plants in Europe are developing rapidly. In China formal markets around tea seed oil *(Camellia oleifera)*, Chinese chestnut *(Castanea mollissima)*, Persian walnut *(Juglans regia)*, Eucommia *(Eucommia ulmoides)* and purpleblow maple *(Acer truncatum)* are expanding (Sheppard *et al.*, 2020).

Regarding conservation and sustainable use of wild algae, fungi and plants, the International Union for Conservation of Nature Red List of Threatened Species contains over 9,600 wild food species of which 20% are considered threatened. Ironically, agriculture is the greatest threat to plants, followed by logging and gathering, which is only slightly more threatening than land use for residential and commercial development (Antonelli *et al.*, 2020). What part of the organism is gathered, its phenology, and life form, affects how susceptible the species is to over-harvesting **(Table 3.5)**. Gathering the flowers and fruits of annual-biennial plants shows the greatest susceptibility to

Table 3 5 **Susceptibility of wild plants to overharvesting.**

Note: + represents a high probability, ++ higher, +++ highest. Source: (modified from Lange, 2006) © 2017 Springer.

Plant part used \ Life form	Tree	Shrub	Perennial herb	Annual-biennal
Wood	++	++	Not applicable	Not applicable
Bark	++	++	Not applicable	Not applicable
Root	++	++	+++	+++
Leaf	-	-	-	+
Flower	-	-	+(++)	+++
Fruit/seed	-	-	+(++)	+++

overharvesting. Gathering bark and roots also has a high probability of leading to overharvesting.

Removing the bark may threaten the survival of plant individual, for example when gathering the medicinal part of the African cherry *(Prunus africana)* (Fashing, 2004; K. M. Stewart, 2003), *Julbernardia paniculata, Isoberlinia angolensis* (Chungu, Muimba-Kankolongo, Roux, & Malambo, 2007), Himalayan yew *(Taxus wallichiana)* (Lanker, Malik, Gupta, & Butola, 2010) and Pepper-Bark Tree *(Warburgia salutaris)* (Senkoro, Shackleton, Voeks, & Ribeiro, 2019). There are many wild plants whose roots are harvested for medicinal use. Some of the most well-known are ginseng (*Panax* sp.), *Nardostachys grandiflora* (S. Ghimire, McKey, & Aumeeruddy-Thomas, 2005), Oshá *(Ligusticum porteri)* (Kindscher, Martin, & Long, 2019), Black Cohosh (*Actaea racemosa* L.) (Small, Chamberlain, & Mathews, 2011), *Cryptolepis sanguinolenta* (Amissah *et al.*, 2016), *Stemona tuberosa* (G. Chen, Sun, Wang, Kongkiatpaiboon, & Cai, 2019) and *Eurycoma longifolia* (Susilowati, Rachmat, Elfiati, & Hasibuan, 2019). The gathering of major parts of wild plants such as stems and bulbs is also common in herbaceous plants like orchids. These types of gathering activities may kill the plant and are therefore a focus for species conservation and sustainable management efforts. Sustainable harvest programs for gathering flowers, fruit and leaves for medicinal use have secondary benefits for habitat protection.

To study the sustainability of the use and gathering of wild plants a literature review was conducted and studies on the ecological aspect of specific species were collected, based on the parts gathered and the life form of plants used. Note that separate literature reviews were conducted on the sustainable use of wild fungi and for urban gathering (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). For the literature review on wild plants, in accordance with the requirements of the systematic literature review, key word combinations were used such as: #gather/pick/collect# + #plant# + #wild# + #terms of the aim of uses + sustainable# and searched primarily in google scholar, Web of Science SCI (Science Citation Index Expanded) and CNKI (China National Knowledge Infrastructure). A total of 89,400 materials were identified, but most only described how the wild plants were used. Eight hundred and fourteen (814) relevant articles and reports went through the initial screening. Fifty-one (51) cases of specific plant species or groups met the search criteria for inclusion in the study of sustainable use by gathering. The relevant papers were carefully reviewed to determine the credibility of the conclusions of each set of research (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Cases of sustainable use by gathering wild plants are from all IPBES regions, including Africa (13), America (21), Asia and Pacific (11) and Europe and central Asia (6). Of the 51 cases of the use and gathering of wild plants retrieved, more than two-third of tree/shrub gathering were sustainably managed, while more than half of the gathered herbs assessed were considered unsustainable. For trees, the existing cases show that the gathering of bark for uses, mainly medicinal aims, are not sustainable due to the lack of management and regulatory systems. For herbs, gathering root for medicines from perennial herbs led to more unsustainability concerns **(Table 3.6)**.

Table 3 6 **Number of cases of sustainable use and gathering of wild plants through literature review.**

Note: the cases reported here represent those captured through systematic literature review. Additional material is included in the chapter text from contributing authors, personal experiences and expertise. Af.: Africa, Am.: Americas; AP.: Asia and Pacific; EC.: Europe and Central Asia. NA: Not applicable. Uns/Sus: number of unsustainable cases need solutions *versus* number of sustainable cases under specific management or regulations.

Life form / Plant part used	Tree/shrub (Uns/Sus)					Herb (Uns/Sus)				
IPBES Regions	Af	Am	AP	EC	All	Af	Am	AP	EC	All
Barks	3/1	0/1	1/1		4/3	NA	NA	NA	NA	NA
Sap/gum/resin	1/1	0/1	1/0	0/1	2/3	NA	NA	NA	NA	NA
Root/tuber/bulbs						2/0	2/2	5/1	1/1	10/4
Leaves						1/1	1/5			2/7
Flowers							1/0			1/0
Fruits/seeds	1/1	0/5	0/1	0/2	1/9		0/1			0/1
Whole						1/0	1/1	1/0		3/1
Sum	5/3	0/7	2/2	0/3	1/7	4/1	5/9	6/1	1/1	16/13

3.3.2.2 The diversity of contemporary gathering

3.3.2.2.1 Gathering in Western European and Other Group (WEOG) countries

Gathering wild algae, fungi and plants is often assumed to be an activity more prevalent in developing countries and the Global South, and less so in post-industrial countries. However, results of surveys conducted in Europe, North America, and the United Kingdom over the last 20 years suggest high rates of participation in gathering by individuals and households in many of the countries in these regions **(Table 3.7)**. In Scotland, a 2003 random sample general population survey found 18% of individuals had gathered fungi and tree or plant-derived materials in the previous 12 months, including residents of both urban and rural areas (Emery *et al.*, 2006). The Northeastern United States of America includes both the largest urban concentrations of that nation and substantial rural lands. Eighteen percent of respondents to a 2004 survey in that subnational region reported that they had gathered "tree or plant materials around woodlands: e.g., mushrooms, berries, cones, or moss" in the previous 12 months, while 26% had done so in the previous 5 years. Also in the Northeastern United States of America, 36% of respondents to a survey conducted over the five-year period 2005–2009 indicated they had picked mushrooms and/or berries in the previous 12 months (Cordell, Betz, Mou, & Gormanson, 2012; K. Watson *et al.*, 2018). A 2016 survey of households in 28 European countries found that Europe-wide, 26% of households had gathered in the previous 12 months, ranging from 4% of households in the Netherlands to 68% of households in Latvia (B. Wolfslehner, Prokofieva, & Mavsar, 2019). This study noted a general pattern of highest rates of gathering by households in Eastern Europe (Lovrić *et al.*, 2020). Unlike the surveys in Scotland and the United States of America, the European study documented gathering by households, suggesting that the percentage of individuals gathering in the region may be higher.

In Europe, changing patterns in wild plant and fungi use vary by country and region, associated with changing lifestyles, urbanization, large-scale farming, less periods of famine and economic hardship in recent years and changing outdoor recreation patterns. At the same time, large increases in immigrant populations are affecting what is harvested, by whom and for what purposes (Łuczaj *et al.*, 2012). In France, 728 algae, fungi and plants species are extracted from the wild, of which 100 are commonly used (Lescure, Thévenin, Garreta, & Morisson, 2015). Recent research in Norway found a total of 273 wild edible plants from 67 botanical families were identified by collectors, with the majority of harvested material coming from seven families and ten taxa. Fruits and berries, leaves and flowers were the most popular and important plant parts that were foraged by study respondents (Giraud, 2020).

Table 3 7 **Percent of population who gather in three Western European and Other Group (WEOG) subregions.**

Sources: (M. Emery *et al.*, 2006; Lovrić *et al.*, 2020; K. Watson *et al.*, 2018).

Survey location	Survey years	Unit of analysis	% Gathering (previous 12 months)
Scotland	2003	Individual	18
US Northeast	2004	Individual	18
US Northeast	2005–2009	Individual	36
Europe	2016	Household	26

Research suggests dozens to hundreds of wild algae, fungi and plants are gathered in urban, rural, and wilderness ecosystems throughout the continental United States of America, Alaska, Hawai'i and United States of America territories. Of these, a small subset enters into large-scale trade with maple syrup (*Acer* sp.), wild blueberries (*Vaccinium* sp.), and medicinal species such as American ginseng *(Panax quinquefolius)* noteworthy among them. Estimates of the number of United States of America residents who gather at least occasionally range from 18% to 36%, with the vast majority (>80%) gathering for personal use only. It seems likely, then, that a majority of United States of America residents who gather do so for personal use, while a few species gathered for commercial purposes account for the majority of biomass removed. Wild algae, fungi and plants gathering plays an important cultural role for many indigenous peoples and local communities in the United States of America including, but not confined to, those formally recognized as indigenous. Rights of access to wild algae, fungi and plants for subsistence purposes are provided for by law in the United States of America's state of Alaska (for rural residents of that state), Hawai'i (for Native Hawaiians), and under the terms of many treaties between tribes and the federal government (Chamberlain, Emery, & Patel-Weynand, 2018; Cordell *et al.*, 2012; M. R. Emery & Pierce, 2005; M. R. Emery, Pierce, & Schroeder, 2004; Hurley, Grabbatin, Goetcheus, & Halfacre, 2013; Robbins, Emery, & Rice, 2008).

Gatherers have different identities and sources of knowledge in gathering networks. For example, in Austria, organic certification for wild plants has been issued to three types of gatherers: regular, diversified and single-plant gatherers. Among them, regular gatherers are the principal knowledge sources of traditional and local knowledge, and the diversified gatherers who are less common and learning knowledge from formal courses or self-learning, may be more worried by the loss of traditional knowledge (Schunko & Vogl, 2018). In France, present professional gatherers are of multiple origins, urban or rural, and hold their knowledge from different sources. They care for the sustainability of the plants and ecosystems more than occasional opportunistic gatherers. Through their associations or cooperatives, they establish rules of good gathering practices (Lescure *et al.*, 2015) (Julliand, Pinton, Garreta, & Lescure, 2019).

3.3.2.2.2 Urban gathering

Urban gathering is an activity which supports biodiversity and sustainable human-nature interactions, but it is under-recognized as a global activity (McLain *et al.*, 2012; A. Russo, Escobedo, Cirella, & Zerbe, 2017; Tiwary, Vilhar, Zhiyanski, Stojanovski, & Dinca, 2020). Urban gathering promotes positive cultural, ecological, economic, and health outcomes (Shackleton, Hurley, Dahlberg, Emery, & Nagendra, 2017; Synk *et al.*, 2017). As a global phenomenon, it provides three categories of provisioning (woody biomass, food/fibre, and non-timber forest products), and it supports a 'green economy' (Shackleton, Chinyimba, Hebinck, Shackleton, & Kaoma, 2015; Tiwary *et al.*, 2020). Of the 43 studies related to urban gathering retrieved for this assessment, 70% are from the Americas, Europe and Central Asia, 20% are from Africa, and the remaining are from Asia and the Pacific. Common characteristics of gathering, such as health risks, ecological conditions, and pressures on wild algae, fungi and plants species are likely not the same between in rural and urban contexts, making further research on urban gathering a knowledge gap on the sustainable use of wild species for nature's contributions to people (Fischer & Kowarik, 2020; Rupprecht, Byrne, Garden, & Hero, 2015; Shackleton *et al.*, 2017; Short Gianotti & Hurley, 2016). The use of Geographic Information Systems (GIS) and spatial modelling in digital platforms and apps shows promise in quantifying urban natures as baselines for this additional research (Arrington, 2021; Moss, Voigt, & Becker, 2021).

Dozens to hundreds of feral and wild plant and fungi species are gathered for food, medicine, firewood, decoration, and cultural practices in urban ecosystems (Kaoma & Shackleton, 2015; Landor-Yamagata, Kowarik, & Fischer, 2018; Łuczaj, Wilde, & Townsend, 2021; McLain *et al.*, 2012; McLain, Poe, Urgenson, Blahna, & Buttolph, 2017; Palliwoda, Kowarik, & von der Lippe, 2017; Poe, LeCompte, McLain, & Hurley, 2014; Shackleton *et al.*, 2017; Shackleton *et al.*, 2015; Somesh, Rao, Murali, & Nagendra, 2021). In some cases, for example in Uganda, New Zealand, French Guiana, Haiti and India, wild plants are primarily gathered for medicinal purposes (Dejouhanet & de Bercegol, 2019; Mollee, Pouliot, & McDonald, 2017; Tareau, Dejouhanet, Odonne, Palisse, & Ansoe, 2019; Wehi & Wehi, 2010). However, in major urban spaces in these countries gathering wild edible plants and fungi was most commonly for food, followed by medicinal uses and personal enjoyment (Amato-Lourenco *et al.*, 2020; Garekae & Shackleton, 2020a; Landor-Yamagata *et al.*, 2018). Wild edibles, including berries, fruits, nuts, greens, and young shoots, were by far the most frequently mentioned type of product, contributing to diversifying urban diets (Garekae & Shackleton, 2020a; McLain, Hurley, Emery, & Poe, 2014; Sardeshpande & Shackleton, 2020a; Shackleton *et al.*, 2017; Somesh *et al.*, 2021).

Urban green spaces where gathering happens are promising pathways towards biodiversity conservation in cities because they facilitate interactions between people and nature which support physical and mental health (Palliwoda *et al.*, 2017). Equitable access to cultural ecosystem services from urban green space helps overcome sociocultural barriers, strengthens social relationships, maintains knowledge and traditions of families and communities, increases shares in the management of goods and services, and increases healthy food intake and personal participation in healthy behaviors (Askerlund & Almers, 2016; Jennings, Larson, & Yun, 2016; Landor-Yamagata *et al.*, 2018; McLain *et al.*, 2012; Šiftová, 2020; Tiwary *et al.*, 2020). Urban gathering can also support identity, place attachment, or mobility and agency of people and communities in the city (Poe, LeCompte, McLain, & Hurley, 2014).

Gender and income level affect urban gathering activities differently in different regions. They may be evenly distributed along gender or income categories in the United States of America, Germany and the United Kingdom of Great Britain and Norhtern Ireland (Fischer & Kowarik, 2020; Łuczaj *et al.*, 2021; McLain *et al.*, 2012; McLain *et al.*, 2014). Urban gathering in developing countries tends to be more female-dominated in some countries (Garekae & Shackleton, 2020a; Somesh *et al.*, 2021) and male-dominated in other countries (Garekae & Shackleton, 2020b). Residents with lower income and predominantly living or growing up in rural areas or peri-urban areas are more likely to be urban foragers (Garekae & Shackleton, 2020b, 2020a; Mollee *et al.*, 2017; Short Gianotti & Hurley, 2016).

Most urban gathering in the developed world is not commercially oriented; products are mainly for personal consumption and gifting (Charnley, McLain, & Poe, 2018; Rebecca J McLain *et al.*, 2014). In countries in the Global South, rapid urbanization, unplanned settlements, and poor service delivery mean that it remains vital to gather for self-provisioning and income. A substantial contribution of total household income can be generated from urban gathering, particularly in poorer households (Borelli *et al.*, 2020; Dejouhanet & de Bercegol, 2019; Kaoma & Shackleton, 2015; Somesh *et al.*, 2021). However, the potential of urban gathering to affect food sovereignty and security is not evenly distributed across socioeconomic strata (Bunge, Diemont, Bunge, & Harris, 2019).

Most gatherers acquire and pass on knowledge about gathering practices through family and friends or gathering trips (Garekae & Shackleton, 2020b, 2020a; McLain *et al.*, 2014). Oral transmission, amateur society outings, professional scientists, books, and field guides help counteract the decline in more traditional outdoor gathering activities (Łuczaj *et al.*, 2021; McLain *et al.*, 2014; Palliwoda *et al.*, 2017). Stakeholders exchange information on the nature of green spaces, species and ecosystems and allied activities. City managers can make use of gatherers' extensive local ecological knowledge to inform more formal management practices and support the overall management of urban natural areas (McLain *et al.*, 2017; Sardeshpande & Shackleton, 2020b).

Voluntary codes of conduct may be the best way to manage urban gathering to prevent over-harvesting (Charnley *et al.*, 2018; McLain *et al.*, 2017). Urban gatherers usually select common wild plant species and plant parts that have little impact on the reproduction of plants (Schunko, Wild, & Brandner, 2021). Many gatherers have adopted the "principles of practice" and appropriate techniques for preventing or limiting negative ecological impacts; meanwhile, they teach and promulgate sustainable and responsible harvesting (Łuczaj *et al.*, 2021; Schunko *et al.*, 2021).

Despite these benefits, urban gathering is not extensive enough to be considered as a solution to multiple challenges within the food system (Nyman, 2019). With some exceptions (e.g., cities in the Pacific region (Borelli *et al.*, 2020)), the average contribution of wild algae, fungi and plants to diets is low (Shackleton *et al.*, 2017) due to lower tree density in urban spaces, the relatively low proportion of edible parts, or both (Bunge *et al.*, 2019; Estela, Ghermandi, & Margutti, 1995). There are also concerns and potentially physical health risks from eating wild plants or fungi grown on contaminated urban land (McLain *et al.*, 2012; A. Russo *et al.*, 2017), the spraying of chemical herbicides and pesticides (McLain *et al.*, 2014), and mistaking potentially toxic species with edible species (Fischer & Kowarik, 2020). For example, the wild edible food gathered along freeways and arterial roads often have concentrations of lead exceeding safety levels for human consumption (Amato-Lourenco *et al.*, 2020; von Hoffen & Säumel, 2014).

Tensions sometimes exist between urban gatherers and land managers, and between gatherers and other citizens over gathering, particularly in public spaces (McLain *et al.*, 2012). This varies by region. Gathering in many African cities, for example, is permissible in open urban areas, with tacit support from policy and land managers (Sardeshpande & Shackleton, 2020b). However, in many cities in Europe and North America urban gathering is not widely recognized or encouraged, although it is happening. Many cities have some form of regulations that prohibit or discourage urban foraging (Landor-Yamagata *et al.*, 2018; Ortez, 2021; Shackleton *et al.*, 2017).

Urban gathering is growing in popularity. Many scholars agree that more people would like to gather wild algae, fungi and plants (Fischer & Kowarik, 2020), but safety concerns, lack of knowledge, perceived social stigma, and lack of access remain significant barriers to urban gathering for many (Ortez, 2021; Somesh *et al.*, 2021). Conservation practitioners had a negative or ambivalent view about the desirability of allowing or encouraging more foraging, particularly in parks or natural areas (Wehi & Wehi, 2010). Risks to biodiversity seem manageable as overharvesting has not been documented (Landor-Yamagata *et al.*, 2018), and in fact many urban greenspaces conserve considerable biodiversity (Rupprecht *et al.*, 2015). Fruit gathering was likely to be least damaging (Sardeshpande & Shackleton, 2020b), and more abundant species are collected more frequently (Fischer & Kowarik, 2020). Even among those favoring gathering, sustainability assessment and adoption of appropriate rules was a precondition (Sardeshpande & Shackleton, 2020b).

Gathering may support invasive species management in urban ecosystems (Arrington, 2021; McLain *et al.*, 2017). Although most utilized species are native (Charnley *et al.*, 2018; Palliwoda *et al.*, 2017), a species' status as invasive or non-invasive can influence gathering practice (McLain *et al.*, 2017). Since many invasive wild plants have a history of cultivation as food, medicine, and materials, providing some socio-economic values, the gathering and use of edible weeds as a complementary resource has promising possibilities. For example, bracken fern *(Pteridium aquilinum)*, a native plant in the Pacific Northwest region of the United States of America, has been classified and gathered as an edible 'weed' Poe, LeCompte, McLain, & Hurley, 2014).

An emerging approach is to consider urban forests as nature-based solutions in the urban environment and include them in city management and planning (Roeland *et al.*, 2019). Trees are welcomed for their products and regulating services like shade and windbreaks, also their less tangible aesthetic and cultural values (Shackleton *et al.*, 2015). Urban gathering creates ties between people and the surrounding nature, in fact encouraging people to see urban vegetation and green space as natural (Landor-Yamagata *et al.*, 2018). Urban planners may consider these benefits of green spaces and issues of access to nature in the city (Charnley *et al.*, 2018; Shackleton, Drescher, & Schlesinger, 2020).

In summary, the combination of edible green infrastructure and urban beautification contributes to urban food production, as well as co-benefits nutrition, socioeconomics, and environment (Russo *et al.*, 2017). Ecosystem services provided by urban green space create urban gardening and gathering opportunities that contribute to healthy lifestyles (Jennings *et al.*, 2016). Traditional tropical home gardens serve as a model for biocultural diversity in small-scale urban green spaces (Hemmelgarn & Munsell, 2021; Sardeshpande & Shackleton, 2020a). The forest garden helps urban children develop environmental, scientific, and possibly other values (Askerlund & Almers, 2016). The use of edible green infrastructure areas and gardens are playing an important role in the COVID-19 pandemic and post-lockdown period as people have spent more time at home and demonstrated an increased awareness of the need for self- reliance and resilience to emerging threats (A. Russo & Cirella, 2020).

3.3.2.2.3 Gender trends

Gathering wild products is a gendered activity in many parts of the world, depending on cultural rules, on the type of harvested wild algae, fungi and plants and the places where they are harvested. In many countries, women perform the bulk of the labor for gathering and processing wild plants for food, medicine, fuel and handicrafts, as well as for other subsistence purposes, and often sell wild products at local markets (Howard, 2003). Some gathering activities are specific to men, some others are conducted equally by men or women, as well as children, or involve the whole family. Today, commercial gathering is done by men and women who make it their primary profession (Julliand *et al.*, 2019). In low-income households, women are often responsible for gathering for self-consumption and to sell (Sabater, 2020).

A range of examples show a variety of gender dynamics in gathering around the world. In the 1980s, farmers in the mountains of central France, men and women, harvested wild plants and mushrooms for their own consumption, to share with family and for commercial purposes. Children, teenagers and elders dedicated more time to gathering than adults, the latter being busy with agricultural activities (Larrère & La Soudière, 1985). In Turkey, gathering practices between men and women differ in that woman prefer to gather in social groups, and distribute some of the wild plants such as edible greens that they have gathered as gifts to friends and neighbors (Ertug, 2003). In the tropical forests of French Guiana, the Maroon Ndjuka women gather wild plants close to the village and the fields, while men gather wild plants in the deep forest (Tareau *et al.*, 2019). In the savannas of central Brazil, the Xavante women gather wild plants while the men hunt, but men sometimes join them (Flowers, 2014). Extractivism with long expeditions in the forest is usually practiced by men, for instance rubber or piassava collectors in the Amazon (Schmink & García, 2015), eaglewood (*Aquilaria* sp.) collectors in Borneo or Papua; in these last regions, some traders even organize expeditions where they drop a group of several men in the middle of the forest from a helicopter (Mittelman, Lai, Byron, Michon, & Katz, 1997). In the dry and semi-dry areas of Africa, gums and resins such as gum arabic *(Acacia senegal, A. seyal)*, myrrh *(Commiphora myrrha)* and frankincense (*Boswellia* spp.) are usually gathered by men, pastoralists who fulfil this activity while taking their cattle to graze (Mugah, Chikamai, Mbiru, & Casadei, 1997). Tapping resins in general is a male task, especially when it is necessary to climb on trees. Batak benzoin tappers in North Sumatra, Indonesia, describe the benzoin tree *(Styrax paralleloneurum)* as a woman who gets pregnant of the resin after the tapping, a symbolic sexual act (Esther Katz, García, & Goloubinoff, 2002).

3.3.2.3 Uses of wild plants, algae, and fungi, including the leaves and fruits of trees

Unlike the case for some of the other practices, where only selected uses are relevant, all of the uses outlined in Chapter 1 of the assessment are relevant for gathering practices. In fact, in several subsections of 3.3.2.3 the diversity of species gathered for the various uses are so extensive that additional subdivisions have been created. The sections are as follows: Ceremony and cultural expression (3.3.2.3.1); decorative and aesthetic (3.3.2.3.2) with subsections on ornamental, natural cloth and dyes, handicrafts, and perfume and incense; energy (3.3.2.3.3); food (3.3.2.3.4) with subsections on nuts & seeds, starchy fruits, juicy fruits, beverages, syrups, gums, and resins, wild edible mushrooms, and wild vegetables; medicine and hygiene (3.3.2.3.5); recreation (3.3.2.3.6); science and education (3.3.2.3.7); and materials and shelter (3.3.2.3.8). Importantly, the text is not an inventory of all species gathered for various practices. Rather, the focus is on those species of particular interest in relation to sustainable use which emerged through the systematic literature review and those that were highlighted through various rounds of expert discussion and review.

3.3.2.3.1 Ceremony and cultural expression

The world's major cultures and ritual practices observe conservation of species and nature as essentials for human well-being. Cultural expression may take the form of song, stories, dances, art, designs, crafts, rituals, ceremonies, and more. Many wild species, especially wild plants and fungi, perform critical roles in ceremonies of various cultures around the world. They are harvested for use in spiritual observances and practices, and are highly valued for their role in maintaining cultural identity in formal ways (Hamilton, 2004). The Millennium Ecosystem Assessment highlighted that impeding religious and social ceremonies by denying people access to required wild plants or fungi could harm social relations as "many cultures attach spiritual and religious values to ecosystems or their components" (Millennium Ecosystem Assessment, 2005).

Research on gathering for ceremony and cultural expression focus more on the cultural dimensions, such as the types of rituals (e.g., marriage, birth, death, important memorial points and specific religious rituals) than they do on the sustainable use of the species *per se*. Wild species are sometimes mixed with horticultural plants, and used for decoration, smoking, dyeing, as non-pharmacological medicine or for energy and nutrition. Flowers and incenses made out of dried plants or resins such as frankincense or myrrh are often used in rituals. It is difficult to make a complete list of species used for ceremonies, as many ethnobotanists make inventories of dozens to hundreds of wild plants from local surveys (Barceló, Butí, Gras, Orriols, & Vallès, 2019; Des, Rizki, & Fitri, 2019; Yanfei Geng *et al.*, 2017; Rangel-Landa, Casas, García-Frapolli, & Lira, 2017).

Some of the wild species used for rituals are unusual and rare (Naegel, 2004; Rangel-Landa *et al.*, 2017). Gatherers give them as presents to the organizers of the ceremony or communitarian feast, and commercialization is uncommon (Barceló *et al.*, 2019; Rangel-Landa *et al.*, 2017). However, because of important traditional culture, there is often concern about the disappearance of these particular species in studies of national culture. Rare species are harvested at levels just enough to satisfy the needs of the community (Rangel-Landa *et al.*, 2017), and in some cases substitutions are developed (Des *et al.*, 2019). The ritual practices of Naxi people in Yunnan, China for example, pay high respect to conserving natural resources, although these beliefs and cultural expressions receive less attention from younger generations (Yanfei Geng *et al.*, 2017).

Hallucinogenic plants and fungi harvested in the wild are used by shamans or mediums, in religious or curing ceremonies, in particular on the American continent, but also in Siberia *(Amanita muscaria)* and Africa (iboga, *Tabernante iboga*, in Gabon). For the Jotï, an indigenous group in the Venezuelan Amazon, mushrooms play a central role in their religious and spiritual beliefs and are fundamental to their cosmology (Zent, 2008). Among the most known in the Americas are ayahuasca (*Banisteropsis* sp.) from the Amazon, and *Psylocybe* mushrooms and peyote *(Lophophora williamsii)* from Mexico and the United States of America Southwest (Furst, 1972; Heim & Wasson, 1958; Schultes & Hofmann, 1979). In the 1960s, after Wasson's discovery of hallucinogenic *Psylocybe* mushrooms in Mexico, "hippies" rushed to that country to experience these fungi. There has also been a development of shamanistic tourism among the Mazatecs in Mexico (Demanget, 2010) and in the Peruvian Amazon (Fotiou, 2016). Peyote is still traded in the United States of America (Feeney, 2017). Overall, 216 species of fungi are thought to be hallucinogenic, and of these 116 species belong to the Genus *Psilocybe* (Willis, 2018).

Since rituals are not a daily need, there are few relevant management measures that are directly applied to species specifically relating to ceremonial use, and it is recommended that maintaining traditional and cultural practices can complement management strategies (Kideghesho, 2009). In fact, conserving biodiversity based on cultural and religious faiths may be often more efficient and sustainable than government legislation or regulations given peoples' long-term relationships with the particular species.

3.3.2.3.2 Decorative and aesthetic

Wild species are harvested for crafts and decorative use for personal consumption, as gifts, and for sale as raw or value-added items (M. R. Emery, 1999). The gathering of wild species like orchids, Bromeliads, succulents, and wild fungi are important sources of money and livelihood for collectors at local and regional scales and may also enter into global trade. Hence the sustainability of their wild populations, habitat, economies and communities is a subject of concern. Many wild species harvested for crafts are usually listed in inventories as parts of general ethnobotanical research. It can be challenging to distinguish among uses at the local level, as one collection may result in the gathering one species for food, medicine, ritual decoration, and transplant into the home garden. There is a lack of research on the sustainability of this kind of mixed use.

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When the acquisition is part of the organism and managed well, gathering wild plants for the use of decoration may not have too many negative effects. For example, although there is lack of conservation assessment of the 80% of wild harvested Indian plants to make potpourri, the gathering of such 455 species provides a supplementary income to rural poor and is considered as a sustainable use (Cook, Leon, & Nesbitt, 2015). In Minas Gerais, central Brazil, the gatherers of everlasting *(sempre-vivas)* flowers of the Serra do Espinhaço Meridional enrich the native pastures where the flowers grow with the seeds fallen from the collected flowers and stimulate their growth by fire management (Monteiro *et al.*, 2019), demonstrating a form of traditional management and care which supports sustainable use. Their agro-extrative system was recognized by FAO in 2020 as a Globally Important Agricultural Heritage System (GIAHS) (GIAHS, 2020). Trade in exotic wild plants increased in North America and Europe after the Second World War and demand for wild plants increased pressure on wild populations and even drove the extinction of some rare species in the late 1970s (Lavorgna, Rutherford, Vaglica, Smith, & Sajeva, 2018). Twenty-two European countries reported the total value of "ornamental plants" at almost 1,400 million euros, which amounts to 49.6% and the highest of the marketed plant products from forests (Forest Europe, 2020). The Convention on International Trade in Endangered Species of Wild Fauna and Flora has listed more than 32,000 species of ornamental plants in its Appendices, most in Appendix II **(Table 3.8)**.

The gathering for sale of cut flower or foliage of bromeliads, or ornamental plants like aloe and orchids are considered to negatively affect species survival (Flores-Palacios, Bustamante-Molina, Corona-López, & Valencia-Díaz, 2015; Mondragón Chaparro & Ticktin, 2011; Mondragón, Méndez-García, & Morillo, 2016; Negrelle & Anacleto, 2012; Phelps & Webb, 2015; Sakai *et al.*, 2016). Many of these species are also cultivated, but no data was available at the time of this assessment on the share of global market sales from wild *versus* cultivated plants. Sale prices vary between species (Mondragón *et al.*, 2016), but the origin of the plants (wild *vs* farmed) did not affect price, since cultured plants have better physical variables than wild-harvested plants (Elps, Carrasco, & Webb, 2014). Some researchers believe that the supply-side measures to ensure the sustainable use may lack effectiveness. Consumer preferences may help to reduce the market driven push to overharvest (Elps *et al.*, 2014).

More than a half of all cactus species (57%) are used by people. Cacti are prized for their aesthetic qualities. The most common use is for ornamental horticulture (674 species), which in most cases is related to gathering wild plants and seeds for specialized collections. Cacti comprise about 130 genera and 1,500 species distributed mainly in North and South America; however, several species of *Rhipsalis* (mistletoe cactus) occur in tropical Africa. Some species of *Opuntia* (prickly pear) have been introduced in Africa, Australia and South Asia (India). Nearly all genera are cultivated as ornamentals; some of the more common are *Opuntia* and *Carnegiea* (giant saguaro), *Cereus* (hedge cactus, cereus), *Echinopsis* (sea-urchin cactus), *Epiphyllum* (orchid cactus), *Hylocereus* (night-blooming cereus), *Mammilaria* (pincushion cactus), *Melocactus* (Turk's cap cactus), *Rhipsalis*, and *Schlumbergera* (Christmas

Table 3 8 **Ornamental wild plants listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora.**

Source: Species+ data (UNEP, 2021) (The Species+ Website. Nairobi, Kenya. Compiled by UNEP-WCMC, Cambridge, UK. Available at: www.speciesplus.net. [Accessed 01/March/2021])

Common name	Family/Genus	Appendix	Number of listed species in the taxa
Agaves	*Agavaceae*	I and II	4
Snowdrops	*Galanthus* spp. and *Sternbergia* spp.	II	21 + 9
Cashews	*Operculicarya* spp.	II	3
Elephant trunks	*Pachypodium* spp.	I and II	23
Ponytail palms	*Beaucarnea* spp.	II	11
Bromelias	*Tillandsia*	II	3
Cacti	*Cactaceae*	I and II	1532
Zygosicyos	*Zygosicyos*	II	2
Tree-ferns	*Cyathea* spp. and *Dicksonia* spp.	II	686 + 46
Cycads	*Cycadaceae* spp. and *Zamiaceae* spp.	I and II	109 + 228
Alluaudias	*Didiereaceae* spp.	II	12
Elephant's foot,	*Dioscorea deltoidea*	II	1
Venus' flytrap	*Dionaea muscipula*	II	1
Succulent spurges	*Euphorbia* spp.	I and II	709
Ocotillos	*Fouquieria*	I and II	3
Aloes	*Aloe* spp.	I and II	483
Pitcher-plants	*Nepenthes* spp. and *Sarracenia* spp.	I and II	112 + 29
Orchids	*Orchidaceae* spp.	I and II	27,924
Palms	*Palmae*	I and II	13
Poppy	*Meconopsis regia*	III	1
Passion-flowers	*Adenia sp.*	II	3
Sesames	*Uncarina*	II	2
Lewisias, portulacas, and purslanes	*Anacampseros* spp., *Avonia* spp. and *Lewisia serrata*	II	25 + 11 + 1
Cyclamens	*Cyclamen* spp.	II	27
Stangerias	*Stangeria eriopus* and *Bowenia* spp.	I and II	3
Grapes	*Cyphostemma* spp.	II	3

cactus) (Judd, 1999). Native people of the Americas propagate branches, seeds or transplant complete individuals from the wild to their agroforestry systems and home gardens (Casas & Barbera, 2002). People occasionally harvest useful parts of several species of cacti for use in traditional medicine. Cactus pears from *Opuntia stricta* are also considered as a potential source of natural colorants (Casas & Barbera, 2002; Goettsch *et al.*, 2015).

Due to their popularity and the commercialization of so many wild species, poaching entire plants from the wild is a growing problem. Most species are regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora **(Table 3.8)**. Among the threatened cacti species, 64% are utilized by humans in some form and 57% (236 species) are used in horticulture (Goettsch *et al.*, 2015). There is growing concern that a high proportion of cactus species may be threatened with extinction in the near future, mainly due to growing illegal trade.

Orchids are a prominent group of the global horticultural trade. While large numbers of orchids are grown commercially, there are still large numbers taken directly from the wild. Over-harvesting of wild orchids associated with floral and medicinal trade is a serious concern for their long-term survival (Hinsley *et al.*, 2018). Cross-border trade of orchids is well recognized as a threat to orchid conservation and regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora. However, domestic trade may not be regulated or poorly enforced in some orchid-rich countries (Phelps & Webb, 2015; Tamara Ticktin *et al.*, 2020; Wong & Liu, 2019). This legal and illegal domestic trade of wild orchids can be larger than cross-border trade and can also pose serious threats to species survival, but receive far less attention from orchid conservationists (Phelps & Webb, 2015; Tamara Ticktin *et al.*, 2020; Wong & Liu, 2019).

Snowdrops (*Galanthus* sp.) is a relatively small genus of perennial herbaceous plants distributed throughout Europe and central Asia, threatened in the wild due to habitat destruction, illegal gathering and climate change. A cherished garden plant with beautiful flowers blooming in winter and early spring, *Galanthus* is the world's most traded wild-sourced ornamental bulb genus. To implement the Convention on International Trade in Endangered Species of Wild Fauna and Flora regulations, Turkey sets annual export quotas of wild bulbs at 2.5-5.0 million for *G. elwesii* and 2-4 million *G. woronowii*. Georgia sets an export quota of wild *G. woronowii* at 15 million a year to ensure the trade and gathering do not endanger the survival of wild populations (Rønsted, Zubov, Bruun-Lund, & Davis, 2013; UNEP, 2021, p. 2021).

Natural cloth and dye

Numerous wild plants, lichens, and mushrooms have been used as natural dyes for centuries. Some of them, such as Brazil wood *(Caesalpinia echinata)*, were traded across continents. Most natural dyes were substituted by chemical dyes from the 19th century on, but some remained in use in local arts and crafts, and have been revived recently. Some species are not only on textiles but also in the cosmetic and food industries. For instance, the lichen *Rocella canariensis* is used as a food coloring known as E121 (Cardon, 2007).

Cotton, linen, silk, wool and artificial fiber and dyes have replaced many wild sources. Uganda bark cloth was derived from the wild fig or mutuba tree *(Ficus natalensis)* and has been recognized by UNESCO as a masterpiece of the 'Intangible Cultural Heritage of Humanity'. The production process requires collaboration among local laborers, specific skills and specially designed tools. In recent years bark cloth has been explored as a sustainable fashion luxury textile, providing jobs to local communities (Venkatraman, Scott, & Liauw, 2020). The use of bark facilitates scattered planting of mutuba trees in agroforestry systems, which in turn protects crops and soil from erosion on windy hill slopes. World Overview on Conservation Approaches and Technologies (WOCAT) has developed a guide on the use and propagation of the tree. This example highlights the value of this specialized knowledge. However, traditional knowledge on unique dying sources and processes is vanishing fast, and represents a knowledge gap which may become impossible to address in the near future.

Many wild fungi and lichens are also harvested for use in dye making. For example, Emery, Martin and Dyke (2006) found that of the over 200 species harvested from the wild in Scotland, 76 of them were non-vascular species. Of these, 16 were harvested for crafting purposes such as the production of dyes for homespun wool. A group of lichens known collectively as 'orchil' has been used as a dyestuff since the Bronze Age in Europe. Trade in orchil declined as manufactured, synthetic and cheaper alternatives were found. It continues at low levels for artisanal use (Wolfslehner *et al.*, 2019). Some firms specialized in plant dyes aim at meeting standards of environmentally and socially responsible manufacturing and have applied to a certification, but as of 2010 this issue remained unresolved (Cardon, 2010).

Handicrafts

The following is not meant to be an exhaustive inventory of all wild algae, fungi and plants used for handicrafts. Rather, it is a review of the wild species of interest with regards to sustainable use which appeared in the systematic literature searches.

A wild plant material called golden grass *(Syngonanthus nitens)* is used to produce golden handicraft articles in Brazil. Rural communities harvest, process and knit the scapes of *Syngonanthus nitens*, which has been an important source of income for them since the late 1990s. The survival of plant populations was once affected by the increase in community demand for scapes. The Brazilian federal environmental agency (Ibama) has proposed management techniques to prevent overexploitation of the species. For example, the harvest time was set precisely to ensure the removal of inflorescences after seed production or full maturation. Furthermore, returning the capitula of inflorescences used in handicraft to the field represents another important tool for the sustainable management of golden grass (Oliveira, Cruz, Sousa, Moreira, & Tanaka, 2014; I. B. Schmidt, Figueiredo, & Scariot, 2007; I. B. Schmidt & Ticktin, 2012).

There are several types of wild plants in the United States of America called Sweetgrass, that can be used to make handcrafts. *Hierochloe odorata* is native to Northern North America and is commonly used as incense and fragrance by Native Americans. It is used traditionally to craft or decorate baskets and bowls (Leif, 2010). In South Carolina, gulfhairawn muhly *(Muhlenbergia filipes)* is also called Sweetgrass. Its leaves are gathered by the Gullah community, descendants of enslaved Africans, to make a form of coiled basketry. The Gullah basket is now recognized as an artform and a major source of income for the local people (USDA & NRCS, 2009). This native coastal grass on which the basket makers depend has become increasingly scarce due to urbanization and limited access to the resource. Basket makers have to develop social-economical strategies, such as purchasing raw materials from other states, or negotiating access to the grass to maintain the traditional artform and their livelihood (Grabbatin, Hurley, & Halfacre, 2011; Hurley *et al.*, 2013; USDA & NRCS, 2009).

Many species of wild fungi are harvested for craft purposes. Turkey tail mushrooms *(Trametes versicolor)* grow throughout North American forests, and also across Europe and Asia. Turkey tail is a very colorful bracket fungus that grows throughout the year on dead or rotting wood. Pieces of the fruiting body are often harvested for use by artists and jewelry makers, who most commonly use them in earrings and necklaces (Spahr, 2009). *Ganoderma applanatum* (commonly known as the artist's conk) is also a bracket fungus with a cosmopolitan distribution. It is sometimes used as a medicinal tea, but it is most commonly known in North America for its use as an artist's canvas of sorts, where burning or carving into the underflesh of a dried polypore leaves behind brown markings to create images (Wetzel, Duchesne, & Laporte, 2006). In this case, while some mycelia live on in the dying or decaying wood medium, polypores take so long to grow that when the fruiting body is harvested, functionally almost the entire the organism is harvested.

The long-term sustainability of wild mushroom, wild fungi and wild lichen gathering varies depending on several factors. First, how much of the organism is harvested is paramount. In most cases, it is actually only the fruiting body that is taken, leaving the mycelium behind in its substrate. However, if the fruiting body is harvested before the spores are released the reproductive potential is essentially removed. Despite variation across species and regions in what is harvested and how, there is general agreement that most fungi harvested for crafts purposes are harvested at sustainable levels.

Bark is a popular handicraft item. Otomi people in Mexico use barks of *Trema micrantha* and several Ficus species for handmaking paper crafts. With the color paintings by the Nahua people, Amate bark paper has been traded nationally and internationally. Bark harvesters include indigenous and non-indigenous peoples, often of low-income. From the 1980s to 1995, the bark supply increased dramatically from only 4 main harvesters to around 200 people in an area of 1500 km^2. As the main source and preferred species of bark paper, Trema micrantha are fast growing, occur within all vegetation and can be harvested throughout the year. The species is recommended for amelioration of degraded lands. It is planted as a shade tree in coffee plantations. When it reaches five to eight years of age it is removed as part of the management of the coffee plantation. With the expansion of the harvest area, including the above factors, this use of bark to make Amate handicrafts is considered to be growing and sustainable (López, 2005). Birch bark is also harvested throughout central North America and northern Europe and used for a variety of handicrafts including baskets and ornaments. According to Emery *et al.* (2014), "Paper birch *(Betula papyrifera)* is a cultural keystone species for the Anishinaabe in the United States of America Great Lakes region" specifically because of its bark.

Perfume and incense

Aromatic plants often have medicinal values and face the same stress and sustainability problems as medicinal plants. Numerous resins are used as incense around the world, either for local use and small-scale trade or for international trade, such as frankincense (*Boswellia* spp.) or myrrh (*Commiphora* spp.). Frankincense and myrrh products also have wide ranges of other industrial uses such as for food and beverages, and are used as traditional medicines in China. The first two quality grades of final products are sold in international markets and the least quality graded items are for domestic use like in churches, coffee ceremonies, etc. Tapping and gathering of frankincense is carried out around the dry season. It follows a specific pattern including shaving a thin layer of the bark, the moderate widening of the wound one month later, and then the gathering the gum. An average of 500 g of frankincense is obtained from each tree each season after three to four months of continued tapping (W. Tadesse, Desalegn, & Alia, 2007).

Total world export demand is estimated at around 2500-10,000 tons/year with much uncertainty, since the European Union and the United States of America have a broader classification of natural gums and resins in the harmonized system code. The principal exporters are Ethiopia, Kenya, Somalia and Eritrea (Coppen, 2020b; Wubalem Tadesse, Dejene, Zeleke, & Desalegn, 2020). *Boswellia papyrifera* which is the main source (70% of the Ethiopia's natural gum and resins production) is declining at alarming rates, due to expansion of agricultural lands, overgrazing, population increase, growing demand for construction and fuel wood, forest fires, and pests and diseases. Recent increases in demand of frankincense have also led overharvesting. The lack of traceability in the supply chain and the ineffectiveness of organic certification also affects populations of substitute frankincense species. Studies suggested cultivation and substitution to mitigate the impact and sustain this historical activity (Brendler, Brinckmann, & Schippmann, 2018; S. Johnson *et al.*, 2019; Wubalem Tadesse *et al.*, 2020).

The Spikenard, also called *Jatamansi*, is made from the rhizomes of *Nardostachys jatamansi* distributed in the Qinhai-tibet Plateau and Himalayas in Asia. It is vulnerable to harvesting and on the verge of extinction due to overexploitation and habitat destruction in some areas. It was evaluated as critically endangered in India but is common in Himalayas of China and Nepal. Sustainability of harvest is related to the harvesting practices. The sensitivity is higher in outcrop than in meadow habitats. Positive effects are possible with low harvesting levels under strict management conditions (Ghimire, Gimenez, Pradel, McKey, & Aumeeruddy-Thomas, 2008; Ghimire *et al.*, 2005; Kamini & Raina, 2013; Larsen, 2005).

3.3.2.3.3 Energy

As renewable sources of bioenergy, wild plants and fungi have a huge contribution to make to reducing both carbon emissions and energy poverty. Many African countries have high proportions of fuel species. In East Africa, the indigenous tree species *Croton megalocarpus* supports a sustainable seed oil industry that provides biofuel for electricity. One microenterprise, EcoFuels Kenya, sources more than 3,000 tonnes of wild-harvested nuts each year. Fungi, in particular, have much unexplored potential within the bioenergy sector. Microbial fuel cells can be run on fungal enzymes, such as those from baker's yeast *(Saccharomyces cerevisiae)*, to generate electricity from plant biomass (Antonelli *et al.*, 2020).

Switchgrass *(Panicum virgatum)* is native to North and Central America, can grow in many different soils, has low fertilizer requirements and can in some cases promote biodiversity depending on the land use being displaced (Cheng & Timilsina, 2011). It can be used as a biofuel source and has potential economic benefits especially in the United States of America. Despite this potential, the environmental consequences of converting to crop grasslands and large land use needs must be addressed (Barney & DiTomaso, 2010; R. A. Brown, Rosenberg, Hays, Easterling, & Mearns, 2000). Switchgrass has been shown to have the potential to decrease soil erosion rates 30 times during the first year of growth, and up to 600 times during the second and third years when the root system has been established (McLaughlin *et al.*, 2002; Williams, Inman, Aden, & Heath, 2009). Werling *et al.* (2014) found that perennial grasslands that contained switchgrass and prairie plantings have significantly higher biodiversity than maize lands, as arthropods, grassland birds, soil-living methanotrophic bacteria and pollination-insects were found, among others.

Two other interesting wild plant species are *Miscanthus* spp., which is native to Southeast Asia, and Bermudagrass *(Cynodon dactylon)*, native along the United States of America coast. All three grass species are very interesting as biofuel plants, as they grow in the wild but can also be cultivated (Cheng & Timilsina, 2011). The grass genus *Miscanthus* is among the first crops for which bilateral agreements have been developed under the Convention on Biological Diversity to guide breeding of new varieties from wild germplasm collections from Asia (Antonelli *et al.*, 2020; Grace *et al.*, 2020). Certain natural grasslands are found in some climate zones and it may be beneficial for future biofuel production to come from grassland as the root system in the soil can prevent erosion.

Jatropha is a group of non-edible plants found mostly in America that includes 66 species (Dehgan, 1984; Goel, Makkar, Francis, & Becker, 2007). The most common species, *Jatropha curcas*, is a multipurpose plant species useful to control soil erosion, improve soil infiltration, reclaim wasteland and phytoremediation of contaminated soil, and prepare green manure (Subedi, Chaudhary, Kunwar, Bussmann, & Oaniagua-Zambrana, 2021). The species has a high core nonvolatile oil content, between 25 and 35% (Díaz *et al.*, 2017; R. S. Kumar, Parthiban, Hemalatha, Kalaiselvi, & Rao, 2009), and is the most domesticated species of *Jatropha* used today. It was created through a combination of systematic selection, inter-hybridization (between *J. curcas* and *J. integerrima*) and breeding programs and has a higher oil content (Sujatha & Prabakaran, 2003), but *Jatropha* is still a wild plant grown as live fence around agricultural fields (Becker & Makkar, 2008; R. S. Kumar *et al.*, 2009) and is regularly used by indigenous people Subedi *et al.*, 2021). The other plant with oil content—*Croton megalocarpus*— is native to eastern Africa and can have a seed oil content of 30-45% on a mass basis (Aliyu, Agnew, & Douglas, 2010; Hines & Eckman, 1993).

Another interesting wild plant rich with oil is the Beauty Leaf Tree *(Calophyllum inophyllum),* which can carry 10,000 fruits per tree a year and the seeds contain up to 60-70% useful oil (Friday & Okano, 2006; Jahirul *et al.*, 2013). The tree is native to Australia but has been introduced to Southeast Asia and India and started to use as biofuel plant at small-scale (Friday & Okano, 2006). Brock *et al.* (2018) noted the gold-of-pleasure *(Camelina sativa)*, which is an old-world oilseed crop that went out of use in the mid-20th century but has now gained renewed interest as a biofuel source.

There are various studies about wild-living plants and crops and even Yang *et al.* (2013) have studied possible wild plants for biofuel production and to avoid competition of using of edible plants for food industry. They studied wild plants from salt-alkali wastelands, which often occur in many arid and semi-arid regions of the world. They note that "[…] the direct competition with food production should be avoided and a much wider range of plants possible sources of biomass should be made or screened so that they are able to be grown on marginal lands. The non-edible biofuel plant species with fewer inputs, higher tolerant are required so that the diesel plants can be planted in the desert or on the saline-alkali land." They listed several wild herbaceous plants rich in oil from stems and leaves in China: *Euphorbia heyneana* (15.01%), *Ricinus communis* (13.9%), *Cirsium setosum* (12.5%), *Euphorbia nutans* (11.02%), *Cirsiu japonicum* (9.27%), *Metaplexis japonica* (8.27%), *Taraxacum officnala* (7.75%), *Lactuca raddeana* (7.63%), *Euphorbia humifusa* (6.88%), *Euphorbia thymifolia* (6.81%), *Euphorbia* *esula* (6.57%) and *Aster tataricus* (5.64%). It is possible to develop a method to extract biofuel from these herbaceous plants and at the same time use the semi-alkali wasteland as possible cultivation land and avoid competition with crops for food production.

3.3.2.3.4 Food and beverage

Food consumption is the most common form of use for gathering wild species. Foraging is the oldest productive activity of people, but it keeps being practiced, in rural as in urban environments (Svizzero, 2016). Information on wild species used for food historically came from ethnobiological/ethnobotanical inventories. It is more recently increasing in the scientific literature due to renewed interest in gathering and sustainable use. The most important sources of human food are almost all vascular plants (flowering plants, conifers and other gymnosperms, ferns, horsetails and clubmosses), accounting for 7,014 species of the 7,039 included in the reviews cited. The remainder are bryophytes (mosses, liverworts and hornworts), and green and red algae (Antonelli *et al.*, 2020; Ulian *et al.*, 2020). In agricultural and forager communities in Asian and African countries, the mean use of wild foods is 90-100 species per location, and in indigenous communities there are an estimated 120 wild species used as food in communities in both industrialized and developing countries (Bharucha & Pretty, 2010).

With economic and social development, the acquisition of wild food through gathering has been gradually marginalized. In some places, the harvest and consumption of wild foods is considered antiquated behavior and may even be denigrated and abandoned (Garcia, 2006; Łuczaj *et al.*, 2012). For example, islands of Western Oceania are particularly rich in native fruit and nut trees; in Vanuatu, out of 40 of these native species, 30 are not cultivated; they used to play an important part in local diets but presently are often substituted by industrial food (Walter & Sam, 1999). In places where gathering persists, it has been suggested that some people consider it an optimal alternative to farming. This may include trading foraged goods with farmers. This is recognized to be the case in places where gatherers refrain from practicing agriculture for cultural, social, or institutional reasons. (C. Tisdell & Svizzero, 2015). Nevertheless, it is now valued again in some countries as health food and in haute cuisine (Łuczaj *et al.*, 2012; Doyon, 2019). There is also a growing demand for wild plants in the food and aromatics industry (Lescure *et al.*, 2015).

In addition to being a food source, evidence shows that for some indigenous peoples and local communities, during times of food shortage wild foods provide nutritional supplements of important vitamins and minerals (Harris & Mohammed, 2003). This finding extends to urban dwellers in developed countries. Gathering wild foods sustains dietary traditions and supports community livelihoods. Trends in consumption of wild foods in Europe vary according to regions and countries, and according to categories of species. One study found that across European Union countries at least 27 species of mushrooms and 81 species of vascular plants are harvested and consumed as wild food (Schulp, Thuiller, & Verburg, 2014). Gathering for food is not a static process; some wild plants are consistently gathered, others are forgotten or re-emerge after periods of unpopularity (Łuczaj *et al.*, 2012).

Scientific studies have focused on the analysis of dietary conditions related to human health, such as the nutritional content of wild species, toxic side effects, heavy metal concentration (mainly fungi) and health risk assessment. Recorded indigenous and local knowledge combined with scientific analysis, is promoting new resources for crop development, the protection of crop wild relatives, and the provision of new solutions or ideas to address global hunger and protein sources. Because the number of wild plants (and fungi) gathered for food is so extensive, we have further divided this section into sub-sections.

Wild fruits are important source of nutrition, medicine, materials for cosmetics, crafts, fiber, and fuel and are the most widely used wild algae, fungi and plants. Clement (2006) distinguishes three types of fruits: (i) nuts and seeds, which contain oil and are rich in proteins and so can play an important part in the diet, (ii) starchy fruits rich in oil and starch (such as palm fruits) and (iii) juicy fruits, such as berries, rich in vitamins. In the United States of America alone, permitted harvest volumes of edible fruits, nuts, and berries were as follows: 303, 748 gallons and 670,726 pounds (Chamberlain, Emery, & Patel-Weynand, 2018). While these figures represent the best available data, they likely do not represent total harvest of popular species black walnut (*Juglans negra* L.), pine nuts, and low-bush blueberries.

A recent literature review on wild edible fruits found that studies have increased over the last three decades, a majority of it reports ethnobotanical and taxonomic descriptions with relatively few studies on their landscape ecology, economics, and conservation. Among them, a third of retrieved articles were based on studies in Africa and a quarter were from South America. (Sardeshpande & Shackleton, 2019).

Different fruit species respond differently to harvesting and other disturbances, such as fire and herbivory. Although the review by Stanley *et al.* (2012) concludes that the majority of case studies surmise that wild algae, fungi and plants harvests are ecologically sustainable, Sardeshpande and Shackleton (2019) found 14 of the 25 studies explicitly addressing harvest sustainability illustrated overexploitation beyond recovery to optimal vitality. In some cases, extraction in a commercial scale is the attempt to make benefits to avoid tree logging and deforestation, such as the marula *(Sclerocarya birrea)* fruit, the Brazil nut (*Bertholletia excelsa*, Lecythidaceae) and the bush mango (*Irvingia gabonensis* Baill. ex Lanen.). When harvest is lethal to the plant or market demand is high which drives to intensive production, the species of wild edible fruits is domesticated and cultivated as tree crops. Certification is considered to ensure the sustainability of gathering under the influence of the trade chain and to promote socio-economic conditions for harvesters and forest communities (Sardeshpande & Shackleton, 2019). The following examples collate several species of wild edible fruits are a complement to the aforementioned review that are mainly gathered from the wild and also support a certain scale of trade in a medium term.

Nuts and Seeds

In the United States of America, pine nuts (*Pinus monophyla* Torr. & Frém.) are highly prized nuts harvested primarily from natural stands on public lands in the western half of the country. These forests are usually not actively managed for pine nut production and in fact are a forest complex (pinyon-juniper) that was historically seen as without much value and eradicated in favor of range lands. However, pine nuts have a long history of use among indigenous peoples and local communities in the southwestern United States of America, where pine nuts continue to be harvested for local markets and for export. While the United States of America exported approximately 20,000 United States Dollars worth of pine nuts in 2007, it imported about 54 million United States Dollars worth (Chamberlain, Emery, & Patel-Weynand, 2018), suggesting that the majority of pine nuts harvested are for personal and local use. Also in the United States of America, approximately 25 million pounds of black walnut (*Juglans nigra* L.) were harvested from natural populations in 1998, although it is unknown if this constitutes a sustainable harvest amount (Chamberlain, Emery, & Patel-Weynand, 2018).

The Brazil nut tree is an iconic tree occurring in *terra firme* (non-flooded) forests throughout the Amazon basin. It can reach up to 50 meters tall and live for hundreds of years. Brazil nut seed harvesting from natural forests is a cornerstone algae, fungi and plants economies in Amazonia. Brazil nuts are the only globally traded seed gathered from the wild by tens of thousands of rural households and are an integral component of the extractivist culture of many indigenous peoples and local communities in the area. In the Brazilian Amazon alone, over 45,000 tons of Brazil nuts are gathered annually, with sales of over 33 million United States dollars (Guariguata, Cronkleton, Duchelle, & Zuidema, 2017; Peres *et al.*, 2003; Wadt, Kainer, Staudhammer, & Serrano, 2008).

Brazil nut is organized in a concession system and the supply chain includes three certification schemes: (i) organic certification; (ii) Fairtrade certification; and (iii) Forest Stewardship Council certification. It is considered a model of the use of wild species for promoting "conservation-through-use". Extensive research suggests the Brazil nut tree reacts robustly to the type and level of extraction currently practiced in the medium term (Guariguata *et al.*, 2017).

Given the importance of this species to the local economy, this assessment highlights some specific concerns that may affect future status and trends of Brazil nut production. Without active management, in the past extensive and intensive exploitation led to insufficient juvenile recruitment to maintain populations, and harvested populations went into a process of senescence and demographic collapse. Rainfall is also a key factor in determining tree performance and demography and the forecasted declines in pollinator diversity may threaten the long-term resilience of the Brazil nut trees. Climate change therefore could potentially negatively impact *B. excelsa* populations (Peres *et al.*, 2003; Thomas *et al.*, 2017). Changes in human use of the forested landscape are also an immediate concern. Brazil nut extraction is accompanied by unsustainable forestry activities outside the gathering seasons in a given year. Due to development pressures, Brazil nut forests have been gradually destroyed and transformed into market-oriented agricultural areas to support global beef markets. Land conversion in the basin has also sparked violent conflicts and led to decreased sustainable management of Brazil nut producing areas. Some of these challenges are being addressed in Brazil, Bolivia and Peru (Bertwell, Kainer, Cropper Jr, Staudhammer, & de Oliveira Wadt, 2018; Escobal & Aldana, 2003; C. S. Simmons *et al.*, 2019; Wadt *et al.*, 2008).

Starchy Fruits

At least 30 Amazonian palm species are used as food, most of them for their fruits (*Attalea* spp., *Euterpe* spp., *Mauritia flexuosa, Oenocarpus* ssp.), consumed raw, cooked or processed into drinks (Kahn, 1997). *Oenocarpus bataua* is the seventh most abundant tree in the Amazon and one of the most used palms in neotropical forests in the Americas. Once, felling adult palms was the most common technique used to harvest fruits, which negatively affected the demography of its population. Inconsistent regulations on *O. bataua* harvesting across different countries contributes to confusion and threatens sustainable use of this species. Colombia has a harvest quota; Ecuador requires management plans; Peru and Bolivia forbid killing the tree. However, in all cases enforcement is difficult. To support sustainable use, in some villages, adult palms are climbed when they are not too tall to cut racemes with ripe fruits, and such non-destructive harvest techniques may meet the increasing demand and maintain the populations.

Pequi *(Caryocar brasiliense)* is a native fruit from Brazil, found in the Amazon, Caatinga, Cerrado, and Atlantic rainforest regions, and has high potential for sustainable use (Guedes, Antoniassi, & de Faria-Machado, 2017). Pequi was harvested in 265 municipalities in the Cerrado ecoregion, which produced approximately 76 thousand tons. Finally, 42 thousand tons of pequi were harvested from 2012 to 2017.

Juicy Fruits

Berries and juicy tree fruits are harvested all over the world for personal, informal economic and formal economic use. In the United States of America people commonly harvest wild low-bush blueberries, wild raspberries, wild strawberries, and less commonly serviceberries (*Amelanchier* spp.), chokecherries *(Prunus virginiana)*, and other species of wild cherry (Chamberlain, Emery, & Patel-Weynand, 2018).

Lingonberry or cowberry (*Vaccinium* vitis-idaea) is one of the most popular berries in American and European Nordic countries, and it is widely used in the human diet. It is a perennial evergreen shrub distributed in circumboreal regions of northern Eurasia and North America. Lingonberries are most commonly harvested by hand with berry rakes. Lingonberry is an important element of coniferous forests understories in terms of nature's contributions to people, and it also has cultural and economic importance, linked to a rural lifestyle. Major lingonberry-exporting countries are Sweden, Finland, and the Russian Federation (Padmanabhan, Correa-Betanzo, & Paliyath, 2016; Pouta, Sievänen, & Neuvonen, 2006; Woziwoda, Dyderski, & Jagodziński, 2020). A set of criteria and indicators were involved in assessing the commercial supply chain of bilberry in Finland, and suggested a lack of social sustainability due to decreasing involvement and consultations with forest owners and the local communities (Hamunen, Kurttila, Miina, Peltola, & Tikkanen, 2019).

Lingonberries are most commonly harvested by hand with berry rakes. In Finland, 11-26 million kg of bilberries and lingonberries were gathered in the 1990s. It is estimated that over half of the population still participates in berry picking based on the Nordic *allemannsretten* or "everyman's right", which is a long-standing right to move through and share resources on both private and public lands, including the right to pick berries and mushrooms in communal areas.

Some estimates suggest utilization rates of the two most common berries, bilberry (*Vaccinium myrtillus* L.) and lingonberry are low (4–15% of the total annual yield of wild berries), making this a very sustainable activity. One study found that approximately 32% of the total harvested of berries were for commercial sale (Turtiainen, Salo, & Saastamoinen, 2011). However, the demand for so called "super foods" has accelerated exports for global markets, and the volume of the Nordic wild berry harvest has doubled during the past two decades. Along with an increase in the market demand, lingonberry has been domesticated and commercially cultivated in several locations across Europe, Scandinavia, and also recently in the United States of America (Forest Europe, 2020; Padmanabhan *et al.*, 2016).

The land area covered in bilberry *(Vaccinium myrtillus)* bushes and locally harvested berries have declined in Central Italian Apennine regions in recent last decades (Nin, Petrucci, Del Bubba, Ancillotti, & Giordani, 2017). Regular gatherers of bilberry in Estonia use clearly delineated picking areas, and typically do not share their areas outside close family relations (Remm, Runkla, & Lohmus, 2018). Bilberries are also a popular wild food in the Czech Republic, where the number of households involved in the gathering of wild fruits has increased in recent years. The ratio of participants and yield of bilberries are the highest in wild fruit (Wolfslehner *et al.*, 2019). There is also a high demand on bilberries in France. The boom started in the late 1960s. At that time some gatherers in the Massif Central area increased the quantity of berries they were gathering by 500%. This gathering is regulated for non-residents (Larrère, 1982).

Most cacti produce edible fruit for humans but prickly pears of *Opuntia* species and fruits from *Stenocereus, Cereus,*

Box 3 8 **The many lives of a single plant.**

Based on (Paye, 2000, p. 142; Yetman *et al.*, 2020, p. 69).

The Saguaro cactus *(Carnegiea gigantea)* grows in desert of Arizona, California, and Mexico, and can reach up to height of 15 meters (50 feet) with a life span of about 200 years (Yetman *et al.*, 2020). The fruits are harvested by O'odham Indians, who cook the pulp to make jam, candy, syrup, and wine, but the wild plant also plays an important role in the lives of many other organisms in these environments of which humans are a part. It takes 50 years for this cactus to bear flowers and fruits. The cactus provides shelter and food for numerous organisms throughout its life span. Carpenter birds and elf owls make nests in the fleshy body of the cactus, and Harris's hawks build nests in the branches. Bats, doves, butterflies and bees enjoy the nectar when the cactus blooms during May. Many animals such as curved bill thrashers, horned lizards, coyotes, and javelin pigs also eat the fruits. As the cactus nears the end of its lifespan, aquatic beetles swim through the decomposing plant flesh. When the cactus is dead, it is home to termites, spiders, giant centipedes, banded geckos, cactus mice, and spotted night snakes.

Carnegiea and *Pachycereus* species are the most important for numerous peoples of the arid Americas **(Box 3.8)**. Fruits are gathered from the wild, semi-cultivated and cultivated stands. People commonly make use of a tool called "chicole" which is a long stick with a kind of basket in the top. With "chicole" people reach and pull fruits without damaging them or injuring themselves or the wild plant. The fruits harvested are stored in a basket or bucket for transporting them to homes and markets. In agroforestry systems, people sometimes leave fruit-producing cacti because they favor their propagation and take special care of these valued plants. Some species, mainly *Stenocereus, Cereus, Lemairocereus*, are cultivated, and processes of domestication and generation of varieties associated to human selection have been documented in Mexico (Casas & Barbera, 2002; Casas, Otero-Arnaiz, Pérez-Negrón, & Valiente-Banuet, 2007).

Beverages

Mead, Hyssop, Salep, teas, and wild coffees from dandelion greens and chicory are some of the many beverages people make from wild plants. The English term "tea" refers the infusion made of the leaves of *Camellia sinensis* but there are kinds of aromatic and refreshing beverages around the world. In Europe, 142 taxa of plants belonging to 99 genera and 40 families are reported the use of recreational tea (Sõukand *et al.*, 2013). In China, 759 plant species have documented for use as teas, and a market survey identified an additional 23 species used as herbal tea (Fu *et al.*, 2018). The majority of wild plants used are perceived as medicinal plants in local folk medicine or "folk functional foods". The status of the use of herbal tea is dependent on access to the natural resources, cultural and social contexts, and the habit of its use in the region and personal preferences of the consumer.

Salep is a beverage made from orchid tubers in Europe and central Asia. Harvesting wild orchid tubers for this purpose dates back to the medieval period. Six species of orchids are named as components of Salep. Tuber gathering for Salep has been cited as a cause of orchid population decline and causes conservation concern in Turkey and neighboring countries (Charitonidou, Stara, Kougioumoutzis, & Halley, 2019; Ghorbani, Gravendeel, Naghibi, & de Boer, 2014; Kreziou, de Boer, & Gravendeel, 2016; Masters, van Andel, de Boer, Heijungs, & Gravendeel, 2020). Scientists and conservationists recommend cessation of wild orchids harvest for this purpose (Ghorbani *et al.*, 2014).

Syrups, Gums and Resins

Indigenous tribes in Eastern North America know the sap of maples (*Acer* spp.) and call it "sweet water." When the first European explorers and colonists arrived, they learned of maple sap and boiling the sap down to produce syrup or sugar. Sugar maple *(Acer saccharum)* is the species most frequently tapped for sap production. Under the best conditions, sugar maples reach a tappable size in about 40 years and can continue to produce sap for a century (Ciesla, 2002). During the maple sugaring season, which lasts about six weeks in spring, an average maple tree will yield between 35 and 50 liters of sap, which will produce between 1 and 1.5 liter of pure maple syrup (Ciesla, 2002).

Maple syrup is produced only in the Eastern United States of America and Canada. Maple syrup production is a hobby that connects people to nature, provides supplementary income for farmers, and is an important cultural practice for indigenous peoples (Weiss *et al.*, 2019). As a large-scale commodity, maple syrup is a luxury item consumed worldwide **(Figure 3.41)**. The largest market for syrup is in the United States of America. Since the late 19th century, maple production in the United States of America has declined while that in Canada has increased. With sugar maple (*Acer saccharum* Marshall) often distributed throughout the region's forests, only a small percentage of potentially tappable trees are in use for maple syrup production (an estimated 0.4% in the United States of America; Ciesla 2002, Farrell and Chabot 2012). Maple syrup production is weather dependent and expected to be heavily affected by climate change, with the potential for it to be eliminated in southern reaches of its current distribution peaked in the 19th century, reaching a record 25,032,928 liters of maple syrup in 1860. (Iverson & Matthews, 2018).

In Europe, the main sources of tree sap are silver and downy birch trees (*Betula pendula* Roth and *Betula pubescens* Ehrh). Birch sap is colorless or slightly opalescent. It is used as a traditional drink, in traditional medicine, in veterinary medicine and as a cosmetic product. Gathering sap from birch and other trees was more widespread in earlier times. In Russia, Ukraine, Belarus, Estonia, Latvia and Lithuania it remains a more common practice. The most productive silver birch trees for sap gathering are those taller than 28 m. A birch tree can produce 36l gallons of sap in nine days. Experiments conducted in Estonia in the 1970s showed that the profit gained from the sap was six times the profit gained from timber. More recently birch sap is becoming a more commercial product, and is of interest to pharmaceutical companies (Grabek-Lejko, Kasprzyk, Zagu\la, & Puchalski, 2017; Mingaila *et al.*, 2020; Svanberg *et al.*, 2012).

Gum Arabic or acacia gum is a tree gum exudate gathered from a number of *Acacia* species and has been an important part of commerce since ancient times. Gum Arabic is used in food and drink industries, in pharmaceuticals and in printing and textile industries as thickening, stabilizing, binding and sizing agents. Gum resin products are harvested from natural exudates by herdsmen, women and children while herding and doing other activities. Yields of gum Arabic from individual trees are very variable.

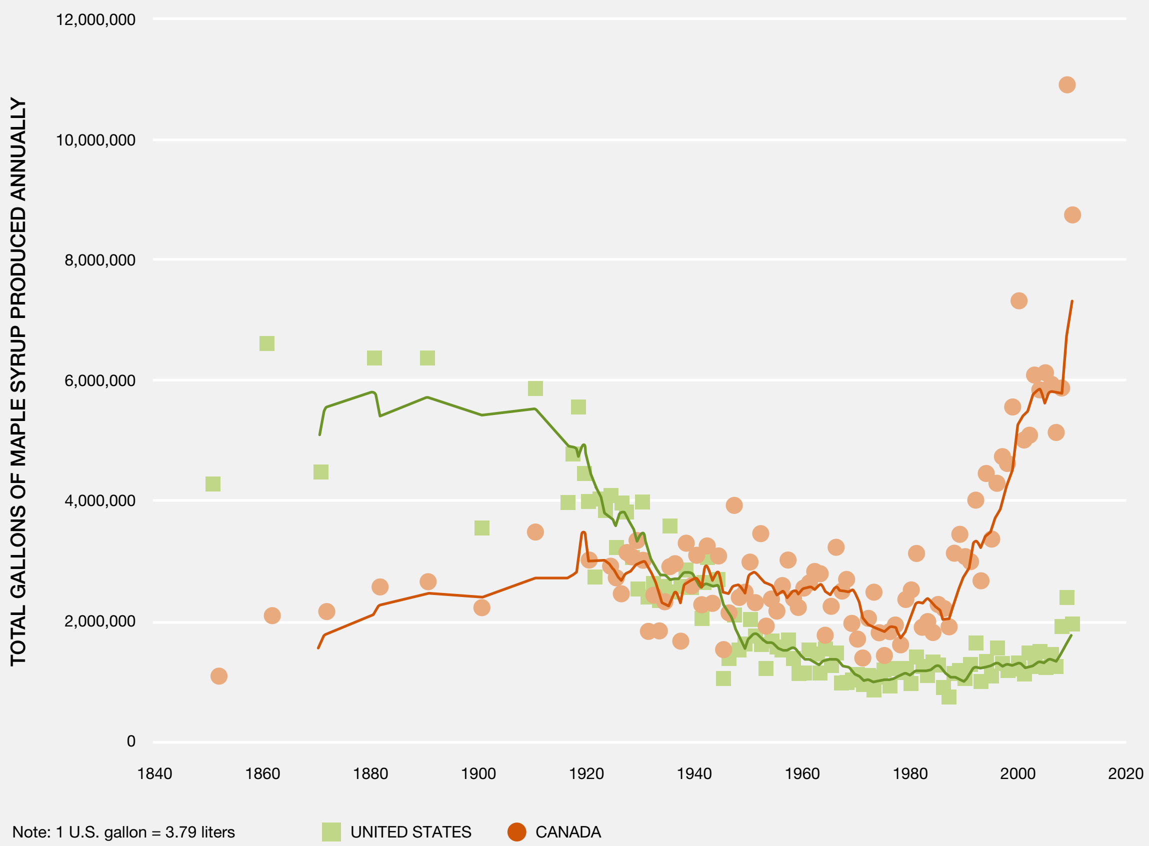


Figure 3 41 **Maple syrup production in the United States of America and Canada 1860–2010.**

Source: (Freire *et al.*, 2020) under license CC BY 4.0.

A tree yields an average of 250g of gum per season. Very small proportions of gum enter the local market, but some is directly sold as a road-side snack in some West African countries, in Niger for example (E.S. Barron personal observation). African countries export about 100,000 tons of gum Arabic annually, and demand was previously projected to reach 150,000 tons by 2020. The European Union is responsible for 80% of global trade in gum Arabic, worth around 125 million euros. Sudan is one of the biggest gum Arabic producers in the world and produces more than 80% of the total world gum Arabic (Wubalem Tadesse *et al.*, 2020; B. Wolfslehner *et al.*, 2019) **(Table 3.9)**.

Karaya gum is produced as an exudate from the genus *Sterculia* including *Sterculia urens* tree found in India and *Sterculia setigera* found in Africa and is used for many industries. World demand for karaya gum is about 7,000 tons, and Senegal is the leading exporter in Africa. The population of karaya trees once markedly declined due to crude traditional tapping methods which lead to the death of the tapped trees and over exploitation. Scientific tapping and proper harvesting methods are now priorities (Nair, 2004; Wubalem Tadesse *et al.*, 2020).

Wild edible mushrooms

More than 350 species coming from 18 orders of fungi are commonly eaten as food (Willis, 2018). The number of used wild edible mushrooms is likely much higher than that based on lists and assessments from individual countries, e.g., over 1000 species of edible mushrooms are listed in China (Wu *et al.*, 2019), 371 in Mexico (Moreno Fuentes, 2014) and 268 species are traded in Europe (Peintner *et al.*, 2013). The last comprehensive global assessment was conducted in 2004 (Boa, 2004), and given the high rates of taxonomic discovery among fungi, including of useful species (Dentinger & Suz, 2014; Willis, 2018; F. Wu *et al.*, 2019), a re-evaluation is overdue. Wild mushrooms are harvested for food in over 80 countries worldwide (Pieroni, Nebel, Santoro, & Heinrick, 2005a). Among wild-harvested fungi, most commonly consumed and traded are Chanterelles (*Cantharellus* spp.), Porcini (*Boletus* spp.). Truffles (*Tuber* spp.) Morels (*Morchella* spp.), Brittlegills (*Russula* spp.), Milkcaps (*Lactarius* spp.), Button mushroom (*Agaricus* spp.), and Matsutake (*Tricoloma* spp.). Wild edible mushrooms can be found in over 200 genera, and grow in a wide variety of habitats (Boa, 2004). Many of the most popular used species form symbiotic relationships, making them difficult if

Table 3 9 **Exports of gum Arabic (tons) from different African countries 2001–2010.**
Source: (Wubalem Tadesse *et al.*, 2020) under license CC-BY 4.0.

Country / Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Sudan	7949	34382	13217	27444	33079	23149	n/a	37860	36636	48598
Nigeria	0	0	0	n/a	n/a	1314	14463	14124	40862	34780
Chad	12891	9161	9672	12044	14188	17816	11860	16219	9417	9509
Ethiopia	830	875	381	234	111	317	956	614	622	909
Tanzania	843	693	1252	1361	1169	965	1031	935	631	824
Cameroon	571	592	338	264	371	413	310	151	520	510
Senegal	121	0	0	213	323	475	610	836	935	330
Mali	482	750	704	52	28	17	29	1308	703	275
Burkina Faso	2	0	21	18	81	n/a	90	57	63	83
Kenya	23	0	92	23	32	28	75	165	41	75
Eritrea	n/a	n/a	116	49	495	38	688	419	350	51
Somalia	26	12	4	70	714	92	473	513	50	47
Niger	2	20	38	43	42	73	67	66	44	44

not impossible to cultivate. For example, all of the above-listed genera (with the exception of button mushrooms) form ectomycorrhizal symbioses with trees, while *Termitomyces* spp. which are widely consumed across Africa and Asia are symbionts of termites (Boa, 2004). Popular saprotrophic species include button mushrooms, straw mushrooms (*Volvariella* spp.), shitake *(Letinula edodes)* and oyster mushrooms (*Pleurotus* spp.), although these species are cultivated at large scale (Boa, 2004), they are also frequently harvested in the wild, for example in Malaysia (Fui, Saikim, Kulip, & Seelan, 2018), Benin (Codjia & Yorou, 2014), Mexico (Haro-Luna, Ruan-Soto, & Guzmán-Dávalos, 2019) or Italy (Pieroni, Nebel, Santoro, & Heinrick, 2005b).

To assess status and trends of wild useful fungi, literature searches were conducted via a variety of search engines (Google Scholar, EBSCO Host and SCOPUS). To this end a Google Scholar search with the terms "(gathering OR collecting OR picking OR hunting OR foraging) AND (mushroom OR lichen OR fungi) AND sustainable AND wild" served as the basis and variations in the combinations of these terms, as well as supplementation with the different use categories (e.g., ceremonial, medicinal, food) were used until 50% saturation of articles already in the database were reached. In total, 112 sources were reviewed (see the data management report for Chapter 3 systematic literature review for the gathering of fungi at https://doi.org/10.5281/zenodo.4659811).

The extent of usage of different species varies widely. Typically, ethnomycological studies report the use of tens to hundreds of species where a majority is harvested for personal use, gifting or barter (based on 20 articles from the literature review). A smaller number of popular species is sold at local and regional markets, while select species, often global commodities, are sold on to middlemen and traders to enter national and international markets (based on 9 articles from the literature review). This phenomenon is particularly well-documented in Mexico. For example, the Mazahua people use 31 species of wild mushrooms, of which 18 are sold in local or regional markets (Farfán, Casas, Ibarra-Manríquez, & Pérez-Negrón, 2007). The less popular species are also sometimes sold in mixed species bags, while a handful of highly-prized species including *Amanita caesarea* complex, porcini, morels, chanterelles and matsutake are targeted for export (Montoya, Hernández, Mapes, Kong, & Estrada–Torres, 2008; Pérez-Moreno, Martínez-Reyes, Yescas-Pérez, Delgado-Alvarado, & Xoconostle-Cázares, 2008). A similar imbalance in usage among taxa also exists at larger geographical scales as indicated by a comparison among European guidelines and legislations, where on lists from 24 countries with an average length of 55 taxa and a total of 268, only two taxa were listed in all countries: porcinis (*Boletus edulis* complex) and chanterelles *(Cantharellus cibarius)*. A further five (*Lactarius deliciosus, Morchella esculenta, Boletus badius, Agaricus campestris* and *Craterellus cornucopioides*) were listed in more than 70% of countries, while 134 (about 50%) were listed in only one or two countries (Peintner *et al.*, 2013). Finally, species preferences and use may shift over time as is highlighted by *Russula virescens* which was highly appreciated in the Southwest of France in the 18th century but is no longer consumed nowadays, while the chanterelle increased in popularity in this region (Duhart, 2012).

The use and appreciation of different mushroom species is deeply cultural, and whether a species is used and what for is often due to a multitude of factors, including language, geography, cultural and culinary traditions (Comandini & Rinaldi, 2020). For example, regions in Europe with similar occurrence of mushroom species (e.g., Southeast Europe *versus* Southwest Europe, or Eastern Europe *versus* the nordic countries) favor different species and the use of species is more strongly influenced by local tastes, traditions and commerce with neighbors than climatic variables or vegetation (Peintner *et al.*, 2013). In line with this, usage frequently reflects cultural interactions, for example in Finland, gatherers in Eastern parts of the country with stronger cultural influence from Russia prefer milk caps (*Lactarius* spp.), while those in Southwestern regions where French cuisine permeated through Swedish influence prefer porcinis and chanterelles (Comandini & Rinaldi, 2020). Immigrant populations often bring culinary traditions and preferences to their new homes, nicely illustrated in the Western United States of America, where a culture and tradition of gathering, along with different species preferences, was established by early immigrants from Europe, Asia and Russia (Arora, 2008a; Parks & Schmitt, 1997). Another salient example illustrating, fine-grained, context dependence of use are the false morels *(Gyromitra esculenta)*, which are consumed at quantity in Finland (Turtiainen, Saastamoinen, Kangas, & Vaara, 2012), and *Gyromitra infula*, which is harvested both in Nepal (M. Christensen, Bhattarai, Devkota, & Larsen, 2008) and Mexico (Pérez-Moreno *et al.*, 2008). These species are largely considered toxic and safe consumption rests on the knowledge of correct preparation (Peintner *et al.*, 2013), highlighting the importance of indigenous and local knowledge in shaping use of individual species.

The trade of edible fungi has been valued at 42 billion United States dollars in 2018 (Willis, 2018). However, this estimate includes mostly cultivable species and only two (porcinis and morels) out of the nine species evaluated are exclusively gathered in the wild, while other economically important wild taxa such as truffles, chanterelles and matsutake are omitted. Data on trade volumes also is often aggregated at higher levels that include both taxa from cultivation and wild gathering. For example (de Frutos, 2020) estimated international trade for edible fungi at 1.2 million tons for 2017 based on United Nations Comtrade data (https://comtrade.un.org/), using harmonized customs codes that include all species, except the genus *Agaricus. Agaricus* spp. constitute approximately 30% of the cultivated mushroom trade volume, so this figure is likely still influenced by the other four taxa cultivated at large scale [*Pleurotus, Lentinula, Auricularia* and *Flammulina;* (Royse, 2014)]. FAOSTAT aggregates data for all fungi into a "mushrooms and truffles" category, yielding a production of 10.9 million tons for 2017 (http://www.fao.org/faostat/en/#data/QC; Accessed 27.02.2021). Comparison with the international trade figure suggests that as much as 90% of trade volume may be based on cultivated fungi, although again it is unclear what proportion can be attributed to wild species. The FAO estimates also include *Agaricus* data and other cultivated species. The heterogeneity in taxonomic granularity of data accumulation and aggregated reporting for both cultivated and wild species makes it challenging to produce meaningful estimates of production and trade volumes of wild edible fungi. This problem constitutes an active area of work within the FAO, as reflected by the introduction of new harmonized system codes for widely traded wild plants algae and fungi coming into effect in January 2022 (World Customs Organization, 2019). Nevertheless, a body of literature focusing on specific regions or target species clearly highlights the economic importance and development potential of wild mushroom trade, especially for rural areas.

Our literature review yielded 24 studies that highlight a contribution of gathering and selling wild fungi to incomes of rural populations worldwide (3 Africa, 5 Americas, 8 Europe and Central Asia, 7 Asia Pacific). China, and Yunnan in particular, provides an excellent example of how the gathering of wild edible fungi can fuel economic development in rural areas. Yunnan harbors a large diversity of edible fungi and is the center of the wild edible mushroom industry in China (R. Hua, Chen, & Fu, 2017; Dongyang Liu *et al.*, 2018). Especially in the more remote areas of Yunnan, the contribution from gathering of wild fungi can reach up to 90% of annual household income (Arora, 2008b; R. Hua *et al.*, 2017; Huber, Ineichen, Yang, & Weckerle, 2010). In Nanhua county alone, the yearly production of wild fungi amounted to 7677 tons, valued at 80 million United States dollars (Dongyang Liu *et al.*, 2018). In 2015, the total yield of wild edible fungi for the whole province amounted to 0.17 million tons, with Yunnan being a major supplier of porcini (*Boletus* spp.) which are primarily exported to Europe and matsutake *(Tricholoma matsutake)* which are exported to Japan (R. Hua *et al.*, 2017; Huber *et al.*, 2010).

In all papers surveyed, gathering wild fungi was a supplemental activity to other forms of subsistence, primarily agriculture due to the seasonality of mushroom fruiting and year to year fluctuations in abundance and price. However, due to the highly perishable nature of the product that requires fast processing, the establishment of mushroom supply chains has led to lasting economic diversification in rural areas with the involvement of middlemen, mushroom traders and processing facilities (Arora, 2008b; Huber *et al.*, 2010; Dongyang Liu *et al.*, 2018). In Shangri-la, Diqing Tibetan Autonomous Prefecture, matsutake are often bought and sold several times before leaving the city, spreading the income not only to middlemen, who often do not have access to matsutake habitats themselves, but also to shops, restaurants and other facilities that were established near the mushroom markets (Arora, 2008b). In Mexico mushrooms are also sold to traders and middlemen, although here there was a greater emphasis on sale at local and regional markets for generation of income (Farfán-Heredia, Casas, Moreno-Calles, García-Frapolli, & Castilleja, 2018; Pérez-Moreno *et al.*, 2008).

None of the papers reviewed mentioned commercial export of fungi from Africa, but highlighted informal, local sale as the main form of generating income (e.g., Osarenkhoe, John, & Theophilus, 2014; Wendiro, Wacoo, & Wise, 2019; Yorou *et al.*, 2014). However, small scale export of porcini to Italy and the United States of America, primarily from Southern Africa, were indicated based on personal communication (Boa, 2004; Sitta & Floriani, 2008). Besides direct contributions to household income, wild mushrooms provide a rich source of protein and can help to bridge periods of food scarcity which often fall into the rainy season, e.g., in Ethiopia (Dejene, Oria-de-Rueda, & Martín-Pinto, 2017), West Africa (Yorou *et al.*, 2014) and Mexico (Farfán *et al.*, 2007).

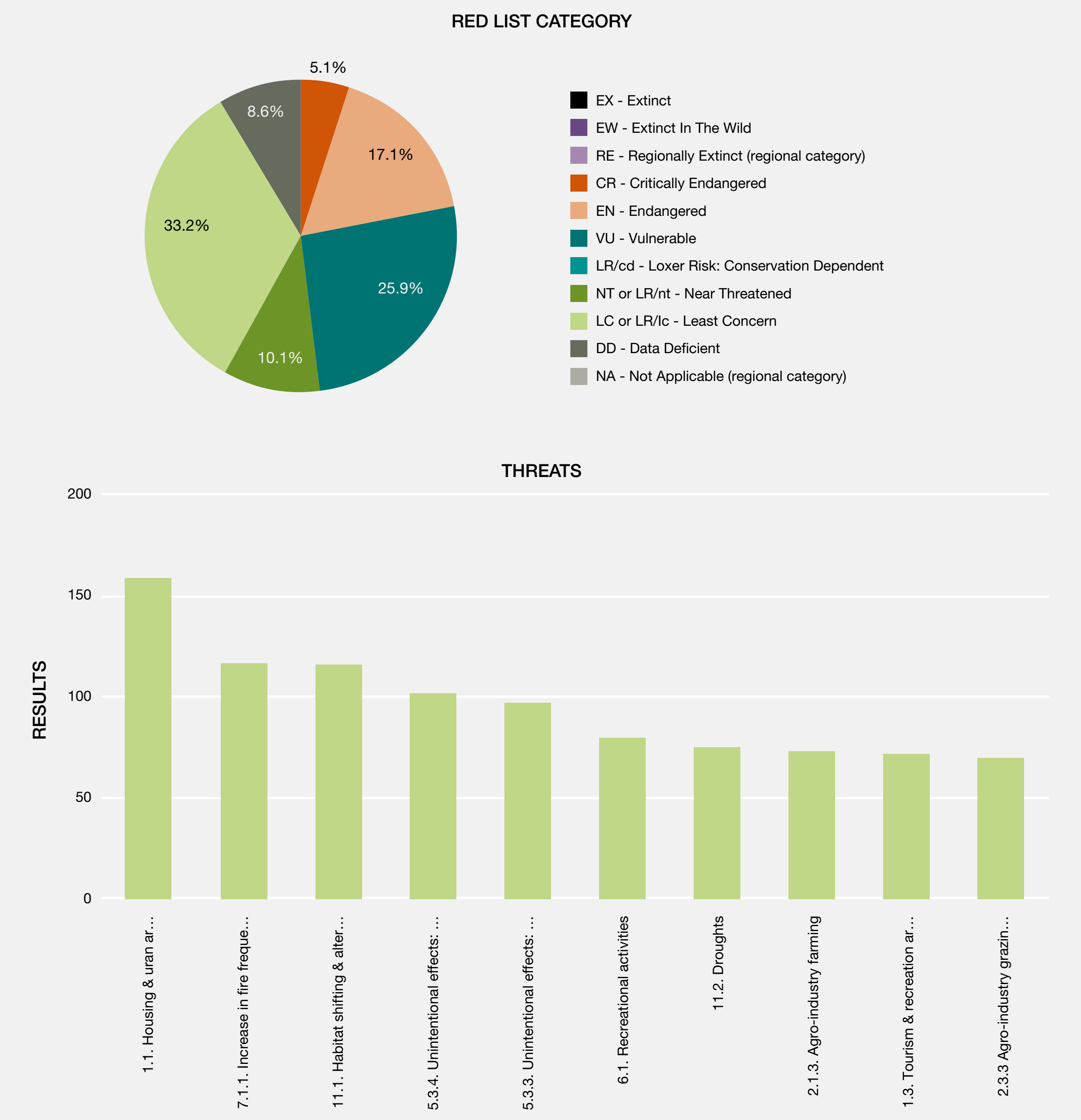


Figure 3 42 **The threatened status and threats of all assessed fungal species.**

At the top, the threatened status of all assessed 545 species and at the bottom, the threats of all assessed 545 species. Source: (IUCN, 2020b) © IUCN Red List Data. This figure was made using the International Union for Conservation of Nature website https://www.iucnredlist.org/search/stats, by selecting “Fungi” in the tab “Taxonomy”.

Table 3 10 **Distribution of edible fungi assessed by the International Union for Conservation of Nature Red List in each IPBES region.**

Abbreviations: CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern. Source: (IUCN, 2020b) © IUCN Red List Data.

IUCN status / IPBES regions	CR	EN	VU	NT	LC	Total
Americas	1	3	3	3	35	45
Asia Pacific		1	5	5	37	48
Africa			1	1	7	9
Europe and central Asia			7	5	36	48
All	1	4	9	5	41	60

In addition to the 27 sources mentioned above, a further ten studies were found where wild mushrooms were important contributors to a healthy diet and subsistence of people in economically marginalized positions. The use of wild mushrooms was also reported among several indigenous groups in the Amazon, most prominently the Jotï (Zent, Zent, & Iturriaga, 2004; Zent, 2008) and the Yanomami people (Fidalgo & Prance, 1976; Sanuma *et al.*, 2016). Recently, the Yanomami in Brazil started trading some mushrooms as a niche market (Sanuma *et al.*, 2016).

Although often considered the "meat of the poor" or emergency foods that can cover protein nutritional needs (Christensen *et al.*, 2008; Guissou, Lykke, Sankara, & Guinko, 2008; Oyetayo, 2011; Redzic, Barudanovic, & Pilipovic, 2010), this view diminishes the cultural importance of wild edible fungi. In some communities in Mexico, for example, mushrooms are considered delicacies with great flavor that are superior to meat (Farfán-Heredia *et al.*, 2018; Haro-Luna *et al.*, 2019). The strong appreciation and deep cultural traditions associated with gathering and consumption of fungi are reflected in the fact that many papers explicitly mention recreation, social bonding and stress release as a major reason why people gathered wild mushrooms (9 sources). Gifting and exchange of gathered fungi or products prepared from them among friends, family and members of the community were also mentioned several times (Garibay-Orijel, Cifuentes, & Estrada-Torres, 2006; Haro-Luna *et al.*, 2019; Pieroni *et al.*, 2005b).

Gathering and eating wild foods and engaging in culinary traditions provides a sense of place, identity and a connection with nature that is celebrated at festivals, e.g., in Spain (Fusté-Forné, 2019) or China (Dongyang Liu *et al.*, 2018) and has developed into a sizeable foraging tourism industry worth 800,000 euros per year in Spain (Fusté-Forné, 2019). Finally, a study comparing rural populations in Sweden, Ukraine and Russia showed that a high proportion of people engaged in gathering, irrespective of economic status (Stryamets, Elbakidze, Ceuterick, Angelstam, & Axelsson, 2015). Instead, the importance of commercial harvesting to supplement income increased or decreased inversely proportional to the standard of living and employment opportunities, highlighting that the social importance of gathering wild fungi may often be masked by economic necessity and reasons for gathering can shift over time.

In the International Union for Conservation of Nature Red list, 116 of 545 species of evaluated Fungi are used as human food, and 16 species of edible fungi are evaluated as threatened. With the exception of Africa, the distribution of the species assessed is relatively balanced in the other three IPBES regions (IUCN, 2020b) (**Figure 3.42**; **Figure 3.43**; **Table 3.10**). Less than 14% of edible fungi are threatened, which is lower compared to the overall level of the species assessed by the International Union for Conservation of Nature red lists (28%). However, due to the limited number of fungi assessed, the figure may not be representative of the global status. With regards to **Figures 3.42** and **3.43**, it is important to note that the majority of fungal conservation related inventory and monitoring has historically been based in Europe, hence the density of data from that region (Barron, 2011).

In a regional assessment, take China as an example, the threatened species list of China's macrofungi assesses the overall threat status of 9302 species and 1.04% of the total number of species (97 species) is assessed as threatened (Yijian *et al.*, 2020). Among the 97 threatened fungi, there are 13 species used as food, 8 species are medicinal use, and other 8 species are used both for food and medicine **(Figure 3.44)**.

Based on the literature survey, land use change (10 sources), timber harvesting, deforestation (8 sources) and climate change (8 sources) were listed as the most common ecological threats that likely affect a broad range of

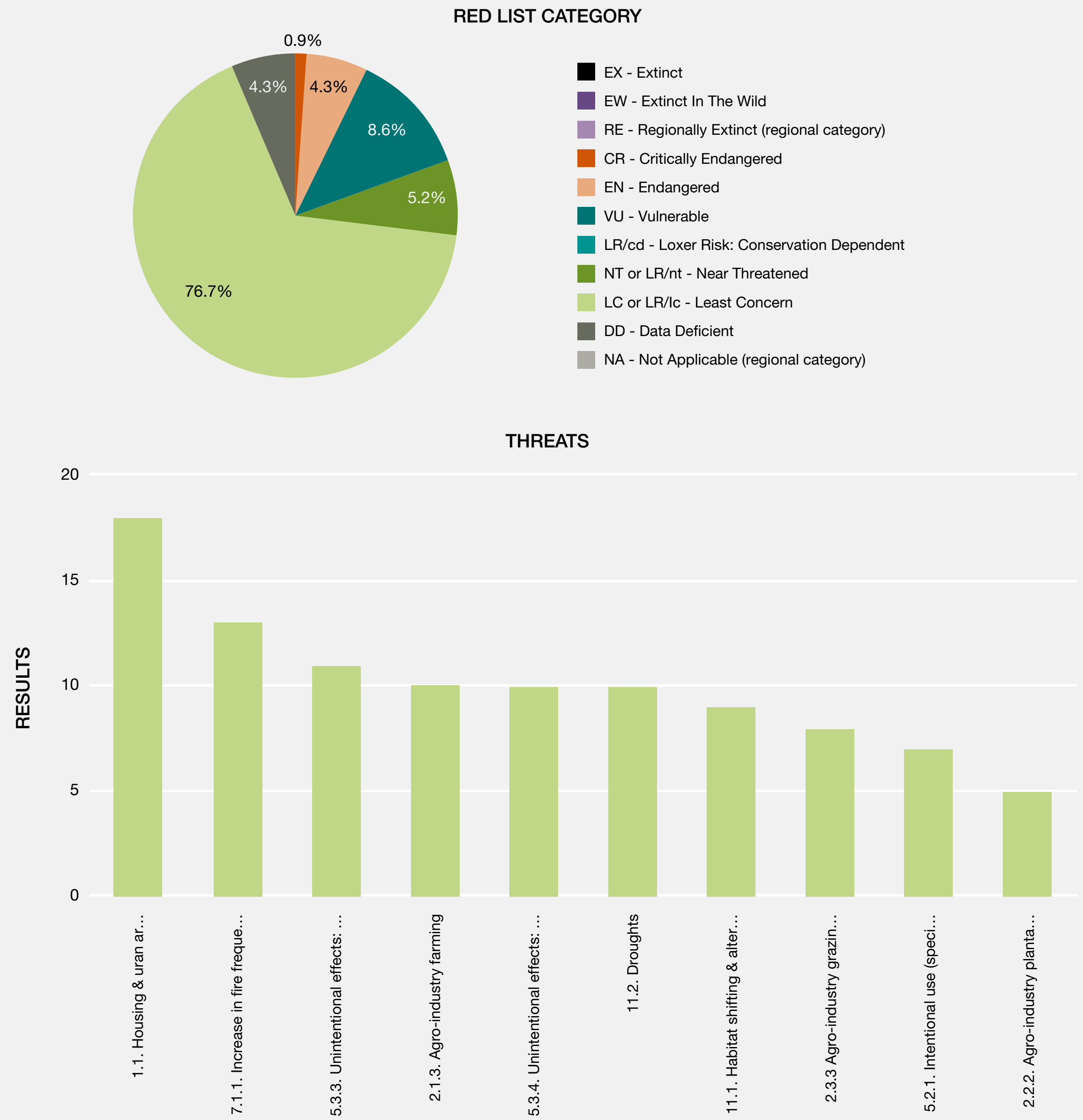


Figure 3 43 **The threatened status and threats of edible fungal species.**

At the top, the threatened status of all assessed 116 species and at the bottom, the threats of all assessed 116 species. Source: (IUCN, 2020b) © IUCN Red List Data. This figure was made using the International Union for Conservation of Nature website https://www.iucnredlist.org/search/stats, by selecting "Fungi" in the tab "Taxonomy" and then by selecting "Food-human" in the tab "Use and Trade".

edible fungi irrespective of their economic importance. Overharvesting was primarily reported on in the context of species gathered for commercial purposes (8 sources), with a particular focus on matsutake (Martínez Carrera, 2002; J. S. Brooks & Tshering, 2010; Dongyang Liu *et al.*, 2018) and truffles (Garcia-Barreda *et al.*, 2018; Radomir, Mesud, & Žaklina, 2018). Long-term scientific studies monitoring the effect of different harvesting techniques (picking *versus* cutting) showed no adverse effects of gathering fruitbodies on future production of epigeous (aboveground) fruitbodies using either technique, but instead identified trampling associated with gathering activities as reducing the number of fruitbodies (Egli, Peter, Buser, Stahel, & Ayer, 2006). Another study focused on harvesting techniques of the American matsutake *(Tricholoma magnivelare)* and also found no adverse effects of gathering on the number and weight of fruitbodies produced when mushrooms were picked using best practice methods (no soil removal, careful plucking of fruitbodies using a small tool) over the course of ten years (Luoma *et al.*, 2006) **(Box 3.9).** However,

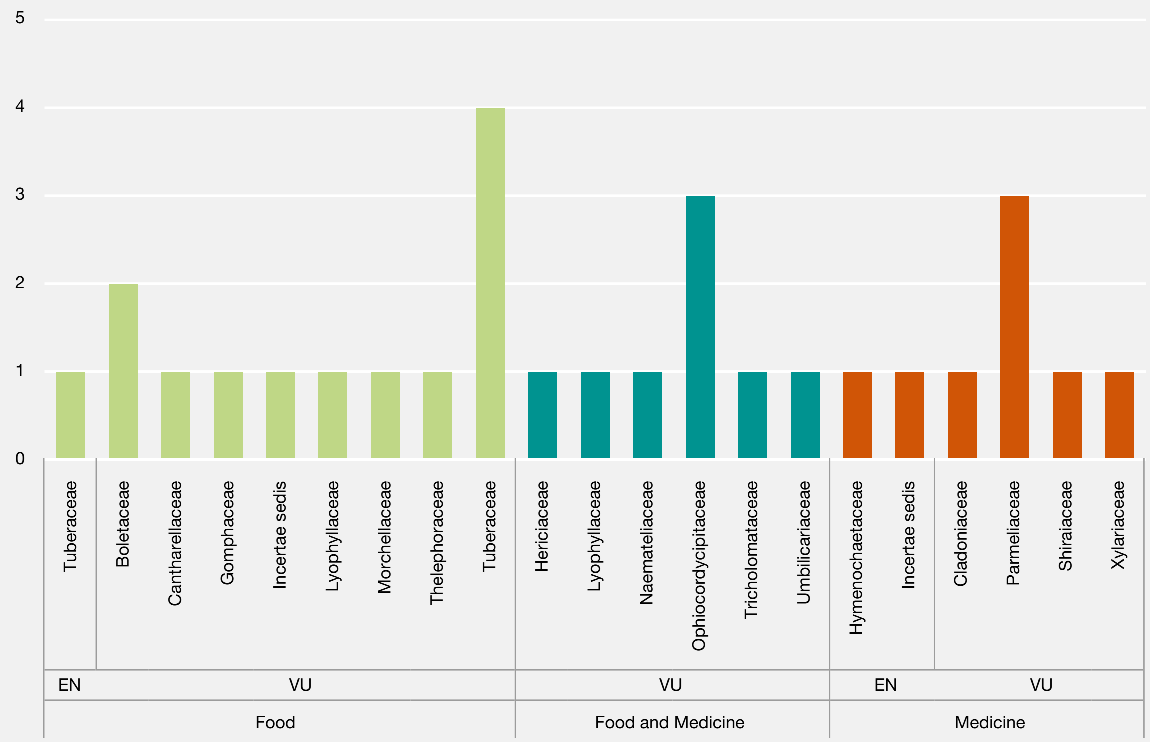


Figure 3 44 **China threatened fungi used as food and medicine.**

Based on (Ministry of Ecology and Environment of the People's Republic of China & Chinese Academy of Sciences, 2018). Abbreviations: EN: Endangered, VU: Vulnerable. See data management report for the figure at https://doi.org/10.5281/zenodo.6453079.

more disruptive harvesting methods using raking and soil removal resulted in fewer and lighter fruitbodies in the nine years following treatment, especially if soil was not replaced. This is in line with reports by Yi gatherers who expressed concerns about younger gatherers uprooting entire fruitbodies instead of using the more careful traditional gathering techniques (Dongyang Liu *et al.*, 2018). Overall, however, the long-term studies reconcile reports of overharvesting with those where no influence was reported despite commercial scale gathering (Arora, 2008b; Christensen *et al.*, 2008; Huber *et al.*, 2010), indicating that a good balance of commercial development and sustainable use is achievable with appropriate management practices. Species most at risk appear to be those subject to disruptive gathering practices such as matsutake and truffles, both of which are developing belowground, although structured research for a larger variety of species is currently lacking.

Indigenous peoples and local communities are both the main sources of knowledge with respect to status and management approaches (7 out of 8 articles reporting overharvesting) and key stakeholders in the use of wild edible fungi. Integrative research articulating local scale indigenous and local knowledge with other sources of knowledge that can incorporate the large year to year fluctuations in fruiting due to climatic variables and the impact of other environmental factors are required to better understand the multidimensional drivers influencing sustainable use. Consequently, the erosion and loss of indigenous and local knowledge also presents a major threat to sustainable use of wild fungi. This was reported in twelve studies reviewed and across all IPBES regions (5 Africa, 2 Americas, 2 Europe and Central Asia and 3 Asia Pacific). Indigenous and local knowledge is usually transmitted orally within families, often while engaging in gathering activities, so factors such as increased urbanization and associated cultural changes can decrease interest in gathering and the opportunity to do so (M. R. Emery & Barron, 2010). In three cases societal changes coincided with decline of wild edible fungi through deforestation and land use change and scarcity was one of the major reasons cited why people did not engage in gathering, e.g., in Burkina Faso (Guissou *et al.*, 2008) or Nigeria (Oyetayo, 2011; Uzoebo *et al.*, 2019). One of the latter also cited social stigmas associated with gathering, which all together can lead to a situation of rapidly declining indigenous and local knowledge.

Case studies from the United States of America and Europe highlight policies that are rooted in different philosophies

Box 3 9 **Matsutake and sustainable management.**

Matsutake *(Tricholoma matsutake)* and the closely-related species *T. magnivelare* and *T. caligatum*) are subject to some of the richest literature available with regards to management practices for wild edible fungi (Tsing, Satsuka, & for the Matsutake Worlds Research Group, 2008). Matsutake are highly appreciated in Japan where productivity has been in decline since the 1940s. *T. matsutake* grows as an ectomycorrhizal symbiont of Japanese red pine, a pioneer species that is commonly found around settlements (Saito & Mitsumata, 2008). For centuries people have been coppicing the *satoyama* (village forests) to harvest wood for fuel and other uses which created a favorable habitat for matsutake. A low point in the matsutake production was reached in the 1970s when many households switched to propane gas and oil fuels, which was considered the main reason for the decline in productivity (Saito & Mitsumata, 2008).

Due to the high market prices, especially for Japanese matsutake which can reach over 400 United States dollars per kg (2006), research has focused on silvicultural approaches for habitat improvement to increase matsutake yields (Saito & Mitsumata, 2008). In a comparison of different land management practices, the most successful one was rooted in the traditional *irai* system, where wild algae, fungi and plants are considered a communal resource of the village. This management practice involves joint habitat improvement sessions and days where everyone can gather which not only improved matsutake production, but also provided community-building social activities and ultimately a virtuous cycle where increased matsutake production and the social aspects leads to increased interest in participating in management activities (Saito & Mitsumata, 2008). Similar community-based management practices have proven successful in Shangri-la, Diqing Tibetan Autonomous Prefecture, China where matsutake harvest rights are organized by village and overharvesting and competition between gatherers are mitigated by instituting “rest days” of 3 to 5 consecutive days where gathering is prohibited once the quantity of matsutake sales declines (Arora, 2008b). Although the measure was implemented as a means to maximize profit, it also prevents harvest of very young specimens and may thereby benefit the reproductive potential of the fungus. Conflict among gatherers was further minimized by charging high fees for gathering permits for outsiders. Despite matsutake contributing the majority of household income in the region, there were no concerns voiced about declining numbers of mushrooms (Arora, 2008b).

of nature and perspectives on resource management (Tsing *et al.*, 2008). When market demand for wild edible mushrooms increased in the United States of America in the 1980s, restrictive gathering laws were put into place, either requiring permits for gathering, selling and buying mushrooms (Rebecca J. McLain, 2008), or forbidding gathering outright (Arora, 2008a). This led to *de facto* criminalization of gathering and gatherers that often had a long history of engaging in this activity but were not involved in the process of developing meaningful regulation. Consequences were increased volumes of mushrooms sold via black and grey markets (Arora, 2008a; Parks & Schmitt, 1997) and a reframing of gathering from a family activity as work or an outright illegal activity, threatening transmission of indigenous and local knowledge (Arora, 2008a; Rebecca J. McLain, 2008).

Similarly, mushroom gatherers and traders were not included as stakeholders in the development of the Forest Development Strategy in Serbia, where only commercial entities can apply for permits to gather wild plants, algae and, fungi (Radomir *et al.*, 2018). Serbia houses a rich variety of popular edible mushrooms, most prominently black truffles *(Tuber melanosporum)* which can fetch a market price of up to 4000 euros per kg. Due to high taxes levied on gathering and selling truffles, and above-mentioned restrictions on permitting, there is a flourishing black market and the majority of truffle export is purportedly going through illegal routes (Radomir *et al.*, 2018), a situation that neither benefits stakeholders nor allows for a realistic assessment of how to balance gathering activities with a healthy forest ecosystem.

In Southern Europe, wild truffle populations have been in decline, largely due to habitat degradation and climate change (Büntgen *et al.*, 2012; Garcia-Barreda *et al.*, 2018; Pieroni, 2016). However, an assessment of policies and regulations relating to truffle gathering in Spain suggest that lack of appropriate management strategies may further exacerbate this trend (Garcia-Barreda *et al.*, 2018). In Spain, gathering rights in public forests are auctioned off for terms of two to six years to private gatherers, which creates little incentive to invest in long-term strategies to maintain harvests. The situation becomes more acute as productivity declines and bidding becomes economically unattractive to commercial entities. In this case harvesting rights are purchased by municipalities which often leads to overexploitation, excessive trampling and damaging picking techniques as a larger number of gatherers face stiff competition with each other (Garcia-Barreda *et al.*, 2018). Nevertheless, overall truffle production in Spain has increased in recent years due to the contribution of truffles grown in plantations, whose share rose from 10% in 1998 to 60% in 2012 (Garcia-Barreda *et al.*, 2018), indicating that cultivation and silvicultural approaches are important avenues towards sustainable use for highly prized and highly commercialized species.

Wild vegetables

Wild vegetables are an important part of the human diet. The gathering and consumption of wild vegetables are of great value in three ways. (i) They contribute to food security and famine, (ii) they are playing an increasingly important role as health food, and (iii) diets including wild vegetables pass on traditional flavors and cultural influences. Wild fruits and mushrooms are more frequently gathered than wild vegetables, and many wild vegetables have been forgotten. Herbicides have also contributed to their disappearance. Some species are regaining popularity as gourmet or health foods (Łuczaj *et al.*, 2012).

Wild vegetables were commonly eaten in the past, especially in times of scarcity. In non-famine times, they diversified monotonous diets. Children ate some wild vegetables with an acidic taste *(Rumex, Oxalis)* as snacks (Łuczaj *et al.*, 2012). Some species are still gathered, such as *Asparagus acutifolius* or *Scolymus hispanicus*, as a part of traditional diets **(Table 3.11)**. The Mediterranean diet is a model of healthy dietary patterns and has been recognized on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity for Italy, Spain, Portugal, Morocco, Greece, Cyprus, and Croatia. Cultural and historical factors diversify the use of wild vegetables (Łuczaj, Zovko Končić, Miličević, Dolina, & Pandža, 2013; Łuczaj & Dolina, 2015; Łuczaj, Łukasz, Jug-Dujaković, Dolina, Jeričević, & Vitasović-Kosić, 2019; Geraci, Amato, Di Noto, Bazan, & Schicchi, 2018).

Wild vegetables can be important local commodities and are sold at high prices in local and regional markets. However, if they are not gathered as wild vegetables, they are often considered weeds because they need little attention or management and are gathered from the wild, agricultural or disturbed spaces. Wild vegetables are often associated with traditional production systems and a long history of local selection and usage. In France, at least until the 1980s, people in some rural areas ate wild vegetables at the turn of the seasons, bitter salads in spring to purify the blood, and diuretic vegetables in autumn to prevent winter rheumatism (Fédensieu, 1988; Schaal, 1993).

Local and traditional knowledge is an important factor in maintaining the sustainability of wild vegetable gathering, cooking and consumption. This knowledge of wild vegetables may serve as baseline data for sustainable use (Ahmad, Ahmad, & Weckerle, 2013; Konsam, Thongam, & Handique, 2016; Maroyi, 2013; Wujisguleng & Khasbagen, 2010). Knowledge on food plants is, however, eroding in various parts of the world. In Mexico, rural indigenous and mestizo populations commonly eat wild greens called *quelites*, mainly gathered when weeding the fields; the most common species are *Amaranthus hybridus, Chenopodium berlandieri, Anoda cristata, Porophyllum ruderale* (Bye, 1981). Perceived as poor people's food, they are disappearing from peoples' diets, but there are actions to promote them (Mera Ovando, Castro Lara, & Bye Boettler, 2011).

Weeds from rice fields are especially consumed in Asia and still play an important part in the diet in Northern Thailand (Cruz-Garcia & Price, 2011) and Laos (Kosaka *et al.*, 2013). There was little evidence of wild greens consumption in South America. In the Amazon, most people are not keen on greens; the few wild species occasionally consumed are *Phytolacca rivinoides* and *Talinum* spp. (Katz *et al.*, 2012). In Africa, a large number of indigenous or naturalized vegetables, such as baobab leaves or spider plant *(Cleome gynandra)*, contribute to dietary diversity and food security, but have been neglected in some areas (Towns & Shackleton, 2018).

Two widely consumed and popular wild vegetables in the United States of America are fiddlehead ferns and ramps (wild onions). Fiddleheads are newly emerging and immature fronds of the ostrich fern (*Matteuccia struthiopteris* (L.) Todaro), which occurs throughout temperate areas of the country with high soil moisture. For many they are an early food of spring, are also part of rural, local economies and can sometimes be found in larger grocery store chains in regions where they are popular. Total yields are estimated at 100,000 pounds annually, which is believed to be a sustainable yield. Ramps *(Allium tricoccum)* are a spring ephemeral species popular in the Eastern and central northern United States of America. Like fiddleheads, they

Table 3.11 **Comparison of the use of wild vegetables among Mediterranean countries.**
Source: (Geraci *et al.*, 2018) under license CC-BY 4.0.

Numbers \ Country	Italy	Spain	Turkey	Morocco	Croatia / Herzegovina	Cyprus / Greece
Families	40	53	36	37	32	23
Genera	162	158	97	98	74	57
Taxa	299	277	151	158	98	76

are an early spring wild crop that is highly prized and celebrated as part of the return of spring. There is a long history of local and subsistence use of this species, which became nationally recognized in the 1990s due to a growing interest in it as a specialty food product. Now sold nationally in restaurants and health food stores, the accompanying market expansion has led to concerns regarding sustainable harvesting. Total quantities harvested are undocumented (Chamberlain, Emery, & Patel-Weynand, 2018).

Seaweeds, or "ocean vegetables", are collected throughout coastal areas all over the world. Historically, coastal people have been gathering and using seaweeds and seagrasses for a variety of purposes, including food, feed, fertilizer, medicine, fibers, biofuel and materials; they are included here as food is a primary reason for collection. Globally, total macroalgal production has increased by approximately 5.7% per annum (including harvest of wild species and cultivation) (FAO, 2014c; Rebours, Friis Pedersen, Øvsthus, & Roleda, 2014). By volume, production is dominated by aquaculture (>96%), which resulted in 27.3 million tons of annual global production in 2014 (Lotze, Milewski, Fast, Kay, & Worm, 2019; Mac Monagail, Cornish, Morrison, Araujo, & Critchley, 2017).

Despite the large scale of production from aquaculture, wild seaweed harvesting still plays an important role in many cultures. Thirty-two countries report active harvesting of seaweeds from the wild, with over 800,000 tons harvested annually from natural beds. Methods, regulations and management regimes vary widely across species and countries. European, Canadian and Latin American seaweed production still comes from harvesting wild populations (Buschmann *et al.*, 2017; Rebours *et al.*, 2014). Chile, China and Norway lead in exploitation of wild seaweed stocks. The Chilean harvest by artisanal fishers has been around 400,000 tons over the last 10 years, and there is concern about the environmental impacts of kelp removals. The marine license vetting committee of Ireland grants licenses to mechanically harvest seaweed and considers the potential negative impact on the marine environment (Mac Monagail *et al.*, 2017). Seaweed has been harvested in Brittany for several centuries, where this activity became industrial in the 18th century (Arzel, 1987) **(Box 3.10)**.

In Hawai'i seaweeds (Limu) are used for food, medicine, and ceremony as a traditional wild green. In recent years, more young Hawaiian men than women reported gathering wild seaweeds, indicating a cultural shift from pre-Contact Hawai'i, when women were the predominant gatherers and consumers of limu. Knowledgeable adults report a decline in the abundance of wild seaweeds driven by over-picking and pollution (Hart, Ticktin, Kelman, Wright, & Tabandera, 2014).

Box 3 10 Seaweeds harvest in Brittany (Western France).

The tip of the Brittany peninsula is particularly rich in seaweed, where over 330 species of macroalgae have been reported. There are two types of seaweed harvesting (Garineaud, 2017). Kelp is harvested from the sub-tidal sea in the archipelago of Molène-Ouessant (off the tip) and on the northern coast of the tip (from Le Conquet to Roscoff). This activity is locally considered as part of small-scale fisheries, with environmental knowledge transmitted within the family (Garineaud, 2015). Two types of kelp are harvested: *Laminaria digitata* (40 000 tons/year) and *Laminaria hyperborea* (25 000 tons/year) (Mesnildrey, Jacob, Frangoudes, Reunavot, & Lesueur, 2012). They are used to produce alginate, a gelling-thickening agent used in industry, especially the food industry. Two companies buy 95% of the harvest. This exploitation is considered sustainable (Frangoudes & Garineaud, 2015) because it is followed and controlled by a scientific institution, IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer), in collaboration with the kelp collectors and industrial companies. However, the economic dependence on two companies and the lack of diversification of trade makes the practice vulnerable.

About 30 species are harvested on shore, in quantities of a few kilograms to several tons per year, reaching a total of about 10,000 tons. Around 300 collectors are involved in this activity, with different status, from seasonal workers to small processing companies (Garineaud, 2017). The most harvested species are Fucales and edible seaweeds such as *Palmaria palmata, Himanthalia elongata* or "pioka" (*Chondrus crispus* and *Mastocarpus stellatus*). The seaweeds are harvested by hand, or with scissors when clinging to a rock. Then they are dried, either preserved in salt or processed and sold fresh, depending on the species, the use and the collector. They are mainly used in food, industrial and pharmaceutical products. It is difficult to analyze this exploitation because of the diversity of harvested species, outlets and stakeholders. The lack of scientific knowledge, follow up, and control of this activity makes it vulnerable to changing conditions. It is difficult to establish administrative frameworks, exploitation regulations and labels matching with the stakeholders and their practices. The main risk with regards to sustainable use would be to turn this small-scale exploitation into a more intensive, more industrial and less diversified trade. Climate change is also likely to have an impact on seaweed harvesting and increase variability of the resource. Some species have already been displaced (Gallon *et al.*, 2014; Raybaud *et al.*, 2013). It is unclear how companies will adapt to variability and changing environmental and social conditions (Garineaud, 2017). Finally, the lack of information, transparency and accessible data makes understanding the social dimensions more difficult.

Protista and blue-green algae

The terrestrial cyanobacterial species *Nostoc flagelliforme*, commonly called Fai-Cai (Fat Choy), lives in desert or semi-arid grasslands in the Asia Pacific region, and is used as a vegetable in Chinese cuisine (Dai, 1992; Gao, 1998; YL Geng & Jiang, 1991). Herders scrape the vegetable with rakes. Indigenous and local knowledge suggests one must forage over approximately 10 acres of grassland to harvest 100 g of dry fat choy. The raking can destroy the delicate grasslands and accelerate desertification. Therefore, the species was up-listed into the Class I of state key protected wild plants (even though it is not a plant) in 2000 and harvest and trade were banned at that time (But, Cheng, Chan, Lau, & But, 2002).

Nostoc commune or Ge-Xian-Mi (Rice of Immortal Ge) is the second edible species of Nostoc, originally listed for use in the The Compendium of Materia Medica (S. Li, 1596) by Shi-Zhen Li (1518–93?) of the Ming Dynasty. The name of Ge-Xian-Mi is related to Ge Hong (AD 284–364), a Taoist theoretician of the Eastern Jin Dynasty, who used *N. commune* as food during periods of famine and later introduced it to the emperor. It is used for health food and herbal medicine however the wild type of *N. commune* has been decreasing as a result of recent increases in market demand and environmental pollution. Artificial culture of the blue green algae generates economic benefits (Diao & Yang, 2014; Nazih & Bard, 2018). Nostoc species are still consumed, not only in China, but also in various countries such as the Philippines, Thailand, Japan, Fiji, Peru, Ecuador, Mexico, Mongolia, and Siberia (Borowitzka, 2018).

High-quality agar and agarose for bacteriology and pharmaceuticals originated from wild harvested *Pterocladiella capillacea*. A report reveals a decline in biomass coupled with a peak in wholesale prices, which have resulted in overharvesting in some countries in due to this increased economic exploitation (Patarra, Iha, Pereira, & Neto, 2019). Ongoing unsustainable commercial harvest of the algae could result in further marine ecological damage; thus, the future of the industry is uncertain.

3.3.2.3.5 Medicine and hygiene

Humans use wild plants and fungi for medicinal purposes all over the world. Gathering wild species for medicines is motivated by a range of factors. These include poverty or difficulty accessing medical assistance, traditional knowledge and beliefs, cultural heritage, or for profit due to commercialization. There is also a growing demand for products produced at least in part from wild harvested plants and fungi, to complement chemical medicines in many high-income countries (Lamrani-Alaoui & Hassikou, 2018; Lanker *et al.*, 2010; H. Liu, Luo, Heinen, Bhat, & Liu, 2014; Nekratova & Shurupova, 2016; L. Petersen, Reid, Moll, & Hockings, 2017; K. M. Stewart, 2003).

A large number of ethnobotanical studies have generated inventories and analysis of medicinal and hygienic uses of wild plants. Online databases summarize information on medicinal plants. For example, the Kew royal botanical garden has established the Medicinal Plant Names Service (https://mpns.science.kew.org), the Africa Museum in Brussels runs the Prelude Medicinal Plants Database (https://www.africamuseum.be), and databases like Native American Ethnobotany (http://naeb.brit.org/), the Indian Medicinal Plants Database (http://www.medicinalplants.in/) and the China National Genebank (https://db.cngb.org) all include information on medicinal uses.

These inventories of medicinal plants outline the threat level to the species, conservation status, or priority of conservation for further actions. In South Africa for example, 2,062 indigenous plant species (10% of the total national flora) have been documented for use as traditional medicine. Of these, 82 wild medicinal plant species (0.4% of the total national flora) are considered threatened with extinction at a national level (V. L. Williams, Victor, & Crouch, 2013). Thirteen percent of Myanmar medicinal plant species are considered threatened in the International Union for Conservation of Nature Red List of Threatened Species (DeFilipps, Krupnick, & Krupnick, 2018). These data suggest possibilities for future research, conservation programs, sustainable harvesting projects, management and regulations.

When and how wild plants or plant parts are gathered have important effects on their medicinal value. Each category of medicinal plant has its specific collection time to maintain not only efficacy, but also sustainability. In this regard, Kletter and Kriechbaum (2001, p. 12) remarks “a plant has medicinal value when it is harvested at the right time, but is mere grass when harvested during the wrong season”.

Local and traditional knowledge is a key to the sustainable gathering of wild medicinal plants. Of the articles retrieved in the Web of Science published between 2000–2020, more than one third (n=117/349) mentioned “traditional knowledge”. By its very nature, traditional knowledge is holistic in nature, thus in these articles it was not always distinguished as being specifically for medical use, and could also be related consumption for food or aromatic uses. This is consistent with the fact that many wild medicinal plants have multiple uses at the same time. Like in Angola, 35% of the 127 Leguminosae plants are only used medicinally by the local communities, while the remaining species were reported to have many other uses (S. Catarino, Duarte, Costa, Carrero, & Romeiras, 2019).

Wild plant species are chosen for pharmaceutical studies through different methods. One method what has come to be known as bioprospecting: the investigation of indigenous uses of wild plant species based on indigenous local knowledge that can offer strong clues to the biological activities of those plants. There are many examples of this knowledge being used by companies who either do not financially compensate local people at all, or do not do so in proportion to the value of their resultant profits. This is commonly known as biopiracy, and is a major issue is many developing countries and with indigenous communities around the world (Benjaminsen & Svarstad, 2021; Shiva, 2007). In relation to the definitions of sustainable use reviewed in Chapter 2, this form of exploitation is considered as a form of unsustainable use. Scientific experimentation is another method through which medicinal knowledge of natural products has over the last few centuries (D. A. Dias, Urban, & Roessner, 2012). About a quarter of all Food and Drug Administration and/or the European Medical Agency approved drugs are plant based (Thomford *et al.*, 2018). From 1981 to 2002, around 49% of the small-molecule new chemical entities that were introduced were from natural products or based on natural-products. The utilization of natural products in order to discover and develop new drugs is an active area of research (Koehn & Carter, 2005; Newman & Cragg, 2007, 2007).

Medicinal Fungi

Fungi are also widely used for medical purposes, especially in the Asia Pacific Region. Our literature review yielded 33 studies that detailed the use of medicinal fungi from all IPBES regions (Africa 8, Americas 7, Europe and Central Asia 8 and Asia Pacific 8). Of these, 90% also reported on species used for food, so many of the aspects pertaining to sustainable use are shared with wild edible mushrooms (see section 3.3.2.3). All studies reporting on wild species and their uses (12 in total) reported fewer medicinal species than species used for food and often species were used both as food and medicine. The largest number of medicinal species was reported from China, with 692 species with medicinal properties with 277 species considered as both food and medicine (Wu *et al.*, 2019). Mexico also hosts a large variety of medicinal fungi with a survey reporting the use of 70 species to treat over 40 different conditions, again many with dual use as food and medicine (Guzmán, 2008). Medicinal fungi also have a long history of use in Europe, where interest in traditional medicines has been increasing again recently after a decline in use in the 20th century (Comandini & Rinaldi, 2020).

Box 3 11 **Status and trends of caterpillar fungus in the Nepalese Himalayas.**

Ophiocordyceps sinensis (Berk.) G.H.Sung, J.M.Sung, Hywel-Jones & Spatafora, (Hypocreales, Ophiocordycipitaceae) is a high-altitude fungus reported only from the alpine meadows in Nepal, India, Bhutan and China. Locally called Yar-tsa-gunbu (summer grass, winter insect), it occurs from 3,540 m to 5,050 m above sea level across 24 different northern districts in Nepal (S. Devkota, 2008) and up to 5,200 m in Bhutan (Cannon *et al.*, 2009). It is an entomopathogenic fungus that parasitizes over 50 species of Thitarodes (Hepialidae) moth larvae (X.-L. Wang & Yao, 2011).

In the gathering season (May – July) and particularly when the snow melts, gathering is extensive. As many as 70,000 collectors (men, women, and children) have been reported across 25 principal gathering pastures in a single district (Dolpa of Nepal), living in temporary tent camps for about two months (S Devkota, 2009). The fungus provides a substantial source of cash income for many households: 21.1% contribution to the total household income and 53.3% to the total cash income among rural inhabitants and helping to fund childrens' education, food purchasing, household construction and debt repayments (Pouliot, Pyakurel, & Smith-Hall, 2018; Shrestha & Bawa, 2014). Apart from this, subsidiary incomes in mountain communities come from farming, animal husbandry, collection and trade of other medicinal and aromatic plants (Olsen & Larsen, 2003).

The global annual collection of caterpillar fungus is roughly estimated at 85-185 metric tons (Winkler, 2008). Indigenous peoples and local communities living in the Nepalese Himalayas use it for the treatment of different diseases like diarrhea, headache, cough, rheumatism, liver disease, and also as an aphrodisiac and tonic (S. Devkota, 2006). However, the main market is China, where there are several reasons behind increasing demand. Many consider the species as valuable medicinal fungi in accordance with traditional Chinese medicine. It is traded as the "Himalayan Viagra" and prices have exceeded 140,000 United States dollars per kg for the best quality in Chinese markets, depending upon size, color, aroma, and region of origin (Shrestha & Bawa, 2014). The high number of collectors, their trampling effects on fragile subalpine and alpine landscapes, wild species poaching, improper garbage disposal and annual large harvested volumes have raised several sustainability concerns (Byers, Byers, Shrestha, Thapa, & Sharma, 2020; S Devkota, 2009; Pouliot *et al.*, 2018).

The Chinese government has supported been thoroughly making efforts to reduce dependence on wild Ophiocordyceps sinensis through cultivation and fermentation technologies (Yue, Ye, Lin, & Zhou, 2013). Advanced biotechnology is being applied to cultivate Paecilomyces hepialid (fermentation mycelium) with active ingredients from the natural caterpillar fungus as well as compounds of its equivalent medicinal value (Ji *et al.*, 2020). There has been intensive focus on the artificial cultivation of the caterpillar fungus which has yielded successful approaches for its propagation and breeding (X. Li *et al.*, 2019). The emergence and application of culture-based techniques as a substitute for wild caterpillar fungus and the development of artificially bred varieties are a promising path towards protection and sustainable use of wild caterpillar fungus resources.

The most common medicinal fungi include *Ophiocordyceps sinensis* (caterpillar fungus), *Ganoderma lucidum* (lingzhi or reishi), *Lariciformis officinalis, Lentinula edidodes* (shitake), *Trametes versicolor* (turkey tail), *Schizophyllum commune* (the split gill) and *Pleurotus* spp., especially *Pleurotus tuber-regium* which is used medicinally across Africa (Milenge Kamalebo, Nshimba Seya Wa Malale, Masumbuko Ndabaga, Degreef, & De Kesel, 2018; Oyetayo, 2011).

Medicinal fungi produce a range of active compounds, many of which have been shown to have anti-oxidant, anti-tumor or anti-microbial properties (Wu *et al.*, 2019). To this end, *G. lucidum* is probably the most intensively studied species. It produces over 400 bioactive compounds and has been dubbed "the mushroom of immortality" in China where it has been used for over 2,400 years (Cör, Knez, & Knez Hrnčič, 2018). Nowadays it is widely used to supplement cancer treatment both in China and Western countries. Several records indicating the medicinal use of lichens in Spain and Nepal were also found (Shiva Devkota, Chaudhary, Werth, & Scheidegger, 2017; González-Tejero, Martínez-Lirola, Casares-Porcel, & Molero-Mesa, 1995). Perhaps the most valuable species globally is the illusive caterpillar fungus *(Ophiocordyceps sinensis)*, which grows only in the Himalayan mountains **(Box 3.11)**.

Gathering of caterpillar fungus *(Ophiocordyceps sinensis)* has dramatically increased over the last 20 years. A short seasonal and rotational approach for gathering is useful for its sustainability. Caterpillar fungus extraction provides up to 72% of household income in the area, and estimates of households involved in the short seasonal gathering range from 52% to 98%. Understanding of local commercial harvest and trade supports sustainable management (J. He, 2018; Kuniyal & Sundriyal, 2013; Woodhouse, McGowan, & Milner-Gulland, 2014).

Seeds, Leaves and fruits for medicinal use

The gathering of seeds, leaves and fruits for medicinal use is usually non-lethal and seasonal. In some cases, the average annual harvest is high but the population size is consistent, such as with *Aloe ferox* in South Africa and *Euphorbia antisyphilitica* in Mexico (Martinez-Balleste & Mandujano, 2013). These species were once included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora, but after assessing the sustainability of harvest and trade, their products have been exempted from strict control. In order to sustain the trade, improving the techniques of wax extraction and promoting fair trade pricing structures that benefit local harvesters have been suggested (Martinez-Balleste & Mandujano, 2013).

Certification schemes can support management for sustainable use. For example, harvesting of the fruits of *Schisandra sphenanthera* in Chinese forests meet sustainable wild harvesting standards, with an incentive to maintain habitat outside formal protected areas based on FairWild Standards (2010) and Giant Panda Friendly Products Standards (2012) (Brinckmann *et al.*, 2018). In the absence of effective management, gathering of leaves, seeds and fruit is stressful for some sensitive species such as *Aloe peglerae*, *Cola nitida* and *C. millenii* which are endemic to Africa and currently endangered. Studies suggest developing silvicultural techniques to improve domestication through *ex situ* cultivation in gardens and orchards (Chungu *et al.*, 2007; Lawin *et al.*, 2019; Pfab & Scholes, 2004; Savi *et al.*, 2019).

Barks and stems

Bark harvesting for medicinal purposes is widespread in Africa as a form of local and free medicine. *Julbernardia paniculate* and *Isoberlinia angolensis* are two species severely negatively affected by bark removal. Traditionally, there have been measures to reduce injuries to the tree. One form of local tree protection is to cover the wound site with mud, which protects the tree from wood deterioration and insect damage (Chungu *et al.*, 2007). In addition to practical measures, domestic legislation can also offer local protection. For example, *Warburgia salutaris* is endangered and overexploited in many regions and deemed threatened throughout its range. South Africa's environmental legislation now prohibits the harvesting of protected wild plants or plant parts (e.g., the bark and leaves of *Warburgia salutaris*) and recommends the use of alternative species (Rasethe, Semenya, & Maroyi, 2019; Senkoro *et al.*, 2019).

Harvesting bark to meet medicinal demands is becoming less sustainable for some species due to increasing demand. *Prunus africana* in Africa and The Himalayan yew *(Taxus wallichiana)* are greatly threatened with unsustainable harvest. Wild-gathering of barks of *Prunus africana* is no longer sustainable. The population has been declining over much of its geographical range in sub-Saharan Africa in recent decades. Only recently have existing standing crop inventories and scientifically based annual quotas being determined (Fashing, 2004; K. Stewart, 2009; K. M. Stewart, 2003). The Himalayan yew *(Taxus wallichiana)* is very slow growing species with poor natural regeneration. Most wild populations in Asia Pacific forests are threatened with extinction and are endangered in the Himalaya due to over-harvesting of their barks and leaves in combination with low seed production and germination. *In situ* conservation and management and artificial regeneration using efficient biotechnological tools have been proposed (Lanker *et al.*, 2010). Both of these species are included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora to restrict international trade, with the intention to develop tools and methods for sustainable gathering or promote alternative source including cultivation.

Roots, Rhizome, Tuber and Bulbils

Gathering roots, rhizome, tuber and bulbils usually does harm to plants. It is fatal to dig out all the roots and tuber. Such gathering, if not managed properly, is unsustainable. Destructive overharvesting is the key threat to *Stemona tuberosa, Gymnadenia conopsea* in Asia and *Siphonochilus aethiopicus* and *Dioscorea bulbifera* in Africa driven by high market demand (G. Chen *et al.*, 2019; Ikiriza *et al.*, 2019; Kala, 2009; Shao *et al.*, 2017; Xego, Kambizi, & Nchu, 2016). The increasing demand on stems and roots coupled with non-sustainable harvesting methods has resulted in a substantial decline of *Cryptolepis sanguinolenta* in its wild populations in Africa forests. The development of domestication protocols has been suggested as one way to protect the species and decrease rates of decline (J. He, 2018; Kuniyal & Sundriyal, 2013; Woodhouse *et al.*, 2014).

Panax quinquefolius (American wild ginseng) is a highly valued wild root collected extensively in the United State of America s. Populations have declined significantly over

Box 3 12 The sustainable use of wild orchids in traditional Chinese medicine.

In China, orchids are traded for both ornamental and medicinal purposes (Hong Liu *et al.*, 2020). About a quarter of all Chinese wild orchid species are considered traditional Chinese medicine and market demands for some of them have been extremely high (H. Liu *et al.*, 2014). Wild populations of some traditional Chinese medicinal orchids, such as those in the genus of *Dendrobium*, have either been extirpated or reduced to small, isolated populations. Augmentations or reintroductions are required to bring these populations back to a healthy state.

Recognizing the issue of high demand on exhausted natural resources, the Chinese government has embraced the conservation intervention to increase supply by farming (Hong Liu, Gale, Cheuk, & Fischer, 2019) and has been very successful in encouraging massive shade house commercial cultivation of threatened traditional Chinese medicinal orchids. The total shadehouse products of *Dendrobium officinale*, one of the most used medicinal orchid species in China, was more than 6.4 billion United States dollars in 2011 (H. Liu *et al.*, 2014). However, it appears as though large commercial shadehouse cultivations have not alleviated pressure on wild populations. One reason for this is related to the public perception that cultivated products are considered to be less potent than wild harvested orchids, and so wild harvested products are considered to be of higher quality and are sold at premium prices (H. Liu *et al.*, 2014). In addition, orchids growing in industrial shade houses are subject to synthetic fertilizers and pesticides, which also make the cultivated product less desirable.

A semi-wild cultivation approach in which specimens are outplanted into native wooded areas specifically for harvesting has been implemented in a few places in southern China, such as Renhua County in northern Guangdong province, Xingyi County in Southwestern Guizhou province, and Leye County in northwestern Guangxi province. These areas are relatively undeveloped compared to the Pearl River Delta area in southern China and are within the native ranges of several medicinal Dendrobium orchids. These cultivation operations are a hybrid between commercial cultivation and population restoration because farmers can harvest certain number of stems (pseudobulbs) without killing the plants, and allow some plants to flower and fruit. Seeds produced from these plants are potential sources of population recovery and thus this form of outplanting is called "restoration-friendly cultivation" (H. Liu *et al.*, 2014). The market share of these semi-wild products is unknown.

This semi-wild or restoration-friendly cultivation approach has been suggested for other epiphytic orchids that are harvested for cultural and religious festivals and ceremonies in Latin American Countries (Tamara Ticktin *et al.*, 2020). For example, Mexico has more than 1,300 species of orchids (Hágsater *et al.*, 2015) and among these more than 300 orchid species in 90 genera were used for religious and cultural celebrations (Menchaca García, Lozano Rodríguez, & Sánchez Morales, 2012; Tamara Ticktin *et al.*, 2020). About a dozen of these species (e.g., *Laelia speciosa, Euchile karwinskii, Barkeria vanneriana*) are traded in high volumes legally and illegally (Tamara Ticktin *et al.*, 2020). There have been attempts to establish a rural community nursery system in the relevant areas, in which farmers were encouraged to plant these orchids in their backyard and adjacent community forests. The nurseries were then registered as Environmental Management Units (UMA, for their acronym in Spanish) (Menchaca García *et al.*, 2012). The nursery system was intended to promote sustainable harvesting in rural communities, as non-lethal harvesting can be done sustainably from the nurseries which then in turn allow wild populations to recover, as shown in population viability simulation models in Ticktin *et al.* (2020).

Semi-wild or restoration-friendly cultivation operations have positive impacts on sustainable use, but are not widespread in comparison with harvest quantities. Ecological and socioecological infrastructure needs to be developed and supported to achieve orchid conservation and support livelihoods (H. Liu *et al.*, 2014). For example, mass reproduction centers coordinated with farmers to deliver enough plants for semi-wild planting requires support (Menchaca García *et al.*, 2012). These centers can also provide technical support on growing and harvesting and marketing support. Restoration-friendly cultivation can directly facilitate the recovery of threatened species, encourage protection of natural forests, and benefit marginalized rural communities. However, it is unclear exactly what ecological growth conditions, harvesting regimes, and market conditions are suitable to achieve population restoration while generating enough income for participants, and what policies are needed to enable marginalized rural small holders to engage with the centers.

time in six northern states in the United States of America and harvest pressure is now restricting harvestable stocks. Annual wild ginseng harvests decreased from the high point in the late 1980s to early 1990s, but subsequently increased after 2005. Natural rates of population recovery are slow. Market prices for this species do seem to operate on a supply and demand logic such that quantities supplied are negatively related to prices, theoretically providing economic incentives for forest retention. A federal regulation has banned exports of roots from plants under five years old in effect since 1999. Management includes stewardship-oriented harvest restrictions such as delays in the opening of the permitted harvest season by two weeks, self-limits on harvest intensity, and planting ginseng seeds at the time of harvest (Burkhart & Jacobson, 2009; Burkhart, Jacobson, & Finley, 2012; Case, Flinn, Jancaitis, Alley, & Paxton, 2007; Frey, Chamberlain, & Prestemon, 2018; J. Schmidt, Cruse-Sanders, Chamberlain, Ferreira, & Young, 2019).

Some perennial wild plants can tolerate a certain degree of gathering activities. Populations of *Neopicrorhiza scrophulariiflora* were heavily exploited in one area of the alpine Himalayas but appear more resilient to extraction than other commercially exploited populations (S. Ghimire *et al.*, 2005; Poudeyal, Meilby, Shrestha, & Ghimire, 2019). In the American highlands, the local risk index for conservation status of *Oxalis adenophylla* was medium, driven by changes in its environment and not directly related to gathering. In fact, gathering of leaves and roots of this species is thought to promote its conservation through the understanding of its sensitivity to harvesting (Ochoa & Ladio, 2014).

The rhizome of *Hydrastis canadensis* (goldenseal) is widely harvested in America's woodlands and has been used for traditional medicine by native peoples. Regeneration time varies between populations, making it difficult to predict overall abundance. Late-summer and fall are the ideal periods when goldenseal rhizomes are traditionally gathered (Albrecht & McCarthy, 2006; Burkhart & Jacobson, 2009; D. L. Christensen & Gorchov, 2010).

In the majority of cases, proper management and predictable harvest volumes are required to ensure that root gathering meets the need of regeneration and renewal, but habitat conditions are also critical. For example, black cohosh *(Actaea racemose)* is highly responsive to harvest intensity in the United States of America. Low to moderate harvest intensities and/or longer recovery periods will be necessary for prolonged and sustainable harvests (Small *et al.*, 2011). A low harvest rate, for example 50% of mature plants every 10 years, may be sustainable for the harvest of osha or wild parsnip *(Ligusticum porter)* in America's highlands (Kindscher *et al.*, 2019). Harvesting of *Rheum acuminatum R. australe* and *Rhaponticum carthamoides* in central Nepal can be considered sustainable under optimal management. Predictable exploitable reserves and volume of harvesting, however, partly differ between species and strongly depends on habitat conditions (Nekratova & Shurupova, 2016; Rokaya, Münzbergová, & Dostálek, 2017). Management including wild cultivation can also protect habitats. Micro-propagation can aid in re-establishing plants in their natural habitats (Ikiriza *et al.*, 2019; Kala, 2009). Overexploitation for traditional medicine and health food sipplements, combined with habitat destruction, has resulted in the rapid decrease of *Dendrobium* sp. in Asia. However, epiphytic orchids planted in natural forests as part of *in situ* cultivation are facilitating more sustainable harvesting (H. Liu *et al.*, 2014, 2014; Shao *et al.*, 2017) **(Box 3.12)**.

3.3.2.3.6. Recreation

Many of the other uses covered throughout section 3.3.2 include some sort of recreational component. Only a few examples are provided here that stand out in terms of their recreational value.

A trend has been observed in recent years to promote forest management and sustainable use by combining gathering of wild algae, fungi and plants with non-extractive practices such as tourism. For example, mycological tourism is growing in popularity, often associated with amateur societies in North America and Europe, where people go mushroom gathering, harvest wild mushrooms and then identify them with the help of professionals (Barron, 2010). On one hand it is considered professional exploitation of wild resources, on the other hand it is a form of forest management (Jiménez-Ruiz, Thomé-Ortiz, Espinoza-Ortega, & Vizcarra Bordi, 2017). In fact, amateur mycological associations continue to grow and are considered a valuable resource by mycologists for everything from taxonomic assistance to data collection (Barron, 2011).

Many cultural services and values support recreational gathering of wild species. In the Northeastern United States of America, gathering wild edible huckleberries has been related to maintaining social relations, recreational use and commercial purposes (Carroll, Blatner, & Cohn, 2003). In Spain, while the gathering and consumption of wild edible plants is generally decreasing, there is an increase in the harvest of foods with high cultural value (Reyes-Garcia *et al.*, 2015). In Austria, interviews in 2008–2009 reveal the multiple motivations for gathering wild plants; women, older respondents and home gardeners gather wild plants more often for fun (Schunko, Grasser, & Vogl, 2015).

3.3.2.3.7 Science and education

Around the world, gathering wild specimens continues to generate information of scientific value. This includes dried plants and fungi for herbaria and fungaria, living plants and fungal cultures grown by botanical gardens and mycological institutes, and seeds stored in seed banks (Antonelli *et al.*, 2020; Paton *et al.*, 2020). The world's preserved botanical and mycological collections mostly date back to the late 1800s and early 1900s. There are 3,324 active herbaria in the world, containing 392,353,689 specimens. Norther America, Europe and temperate Asia (including Russia and China) have the highest number of herbaria (Antonelli *et al.*, 2020; Paton *et al.*, 2020; Pearce *et al.*, 2020). The Millennium Seed Bank Partnership conserves high-quality propagules. It has involved 96 countries and territories, and 32% of taxa (representing half of the collections) have at least one identified use for humans (U. Liu, Breman, Cossu, & Kenney, 2018).

Regarding live wild plants gathering, analysis of the PlantSearch database hosted by Botanic Gardens Conservation International indicates that 107,340 accepted species grow in botanic garden collections, representing 31% of vascular plant species. However, 93% of these species are held in temperate parts of the world. As a result, a temperate species has a 60% chance of being cultivated within the botanic garden network, whereas a tropical species has only a 25% chance.

Collection for scientific purposes, however, is on the decline (Heberling, Prather, & Tonsor, 2019), and there have been recent calls for more "holistic sampling" to maximize the usefulness of collections to protect individuals in the wild (Heberling *et al.*, 2019; U. Liu *et al.*, 2018). Good photographs, non-lethal harvest techniques, and the sharing of specimen information or molecular methods (Minteer, Collins, Love, & Puschendorf, 2014; D. Russo, Ancillotto, Hughes, Galimberti, & Mori, 2017) all represent good alternatives to lethal harvesting for scientific use. The Global Biodiversity Information Facility (GBIF) provides access to more than 1.4 billion records (including observations, preserved samples, fossils and living specimens) of all types of life on Earth in nearly 53,000 datasets supported by 1,600 institutions. The data of observation-based occurrences is surpassing the harvest of specimen-based occurrences in the Global Biodiversity Information Facility (Troudet, Vignes-Lebbe, Grandcolas, & Legendre, 2018). However, African countries, Central, South and Southeast Asian countries and East European countries have been poorly represented in harvest of vascular plants species aggregated in the Global Biodiversity Information Facility and data in the World Checklist of Vascular Plants are also poor (Antonelli *et al.*, 2020; Paton *et al.*, 2020).

Rocha *et al.* (2014) have argued that halting the collection of voucher specimens by scientists would be detrimental. Scientists believe that in order to describe the earth's biodiversity and understand wild species, museum collections should increase by 600%, while still being collected responsibly following best practices (Henen, 2016). Continued gathering would also support herbarium-based publications, which have dramatically increased in the past century (Heberling *et al.*, 2019). To that end, regulatory authorities could develop quotas for specimen harvest that are based on scientific guidelines (Maya & Gómez, 2016). Scientific gathering practices also face a series of economic and social pressures, including budget cuts and shortfalls in university and museum settings (Suarez & Tsutsui, 2004), high gathering costs (Enrique, Daniela, & Fernando, 2020), ethical considerations, and effects of regulations like the Convention on International Trade in Endangered Species of Wild Fauna and Flora for the cross-border exchange of specimens (Roberts & Solow, 2008). To promote scientific research on species conservation and materials sharing between scientists, the Convention on International Trade in Endangered Species of Wild Fauna and Flora established the registered scientific institute scheme, and encourages Parties to register scientific institutes. So far, 74 Parties have registered a total of 857 scientific institutions and individuals with the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Antonelli *et al.*, 2020; C. Williams *et al.*, 2020).

From Kew's dataset, there are more than 7,039 known species of edible wild plants, but only 417 (5.9%) are considered food crops by the FAO (Antonelli *et al.*, 2020; Ulian *et al.*, 2020). Crop wild relatives are sources of genetic diversity useful for developing more productive, nutritious and resilient crop varieties, and thus contribute to global food security. In 2016, the most important discovered species with potential for new food sources were 11 new Brazilian species of *Manihot* which are relatives of the highly valued food plant *Manihot esculenta* (cassava). *Manihot esculenta* is the third most important food after maize and rice, and it offers more food security than cereals. (Antonelli *et al.*, 2020; Castañeda-Álvarez *et al.*, 2016; Vincent *et al.*, 2013).

The Crop Wild Relatives Project (cwrdiversity.org) used the Harlan and de Wet (1971) gene pool concept to set up an inventory of globally important crop wild relatives' taxa for 173 priority crops. It contains 1667 taxa, divided between 37 families and 108 genera. The region with the highest number of priority crop wild relatives is Western Asia with 262 taxa, followed by China with 222 and Southeastern Europe with 181 (Vincent *et al.*, 2013). However, the diversity of crop wild relatives is poorly represented in gene banks. Kew's Millennium Seed Bank includes 688 crop wild relatives among its over 78,000 accessions. Over 70% of taxa are identified as high priority for further gathering in order to improve their representation in gene banks. The most critical gathering gaps occur in the Mediterranean and the Near East, Western and Southern Europe, Southeast and East Asia, and South America (Antonelli *et al.*, 2020; Castañeda-Álvarez *et al.*, 2016; Vincent *et al.*, 2013) **(Figure 3.45)**. A discussion of crop wild relatives is relevant for this assessment in relation to the sustainable use of collecting

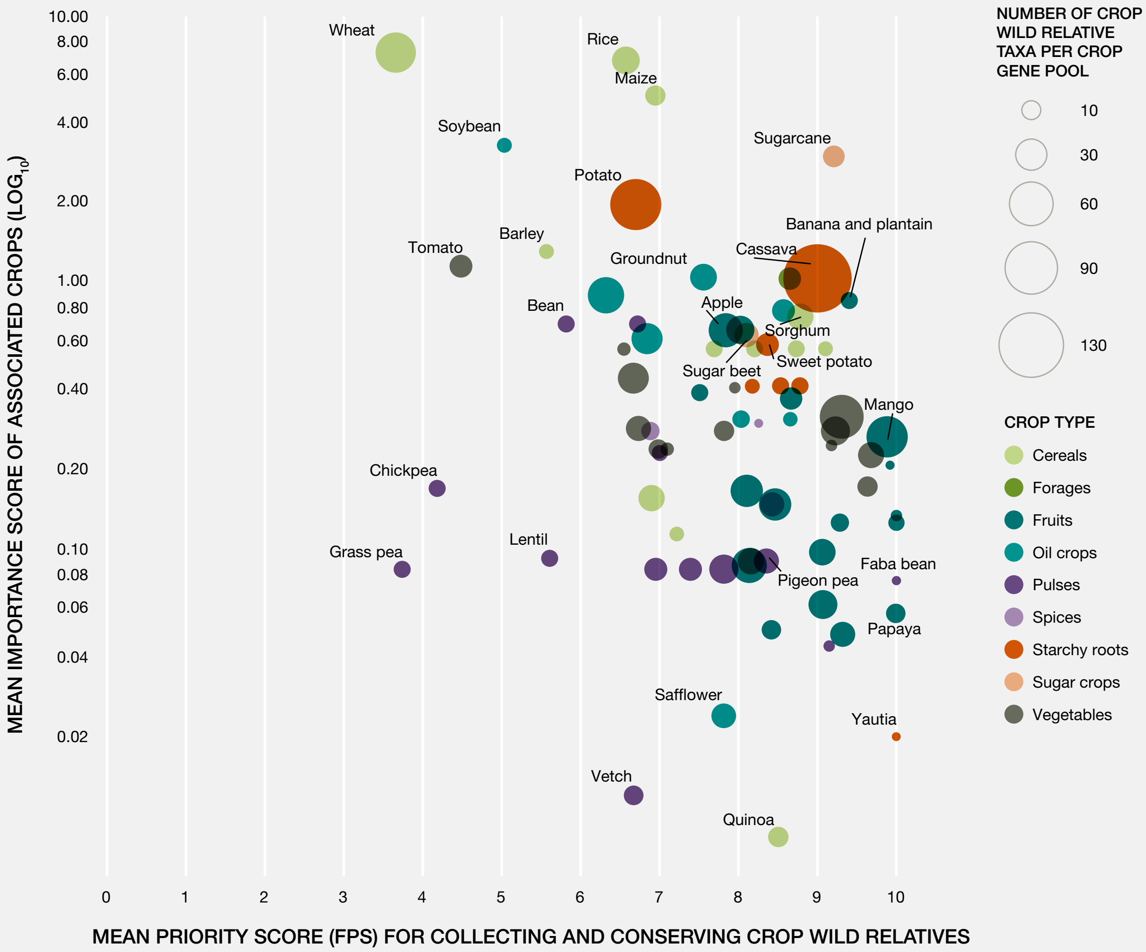


Figure 3 45 **Gathering priorities for crop wild relatives and the importance of associated crops.**

Crop types which occur in the upper portion of the graph are major global good stuffs; those on the far right are in greater need of the genetic diversity that crop wild relatives can provide. For example, of the three major global grain crops, wheat, rice, and corn, corn is in greatest need of genetic diversification from wild relatives in order to enhance food security Source: (Castañeda-Álvarez *et al.*, 2016) © 2016, Macmillan Publishers Limited under licencse CC BY-NC-SA 4.0.

specimens. However, analysis of the role of crop wild relatives in supporting crop diversity and providing genetic resources is beyond the scope of the current assessment.

3.3.2.3.8 Materials and shelter

Artificial materials have replaced many wild sources, but in some remote areas materials from wild species are more readily available and commonly used (**Box 3.13**; **Box 3.14**). Other than wood and bamboo, organic materials in tropical areas used for material and shelter include natural fibers, thatch, grass, reeds, sisal fiber, coir waste, elephant grass and straw (Bengtsson & Whitaker, 1988).

Sisal fibers are long natural fibers derived from Agave *(Agave sisalana)* leaves native to Mexico. In the 1960s the global production was 640 (metric) kt/year (UNIDO/CFC, 2005), but has since declined due to the rise of synthetic fibers. Sisal is grown mainly in Brazil, East Africa and China and has low requirements for fiber production and thus high potential for environmental sustainability (Broeren *et al.*, 2017). The FAO recommends natural fibers as future fibers, such as coir waste derived from coconut palm *(Cocos nucifera)*, Abaca extracted from the leaf sheath around the trunk of the abaca plant *(Musa textilis)* and Jute extracted from the bark of the white jute plant *(Corchorus capsularis)* (http://www.fao.org/economic/futurefibres). Similar to elephant grass *(Pennisetum purpureum)*, the source of these natural materials is shifting due to agriculture.

Palm leaves are an important source of roof thatch for rural communities in many parts of the tropics (Svenning & Macía, 2002). A total of 194 useful palm species and 2,395 different uses throughout northwest South America,

Box 3 13 Bamboo, a plant of many virtues.

Sources: (Laws, 2010; Paye, 2000).

There are over 1,400 species in the world, and they can thrive at high altitudes and low plains. Bamboo is one of the fastest-growing plants on the planet, and its influence has been widely felt: aside from rice, no other plant has played such as important role in the history as bamboo.

Besides being edible, it has medicinal, commercial and practical values: taken together, they yield more than 1,000 different products from their stems and leaves. Many uses of bamboo include preparation of waterproof coat and hat, each wrought out of leaves; agricultural implements; the fishing net, baskets of diverse shapes, arrows, paper and pens, grain-measures, wine-cups, water-ladles, chopsticks, tobacco-pipes, etc. In Asia, the bamboo symbolizes virtues, humanity, and resistance to hardship, and it has played an important role in Asian arts, including in ink drawing and painting.

Use of bamboo is the most common by indigenous and local communities of the world and every year people use over three billion cubic meters of wood worldwide to construct buildings, boats, furniture, and fences. Wood and steel have been the main materials for production in the modern construction industry. As deforestation intensifies, fast-growing bamboo is considered as an alternative to wood, easily used as an alternative in flooring, roofing, and even steel-reinforced buildings in Africa.

Box 3 14 Case study: neotropical palms.

Species or group

Palms are one of the critical elements in the floristic composition of tropical rainforests (Abensperg-Traun, 2009; Montufar & Pintaud, 2006). The Family includes 181 genera and c. 2,450 species distributed in the tropical region worldwide, with some species that extend into subtropical areas in both hemispheres (Baker & Dransfield, 2016). The South American continent hosts a wealth and diversity of palms and the Amazon contains 70% of the genus of palms of this region (Pintaud *et al.*, 2008).

Human uses and practices

Palms are renowned for their extraordinary usefulness for human communities (*Borchsenius*, n.d.), providing basic sustenance, construction materials, tools, and medicines. Palms are also often part of symbolic activities of indigenous communities (Macía *et al.*, 2011). They provide valuable income for rural inhabitants (Bernal *et al.*, 2011),(Kahn & Arana, 2008). However, at times unfavorable conditions and lack of oversight may lead to overexploitation, and possibly subsequent degradation of the local culture, the habitat, and the ecosystem. In South America, (Bernal *et al.*, 2011) documented harvesting and management practices for 96 palm species suggest that overexploitation is common without adequate management. Non-destructive management techniques include the harvest of fruits, leaves, fibers and other parts of the plant (in high palms, users climbing the stems, and a tool is used to cut the desired part), and the destructive ones involve cutting down the palms, which is necessary, for instance, for using stems in the manufacture of building materials or for extracting palm hearts (Bernal *et al.*, 2011).

Ecological responses across manifestations of biodiversity

The impacts of leaf harvesting for roofing purposes of houses and other buildings have been studied for the species *Lepidocaryum tenue* (Navarro, Galeano, & Bernal, 2011) and *Sabal mauritiiformis* (Andrade-Erazo & Galeano, 2015). The impacts due to the extraction of buds for the elaboration of handicrafts and other artifacts have been assessed for populations of *Astrocaryum standleyanum* (García, Galeano, Bernal, & Balslev, 2013), *Astrocaryum malybo* (García *et al.*, 2011), *Astrocaryum chambira* (García *et al.*, 2015) and *Copernicia tectorum* (Torres Romero, Galeano Garces, & Bernal, 2016). Studies on the effects of the palm heart crop have been made for *Euterpe oleracea* (Vallejo, Galeano, Bernal, & Zuidema, 2014) (Vallejo *et al.*, 2011). There is some research about harvesting of *Euterpe precatoria* fruits (Isaza, Galeano, & Bernal, 2014) and *Mauritia flexuosa* fruits (Sampaio, Schmidt, & Figueiredo, 2008).

Socioeconomic effects

Trade statistics are only well documented for species that are traded internationally, such as *Euterpe oleraceae* (açaí) of which Brazil is the leading supplier of palmetto and palm oil from this species (Brokamp *et al.*, 2011). However, for local communities, personal use and informal trade of palm products are part of their primary livelihoods, allowing income creation through the commercialization of raw materials or products traded in local and regional markets. The most commercialized palms in northwestern Amazon (Bolivia, Ecuador, Peru, and Colombia) are *Iriartea deltoidea* (timber), *Mauritia flexuosa* and *Oenocarpus bataua* (fruit, oil), *Lepidocaryum tenue* (thatch), *Ceroxylon* spp. (religious ornaments), *Phytelephas* spp. (Vegetable Ivory), *Astrocaryum* spp. (fiber, fruit) and *Euterpe* spp. (Palm hearts, fruit) (Brokamp *et al.*, 2011).

Palm fruits and oils have high nutritional value, and high economic value in international markets, however competitive technologies for the extraction and processing of raw materials must be developed (Brokamp *et al.*, 2011). Additionally, increasing economic sustainability would require strengthening value chains and the implementation of existing international and national legislation. This can

Box 3 14

be quite complicated in countries of South America where there are contradictions between national legislation and the rights of indigenous peoples, as well as the lack of technical and operational capacity of public institutions to control and verify compliance with the rules (de la Torre, Valencia, Altamirano, & Ravnborg, 2011). While implementation of standards that regulate the extraction of forest products is inconsistent, successful examples do exist (*Ceroxylon* spp.) and sustainable harvest is encouraged *(Lepidocaryum tenue)* (Brokamp *et al.*, 2011).

including Amazonia, Andes and Chocó have been documented (Macía *et al.*, 2011). In the Yucatan peninsula, leaves of xa'an palm trees (*Sabal yapa*, and *Sabal mexicana*) have been widely used for family homes. The palm is managed by Maya farmers through indigenous and local knowledge. When they clear a forest patch to grow maize, they spare palm trees, introduce them into home gardens and improve their growth. There are one or two harvest events per year and locals recommend leaving one or two leaves in each event. This traditional practice can stimulate palms to compensate for the effects of defoliation by producing new leaves (Martinez-Balleste, Martorell, & Caballero, 2008).

Although the harvest of *S. yapa* in natural systems has been sustainable for the last 90 years, the availability and quality of mature palm leaves is decreasing as agriculture becomes more intensive (Pulido & Caballero, 2006).
In dry forests of northwest Mexico, the recruitment of *Brahea aculeata* may be threatened by the harvesting and livestock grazing. Therefore management, conservation and restoration of palms require careful consideration related to human and environmental factors (Lopez-Toledo, Horn, & Endress, 2011).

3.3.2.4 Emerging issues in gathering

The COVID-19 pandemic has had an enormous economic impact on people in many parts of the world, especially jeopardizing livelihoods among already economically marginalized communities. The Center for People and Forests (RECOFTC, 2020). Restrictions imposed due to COVID-19, such as limiting or prohibiting access to forests and the inability to manage land are having a noticeable (RECOFTC, 2020). In Nepal, commercial gathering of the highly-prized medicinal fungus species *Ophiocordyceps sinensis* **(Box 3.11)** was officially halted due to COVID-19. However, collectors, including many returning from India after losing their jobs, were forced to disobey orders issued by the District Disaster Management Committees and District Forest Offices to overcome humanitarian crises due to the sale of the fungus being the only source of household income (Singh, 2020). In other instances, locals returned to fallow land to cultivate seasonal crops to compensate for the lack of income from fungus harvest (Samiti, 2020). Overall, the pandemic not only reduced the livelihood opportunities for mountainous communities but also substantially affected generation of revenue due to the sale of the fungus for the Nepalese (NRB, 2015) has estimated that Nepal had generated about 4.7 million United States dollars in revenue from the fungus in 2014, presenting a significant source of income for residents. The loss of income from fungus harvesting during the pandemic has therefore most likely had negative financial effects that are as of yet undocumented.

During the pandemic, the biggest flow of "wildlife" in trade has involved wild plants, not animals. The volume of trade in herbal medicines is likely to increase across the world as an impact of the long-term economic crisis due to COVID-19. There have been reports around the use of herbal products as part of the COVID-19 response in Africa, Asia, Europe, South America, and the United States of America (Timoshyna, Ke, Yang, Liang, & Leaman, 2020). In the Asia-Pacific region, there has been an increase in the volume of trade in herbal products, such as those used in traditional Chinese medicine in China and neighboring countries, and Ayurveda in India and neighboring countries. It is anticipated that the number of gatherers of wild species for a variety of uses may increase as the long-term economic impacts due to COVID-19 continue to develop, especially in areas where wild harvesting correlates with high unemployment and poverty rates (Luo *et al.*, 2020; Timoshyna *et al.*, 2020). Communities where indigenous and local knowledge is well-maintained were able to quickly pivot towards gathering wild algae, fungi and plants to cover their food and medical needs as other sources of income fell away (Walters *et al.*, 2021). This underlines the importance of protecting indigenous and local knowledge and wild algae, fungi and plants as a social safety net (Pierce & Emery, 2005).

Increased engagement in gathering to meet subsistence needs and for recreational proposes has also observed in many locations worldwide, for example in Canada, Ukraine and in the United Kingdom (Deutsche Welle, 2020; SickKids, 2020; The New York Times, 2020). Along with increased gathering there have also been reports of increasing incidence of mushroom poisonings, as more people who had not previously engaged in gathering are taking to the forests.

3.3.3 Terrestrial animal harvesting

3.3.3.1 Introduction

Terrestrial animal harvesting is defined in Chapter 1 as the temporary or permanent removal from their habitat of animals (vertebrates and invertebrates) that spend some or all of their life cycle in terrestrial environments. This definition provides a higher-level classification for several practices relating to the direct use of wild animals, most notably hunting, which results in the death of the animal being harvested, but also live capture and removal from the habitat (e.g., for the pet trade), capture and release back into the environment such as can occur with harvest of animal fiber, and practices in which products of animals are removed without intended mortality (e.g., wild honey).

The conceptual framework for this assessment (Chapter 1) recognizes that practices such as terrestrial animal harvesting are influenced by the end use and the associated relational values with wild species. For example, hunting is an ancient practice and continues in many contemporary societies where people hunt to meet a range of nutritional, economic, medicinal, scientific, cultural and recreational needs (A. Fischer *et al.*, 2013; Storaas, Gundersen, Henriksen, & Andreassen, 2001). It is therefore not always possible or meaningful to assess terrestrial animal harvesting according to separate types of use, for example distinguishing the recreational aspect of hunting from other components that may be critical to an assessment of sustainable use. Even the taking of some part of the hunted animal as a memory, or 'trophy', almost never occurs on its own and needs to be considered in the context of all the other uses. Nevertheless, this section presents the evidence according to uses in order to maintain consistency throughout the chapter.

Studies relating to terrestrial animal harvesting often focus on activities for particular species, referring to a wide variety of animal species that are harvested under circumstances that range from abundant to threatened and for populations that are defined as wild, introduced or feral in this assessment (Chapter 1). Ungulates are commonly hunted in many countries and are the subject of the most scientific studies but a wide range of other species are also frequently harvested, such as birds, reptiles and invertebrates (Alves & van Vliet, 2018; Barboza, Lopes, Souto, Fernandes-Ferreira, & Alves, 2016; Coad *et al.*, 2019). For this reason, the assessment provides a summary of evidence for sustainable use of different taxonomic groups.

The assessment of sustainable use for terrestrial animals often needs to occur at a landscape level and should consider the spatial distribution and size of areas with and without use, as well as the population dynamics and dispersal behavior of the hunted species (Novaro, Redford, & Bodmer, 2000; Ohl-Schacherer *et al.*, 2007). For example, if hunting occurs only in some parts of the landscape but not in others (due to protected status, regulation, land-use practices, or placement of human settlements) it can result in heterogeneous hunting pressure across the landscape. In these circumstances, source-sink dynamics can mean that declining population productivity in hunted areas can be compensated by constant dispersal and replenishment from areas where hunting does not occur (Koster, 2008; Novaro *et al.*, 2000; Ohl-Schacherer *et al.*, 2007; Peres & Nascimento, 2006; van Vliet & Nasi, 2008). In addition, economic aspects of terrestrial animal harvest seldom involve the use of just one species but more typically involve the use of a variety of species occurring in the same landscape. This means that the assessment of sustainable use should include a more integrated approach, which considers not just the taxa that are being used or the reasons they are being used, but also the social-ecological systems in which the use of animals occurs (Di Minin *et al.*, 2021). These broader landscape and land-use aspects of use require the inclusion of additional dimensions in the assessment of sustainable use, such as governance systems and issues of land ownership, which have been identified as critical factors affecting sustainable use (Fargeot, Drouet-Hoguet, & Le Bel, 2017; Van Schuylenbergh, 2009). The evidence relating to these broader social-ecological issues is often lacking (Di Minin *et al.*, 2021) making it difficult to assess sustainable use across multiple dimensions.

In the rest of this section different types of terrestrial animal harvesting are explored. The sections are not meant to be mutually exclusive but are designed to consider sustainable use for different aspects of contemporary terrestrial animal harvesting. Scientific literature for this section was obtained through a systematic literature review following the IPBES protocol. Search results are available in the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651. Perish software (https://harzing.com/resources/publish-or-perish) and Google Scholar were used for the literature search with keywords: "sustainability" or "sustainable" + hunting type (for example, "trophy hunting" or "commercial hunting"). Or "trends" or "status" + hunting type. This search returned over 20,000 literature sources. To reduce this number a ranking/citation rate of publications was applied, and the first 50 publications were selected (as recommended in IPBES methodological guide). It should be noted that the obtained results were (1) geographically imbalanced (covering mostly certain regions of Africa or the United States of America); (2) sometimes quite old (an artifact of the methodology because older publications often have higher citation ranking); (3) Neither Perish or Google Scholar search for thematic reports. To overcome these imbalances experts supplemented the literature search from their own collections and those recommended during the external review processes. Invited contributing authors added literature for their sections following literatures searches and relying on their professional experience.

3.3.3.2 Uses

3.3.3.2.1 Ceremonial and cultural expression

Cultural and religious factors influence hunting practices in all regions of the world. Wild species are an important part of cultural life since various animal parts are used as adornments in ceremonies or as ornaments (e.g., feathers and fur) and tools (e.g., bones and teeth) in daily life (Pangau-Adam, Noske, & Muehlenberg, 2012). Hunting as a 'socio-cultural' phenomenon involves non-market values, symbolic and social capital, social status and impacts on good quality of life (see Chapter 4). Hunting supports social interaction and community, especially in terms of creating and maintaining bonds within one's social group, as well as benefits to physiological and psychological welfare for hunters (Bioeconomy.fi, 2017; A. Fischer *et al.*, 2013).

In many cultures across the world, hunting is associated with power, prestige and success, especially when the animals are killed in wild conditions. Europe has a diverse and complex legislative and regulatory hunting environment which includes many traditional elements (Higginbottom, 2004). In Scotland, deer stalking is part of a 150-year-old hunting culture, and continues to be one of the main activities of upland estates. Even where stalking is not commercially viable, it is a culturally important activity and has important bonding functions that help develop and reassure one's social status (MacMillan & Leitch, 2008). Similar functions are also observed in Sweden, where moose hunting teams are organized on a voluntary basis by local hunters' groups and landowners (Gunnarsdotter, 2007).

There are long traditions of bird hunting throughout Europe. However, the only readily available data on numbers of birds legally killed across the European Union are for derogations issued under the Birds Directive. This applies to four countries: France, Italy, Malta and Spain, in which 1.39 million individual birds (11,000 doves, 448,850 finches, 430,000 larks, 3,200 plovers, 200,000 starlings and 297,200 thrushes) are legally hunted each year under these derogations relating to "traditional practices" (Brochet *et al.*, 2016) (these statistics are reported again under the section on recreational hunting). In addition, very restricted derogations are allowed for capture of living finches in some countries, such as Malta and Spain. Whether directly related or not, numbers of migratory birds in the Mediterranean region have declined substantially, with one study estimating that there are 300 million fewer farmland birds in Europe today than in 1980, primarily as a result of agricultural intensification (BirdLife International, 2008).

Consuming meat of wild animals may also demonstrate wealth, prestige, and social standing in some cultures, whereas in others it may be a matter of choice, taste and options. In some urban areas, wild meat is a luxury good which is marketed to and adopted by young men to boost their professional and social status (Gangale, 2016). In Papua-New Guinea, it is a tradition among the Genyem that certain animals could be only hunted by clan leaders, while others could not be killed by hunters at certain times (e.g., when their wives were pregnant) (Pangau-Adam *et al.*, 2012). However, there is some evidence that traditional Genyem beliefs are breaking down as some species that were once considered taboo (e.g., cassowaries, certain birds-of-paradise) are now hunted (Pangau-Adam & Noske, 2010). Wild animals, mainly wild boars, are still occasionally killed for community festivals and religious ceremonies. When a large amount of meat is required for a cultural event, hunting is performed in groups and in more rural areas (Pattiselanno, 2006). Many hunters (91%) also target wild boars because the number of boar jaws they harvested was traditionally a sign of their social status.

Cultural values are considered to be important drivers of biodiversity conservation and sustainable use of wild animals (see Chapter 4). Taboos represent social norms and beliefs that protect species or places because of their cultural values. Taboos have had an important implication, for example, in relation to primate conservation (Infield *et al.*, 2018; Baker *et al.*, 2018). However, the protection of culturally valuable species rarely extends to other species or habitats (Schneider, 2018).

3.3.3.2.2 Decorative and aesthetic uses

The text in this section refers primarily to decorative and aesthetic use of wild animals, documented through formal trade data. Data are not available on informal or subsistence use of wild terrestrial animal species for these purposes. The skin of mammals is used commonly for gloves, shoes, belts, and watchbands. Over 4.6 million mammal skins from wild species were exported for commercial purposes over the period 1996–2010 and vast majority (>99%) were harvested in the wild (CITES, 2012). In Australia, the kangaroo skin industry generates 133 million United States dollars a year. In Peru, total annual value of the peccary-leather trade was estimated at 4,868,500 United States dollars of which only 1.5% was attributed to the rural sector (hunters), 11.1% to the urban sector (the national leather industry), and the majority went to the international leather industry (Bodmer & Lozano, 2001). Since 2007, the skin trade has been decreasing with the decrease in exports of fox (*Lycalopex* spp.) skins by Argentina (CITES, 2012).

Different parts of animals can be legally exported, and legal international trade has contributed to the recovery of some species. For example, skin of peccaries from Peru

(Bodmer & Lozano, 2001), kangaroo meat and animal skin from Australia (Boom *et al.*, 2012), skin of foxes (*Lycalopex* spp.) from South American countries (CITES, 2012), and crocodilian skins (Caldwell, 2017). Legal programs include economic incentives for people to tolerate the recovery of large predators (Fukuda, Webb, Edwards, Saalfeld, & Whitehead, 2020). Conversely, illegal international trade has contributed to the decline of many wild animal species worldwide (Pires & Moreto, 2016; ROUTES, 2020; TRAFFIC, 2008).

In Amazonia, from 1904 to 1969, an average 23.3 million wild mammals and reptiles representing at least 20 species were commercially hunted for their hides; averages of 13.9 million terrestrial mammals, 1.9 million aquatic and semiaquatic mammals, and 7.5 million reptiles (Antunes *et al.*, 2016). Hunted species included the manatee *(Trichechus inunguis)*; capybara *(Hydrochoerus hydrochaeris)*, ocelot *(Leopardus pardalis)*, margay *(Leopardus wiedii)*, jaguar *(Panthera onca)*, neotropical otter *(Lontra longicaudis)*, giant otter *(Pteronura brasiliensis)*, collared peccary *(Pecari tajacu)*, white-lipped peccary *(Tayassu pecari)*, red brocket deer *(Mazama americana)*, black caiman *(Melanosuchus niger)*, common agouti (*Dasyprocta* spp.), Amazonian brocket deer *(Mazama nemorivaga)*, tapir *(Tapirus terrestris)*, iguana *(Iguana iguana)*, tegu lizard *(Tupinambis teguixin)*, caiman lizard *(Dracaena guianensis)*, boa *(Boa constrictor)*, anaconda *(Eunectes murinus)*, and spectacled caiman *(Caiman crocodilus)*. The commercial exploitation of animal hides in the 20th century had led to population collapse for the large-bodied aquatic wild species, signaling the possibility of an "empty river" phenomenon. At the same time, various sustainability indices have shown different results suggesting that drivers other than hunting and complexity of applied models must be taken into account in assessing sustainability (Chapters 2 and 4).

Several species of crocodile are harvested for the leather and fashion industry, with over 5.2 million crocodilian skins reported in trade between 2013–2015 (Caldwell, 2017). The majority of crocodilian skins in trade are from captive bred stock, although many were originally sourced from legal wild egg ranching programs. In many countries, indigenous and local people benefit through the payment of royalties for eggs, and/or employment through the farm supply chain (Fukuda *et al.*, 2020; Joanen, Merchant, Griffith, Linscombe, & Guidry, 2021). As a result, species such as the saltwater crocodile *(Crocodylus porosus)* and American alligator *(Alligator mississippiensis)* have recovered from unregulated hunting in the 1960s and 1970s, back to pre-exploitation levels. The economic value generated through the leather industry has enabled tolerance of this recovery and protection of habitat. The sustainable use of alligators in the United States of America generates more than 100 million United States dollars annually at the raw product level (R Elsey, Woodward, & Balaguera-Reina, 2019).

Feathers are used as ornaments in many cultures. Amazonian indigenous people have a very deep knowledge of birds. They invented the technique of tapirage, which is making the feathers change color on a live bird. They often tame birds that they keep as pets or for their feathers. In some countries of Amazonia there are conflicts with conservation laws that do not allow people to kill birds. In Guiana Amazonian Park (Guyane) a program is being developed to harvest feathers in zoos instead of killing birds to make headdresses.

3.3.3.2.3 Food and beverage

Millions of animals are killed every year in Africa, Asia, and the Amazon for subsistence hunting and the wild meat trade **(Table 3.12)**. The most frequently hunted taxonomic groups in most studies are ungulates, followed by rodents. Large mammals alone comprised 55-75% of total wild meat biomass extracted annually **(Table 3.12)**. Note that given these figures, **Table 3.12** focuses primarily on wild meat from mammals. Wild meat from bird, amphibians and reptiles are discussed in detail elsewhere.

In West and Central Africa, wild meat consumption has increased drastically in recent decades (Wilkie, Bennett, Peres, & Cunningham, 2011). Wild meat comprised 62.2% of the total animal protein consumed by families in Papua New Guinea (Pangau-Adam *et al.*, 2012). Estimates of wild meat consumption differs greatly – with global estimates of more than 5 million tons a year (Kanagavel, Parvathy, Nameer, & Raghavan, 2016) to separate regional estimates of 4.6 million tons in the Congo Basin and 1.3 million tons a year in the Amazon (Rosie Cooney, Roe, Dublin, & Booker, 2018). Wild meat comprised 62.2% of the total animal protein consumed by families in Papua New Guinea (Pangau-Adam *et al.*, 2012). For scale of comparison, it is worth noting that if global wild meat consumption is roughly 5 million tons a year, this is only equivalent to approximately half of the European Union's beef production (Fa *et al.*, 2002; Nasi, Taber, & Van Vliet, 2011).

In semi-arid regions (South America, Africa, Asia), mammal meat is crucial for the nutritional well-being of many human communities especially because the availability of fish or other sources of protein are limited (Barboza *et al.*, 2016; da Silva Santos *et al.*, 2019). In this ecoregion, wild meat can be especially important during the frequent drought periods, a typical phenomenon in these areas, when crops are scarce and domestic animals may die because of starvation and dehydration (Barboza *et al.*, 2016). Within a vast savanna ecosystem, about 50 million people depend to varying extents on wild species for their food security and daily subsistence (Olivero *et al.*, 2016). A significant part of the population, often poor and rural, hunts for their own consumption and as a primary source of income by supplying food to more or less distant consumption

Table 3 12 **Domestic consumption rates of wild meat from subsistence hunting.**
Regions and countries reported based on available literature.

Region/country	Harvest	Main target species or taxonomic group	Share of large animals	Reference
Tropical regions of Africa (Cameroon, Central African Republic, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana)	340 – 84,093 kg/year per site, 16,000 kg per site, on average	ungulates (47%), rodents (37%)	22% of carcasses to total kills, but 55% of total wild meat biomass extracted per year	(Fa, Peres, & Meeuwig, 2002)
Peru	54-255 inds/100 km^2, 1605 – 4581 kg/100 km^2	White-lipped peccary *(Tayassu pecari)*, collared peccary *(Tayassu tajacu)*, lowland tapir *(Tapirus terrestris)*, brown capuchin *(Cebus albifrons)*, howler monkey *(Alouatta seniculus)*, paca *(Agouti paca)*, agouti *(Dasyprocta fuliginosa)*	Large mammals comprised 78% of the estimated biommass of all hunting animals	(Bodmer & Lozano, 2001)
Eastern half of Papua-New Guinea, Indonesia	Between 4 and 8 million individuals	Wild pig, cassowaries, cuscus, and bandicoots	Large mammals comprised 58% of the estimated biomass of all harvested animals	Cuthbert, 2010; Mack & West, 2005; Richards, S. J. & Suryadi, S., 2000)
Papua (the western half of Papua-New Guinea), Indonesia	Wild meat comprised 62.2% of the total animal protein consumed by families	Wild pig, rusa deer, bandicoots	Large mammals comprised 75% of estimated biomass of all harvested animals	(Pangau-Adam *et al.*, 2012)
India	India population ate an average of 0.158 kg of meat per month	Barking deer, Wild pig, Asiatic black bear, Sambar, Serow, Assamese macaque, Goral	Large mammals comprised 70% of the estimated biomass of all harvested animals	(Karanth, Nichols, Karanth, Hines, & Christensen, 2010)
Vietnam	More than 58% of Vietnam population ate 1 kg of meat per month	Wild Pig, soft-shelled turtle, Bear, Snake, Civet	Large mammals comprised 50% of the estimated biomass of all harvested animals	(E.L. Bennett & Rao, 2002)
Amazonian forests	10,691 tons of wild meat might be consumed annually in Amazonia, the equivalent of 6.49 kg per person per year	Mammals, reptiles, and birds	38% of species more than 1 kg	(Bahuchet & de Garine, 1990; H. El Bizri *et al.*, 2020; Fa & Peres, 2001; Noss, 1998)
Tropical forests	177-358.4 kg/km^2/year on average	The main taxa represented are primates (ungulates, rodents, and carnivores	High harvest rates of largebodied diurnal animals	(Fa *et al.*, 2002)

centers. Even before commercial sale of meat, heads, legs and intestines of harvested animals are typically removed (~1–5 kg per animal) for family consumption prior to transporting the prime meat cuts to the market (Pangau-Adam *et al.*, 2012).

Profound social-economic changes (the introduction of a cash market economy through globalization, combined with rapid urban and infrastructure development) have resulted in marked shifts in hunting practices of many indigenous and local communities. The nature of hunting has changed from local-level subsistence hunting towards more intensive commercial hunting for wild meat trade (Pangau-Adam *et al.*, 2012). For many rural families, wild meat trade is the main source of cash income, providing access to modern services and basic necessities such as medicines, energy and education (Abernethy, Maisels, & White, 2016). However, increases in commercial harvesting of wild species threatens the traditional lifestyles of indigenous populations through the weakening or loss of traditional laws and taboos, which may push hunting activities towards becoming unsustainable (Pangau-Adam *et al.*, 2012). In tropical forests, harvesting of wild meat by forest dwellers has drastically increased recently due to large numbers of urban consumers, advances in hunting technology, scarcity of alternative sources of protein, and individual food preferences (Fa & Brown, 2009; Groom, Meffe, & Carroll, 2006). In competition with these families, professional hunters and/or traders organize illegal networks to transport and sell the products (Van Schuylenbergh, 2009).

Reptiles and amphibians also serve as an important source of protein for human populations (Coad *et al.*, 2019). Of all reptiles, turtles and tortoise species (chelonians) are most heavily harvested for human consumption (Alves, Gonçalves, & Vieira, 2012; Pezzuti, Lima, da Silva, & Begossi, 2010). Live animals (e.g., turtles, tortoises, and lizards) as well as processed, dried, and frozen meat (e.g., pangolin) are commonly traded into food markets for consumption (see routespartnership.org). In South America, the giant Amazon River turtle *(Podocnemis expansa)*, the largest South American river turtle, is one of the most consumed species. Caiman meat (as other crocodilians) is a product that is increasing in acceptance in the world food market. Currently there is a supply of meat from many managed areas in Argentina, Bolivia, Brazil and the United States of America (Piña, Lucero, Simoncini, Peterson, & Tavella, 2017). Crocodile and alligator meat is considered a delicacy (Huchzermeyer, 2003a, 2003b), and it is particularly consumed in Australia, South Africa, Thailand, Ethiopia, Cuba, and in some regions of the United States of America (Hoffman & Cawthorn, 2012). The consumption of snakes is generally opportunistic, but in Asian countries and West Africa, these animals are important sources of meat (S. E. Brooks, Allison, Gill, & Reynolds, 2010; Hoffman & Cawthorn, 2012). Although amphibians are consumed on a smaller scale than vertebrates, Mohneke *et al.* (2009) highlight that at least 32 amphibians (3 *Urodela* spp., 29 *Anura* spp.) are used as food.

Many investigations showed that the crucial factor explaining target species preferences is the anticipated benefits from hunting the largest-bodied animals. Usually opportunistically hunted small and medium-sized game are consumed by the hunters themselves, especially in low-income countries throughout Africa, Asia, South America and Eastern Europe (Fischer *et al.*, 2013). In contrast, big game provides a greater return for the energy invested in hunting, more meat for consumption, and significant revenue for hunters' households (Coad *et al.*, 2013; Constantino, 2016; de Albuquerque *et al.*, 2012; D. J. Ingram *et al.*, 2015; P. Lindsey, Balme, Booth, & Midlane, 2012; Maisels, Keming, Kemei, & Toh, 2001; Nasi *et al.*, 2008; Pangau-Adam *et al.*, 2012; Redmond, 2006) with a few exceptions due to underdeveloped markets (MacMillan & Leitch, 2008). It should be noted that while it may seem that hunting larger animals is energetically more efficient, large game are infrequently acquired (there are higher number of unsuccessful days) and storage is often a problem. Furthermore, it is typically a riskier activity. In some traditional small band societies (e.g., the San, the Hadza, the Ache, various Native American and First Nation peoples) small game and plant resources are more regularly gathered as primary sources of protein and daily nutrition (Hawkes, O'Connell, & Blurton Jones, 2001).

Over-harvesting may take place due to the lack of knowledge or monitoring, lack of sufficient regulation, or lack of political will and prioritization of conservation. In these cases varying degrees of hunting pressure often result in faunal biomass collapses, mainly through declines of large-bodied species with low intrinsic rates of population increase, as was the case in Oceania (Pangau-Adam *et al.*, 2012), Africa (Coad *et al.*, 2019; Gill, Fa, Rowcliffe, & Kümpel, 2012; Groom *et al.*, 2006; Ingram *et al.*, 2015; Milner-Gulland & Bennett, 2003; Van Vliet, Milner-Gulland, Bousquet, Saqalli, & Nasi, 2010; van Vliet, Muhindo, Kambale Nyumu, Mushagalusa, & Nasi, 2018; van Vliet & Nasi, 2008; Weinbaum, Brashares, Golden, & Getz, 2013), and Asia (Bennett & Rao, 2002; Karanth, Jain, & Mariyam, 2017). As populations of larger animal decline, the time and effort required to catch these large species will eventually outweigh the potential gain, leading hunters to shift to target mid-size and small species (Jerozolimski & Peres, 2003). Throughout this process, the largest species of a multispecies hunt will continue to be opportunistically captured whenever possible, preventing large species recovery even when the primary target is now a smaller species (Robinson & Bennett, 2004).

Unsustainable hunting for human consumption is only one factor affecting declines in mammalian species **(Figure 3.46)**, (Alves, 2012; Chapman & Peres, 2001; Dirzo *et al.*, 2014; IUCN, 2016; Ripple *et al.*, 2014; Ripple *et al.*, 2016), but is especially prevalent in tropical environments (Coad *et al.*, 2019; Fa *et al.*, 2002; Fa, Ryan, & Bell, 2005; Weinbaum *et al.*, 2013). Overall extraction rates in the Congo Basin, for example, were calculated on the basis of extraction–production models to be as much as six times greater than the maximum sustainable rate (Fa *et al.*, 2002). Fossil evidence suggests that hunting has contributed to the local extinction of several species of larger mammals in New Guinea in the past (Flannery, 2000). Ripple *et al.* (2016) found that 301 mammals are threatened by hunting globally: 113 species in Southeast Asia (13% of all threatened mammals are east of India and south of China) and 61 in the rest of Asia (7%); 91 in Africa (8%); 38 in Latin America (3%); and 32 in Oceania (7%). Unsustainable hunting has been identified as a threat for 1,341 wild mammal species assessed by the International Union for Conservation of Nature, including 669 species that were assessed as threatened (IUCN Red list 2021). Nearly 20% of the International Union for Conservation of Nature Red List's threatened and near threatened species are directly linked to hunting (Maxwell, Fuller, Brooks, & Watson, 2016). Eleven of the 14 species of tree-kangaroos (*Dendrolagus* spp.), most of them endemic to New Guinea, and two of the three cassowaries (Casuariidae; 25–60 kg), are now considered threatened by, or vulnerable to extinction, principally due to

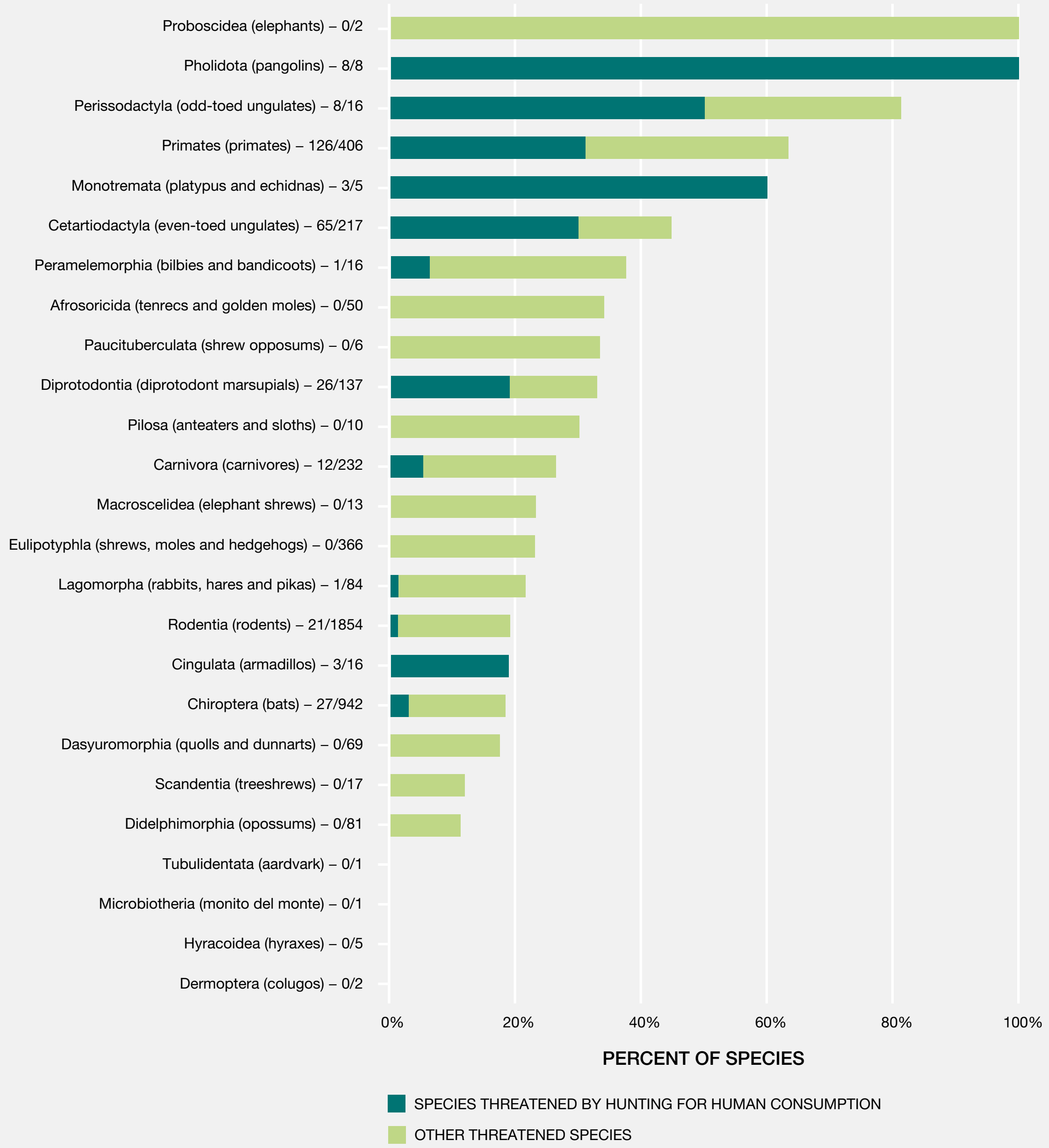


Figure 3 46 **The percentage of species threatened by hunting for human consumption and other threatened species in each mammalian order.**

Values on the x-axis refer to the percentage of species out of all mammal species in each order. The category "Other threatened species" consists of the other threatened mammal species where hunting for consumption is not a primary or major threat. Horizontal bars are sorted from highest to lowest total percentage of threatened species in each order. Numbers on the y-axis after the order names are the number of species threatened by hunting followed by the total number of species in the order. The order Notoryctemorphia (marsupial moles) was omitted as it contains only data-deficient species. Source: (Ripple *et al.*, 2016) under license CC BY 4.0.

hunting (IUCN, 2016; Stattersfield, Crosby, Long, Wege, & Rayner, 1998). Increasing commercial demand, availability of sales markets (Pangau-Adam *et al.*, 2012), lack of adequate monitoring and enforcement by the government (Pangau-Adam *et al.*, 2012), poaching and illegal trade (Pangau-Adam & Noske, 2010) further complicate this process.

The sustainability of wild meat hunting is increasingly driven by social-economic changes, recreation, entertainment, trade, and trafficking, rather than take-off for subsistence. These drivers are discussed in detail in Chapter 4. In the absence of effective governance, many experts continue to focus primarily on total offtake from an area, suggesting that as long as hunting is profitable, the largest animals will be driven to local extinction by hunters (Branch *et al.*, 2013; Harrison *et al.*, 2016; Lindsey, Alexander, Balme, Midlane, & Craig, 2012).

Wild meat consumption **(Table 3.12)** and trade carry health risks related to the transmission of zoonotic diseases to humans through handling (e.g., hunters, middle market distributors, and sellers) or consumption of wild meat. This is especially of concern at traditional food markets when wild animals are caged, and then slaughtered and dressed in close proximity to the public (OIE, WHO, & UNEP, 2021). The emergence of new infectious diseases, particularly zoonoses (derived from animals), is increasing.

With regards to commercial demand for wild meat, there is growing demand in cities stimulated by migration of rural peoples to urban landscapes (Bennett *et al.*, 2007). There is evidence that the commercial trade of wild meat has heavily increased offtakes in West and Central Africa because of the higher prices likely to be paid by urban dwellers, with the situation anticipated to worsen as populations continue to rise and become more urbanized. A similar trend is apparent in Eastern and Southern Africa, where increasing urbanization is associated with a growing consumption of wild meat resources (Barnett, 2000; Cowlishaw, Mendelson, & Rowcliffe, 2004; Peter Lindsey & Bento, 2012). The demand of game meat in many European Union countries is also growing due to beliefs that it is a more ecological and ethical choice consistent with ideas of the green transition. The demand for wild meat in many developed countries among the diaspora communities from developing countries has also created new demand for international trade in wild meat (Chaber, Allebone-Webb, Lignereux, Cunningham, & Rowcliffe, 2010).

Economic incentives and unclear rules and regulations may be leading to additional commercial hunting on indigenous lands (Fischer *et al.*, 2013; Pangau-Adam *et al.*, 2012). In Papua, Indonesia, the anticipated financial gain for a hunter from the sale of three individual wild animals (35–50 United States dollars each) is approximately equivalent to the monthly salary of a locally employed permanent worker (Pangau-Adam *et al.*, 2012). In Central Amazon, Brazil, wild species hunting and consumption are driven by many factors such as source of income, taste preference, culture, lack of alternative meat, meat price, and wealth. The relative importance of these factors varies from place to place (Chaves, Valle, Tavares, Morcatty, & Wilcove, 2021).

Amphibians and Reptiles

Amphibians and reptiles were historically harvested and traded for different reasons. For example, tortoises, large freshwater turtles, sea turtles, and crocodilians were used as an important source of protein for human populations around the world (Klemens & Thorbjarnarson, 1995; Pritchard, P.C.H., 1996; Schlaepfer, Hoover, & Dodd, 2005). Exploitation of these species for food is heaviest in the tropical and sub-tropical regions, but also occurs in temperate areas also. Amazonian markets, for example, include the domestic consumption of wild meat and turtle eggs and the use of crocodile parts and products in the international leather industry. In examples such as these the mixed-use nature of terrestrial animal harvesting is apparent: where meat consumption is a by-product of the commercial skin harvest of crocodilians, snakes, and lizards (Gorzula, 1996; Schlaepfer, Hoover, & Dodd, 2005).

The United States of America plays a major role in the international trade of wild amphibians and reptiles. During 1998–2002 in the United States of America alone, 14.7 million wild-caught whole amphibians, 5.2 million kg of wild-caught amphibians and 18.4 million wild-caught reptile parts and products were imported, and 26 million wild-caught whole reptiles were exported (Schlaepfer, Hoover, & Dodd, 2005). The crocodilian harvest programs in the United States of America (alligator) and Australia (saltwater crocodile) are highly regulated and monitored, with a coordinated system of permits, licenses, and rigorous tagging and export requirements (Elsey *et al.*, 2019; Fukuda *et al.*, 2020; Joanen *et al.*, 2021). More than 50% of all traded individuals of reptiles had no species-specific identification, making species-based regulation especially difficult without extensive genetic testing, which is temporally and financially unrealistic. Crocodilian meat is particularly favoured in Southeast Asia. The top species traded for meat are *C. niloticus* and *C. siamensis*, with trade peaking annually in 2006 at 1000 tonnes (Caldwell, 2017).

The most commonly traded species of amphibians and reptiles are abundant, widely distributed, and have long histories of sustaining use and trade, with varying degrees of regulation matched to their life history parameters. A species with a large range, high density, and high reproduction rate, for example, may be able to sustain a relatively large harvest. In contrast, species with restricted ranges, high levels of endemism (e.g., small island species), or life-history strategies that depend on high adult survivorship like many turtle and tortoise species (e.g. Heppell, 1998), could be detrimentally affected by relatively low harvest rates. Many amphibian and reptile species aggregate in small areas during breeding or hibernation, making them particularly vulnerable to intensive harvest efforts during that period (Klemens & Thorbjarnarson, 1995; Schlaepfer, Hoover, & Dodd, 2005).

Frog meat is considered a delicacy in many countries. The FAO has estimated the worldwide production of frog legs at 80,000 metric tons annually (FAO, 2012a). In Europe, there are 4600 tons of frog meat imported per year, corresponding to c.a. 46 million frogs, mainly coming from Indonesia and Vietnam, where they are predominantly harvested from the wild (Warkentin, Bickford, Sodhi, & Bradshaw, 2009). Human populations from Southeast Asia are estimated to be the largest producers and consumers of amphibians worldwide, even if there is a lack of proper evaluation for comparative purposes (Warkentin *et al.*, 2009).

In his book "The culinary herpetologist", Liner (2005) cites cooking recipes based on 26 salamander and 193 frog species; only a few of these edible species are consumed in large quantities. At the same time, edible amphibian populations are declining worldwide and humans have already faced the risk of losing this food source due to the overexploitation of animals harvested from nature (Carpenter *et al.*, 2007; Carpenter, Andreone, Moore, & Griffiths, 2014). India, followed by Pakistan and Bangladesh, banned the export of frogs in the early 1980s (Fugler, 1985). More recently, Turkish authorities have banned frog hunting in some provinces and advocated the promotion of frog farming (Şereflişan & Alkaya, 2016). Frog farming is already quite extensive in Indonesia, where many exotic and invasive species are harvested for international trade. Indonesian exports of frogs were 28 tons per year in 1969 and increased to 5600 tons in 1992 before decreasing to about 3800 tons in the early 2000s (Kusrini & Alford, 2006). Sustainable frog farming is lagging behind in major consumer countries, the first frog farm in France opened only in 2009.

Unlike in Indonesia, in Africa frogs are mainly used for local consumption and local trading. A long-standing tradition of frog hunting exists in the Lake Chad basin that relies on large populations of grassland frogs *(Ptychadena trinodis)*, edible bullfrogs *(Pyxicephalus adspersus)*, African tiger frogs *(Hoplobatrachus occipitalis)* and the marbled shovelnose frog *(Hemisus marmoratus)* (Seignobos, 2014). In West African countries, six species of frogs are among the most consumed and sold frog species (Mohneke, 2011; Mohneke, Onadeko, Petersen, & Rödel, 2010). Studies carried out in Benin and Nigeria showed that between both countries and over 2.7 million frogs are harvested annually for cross-border trade (Mohneke, 2011). In Central Africa, goliath frog *(Conraua goliath)* and slippery frog *(Conraua robusta)* are heavily harvested from the wild and sold in local wild meat markets in Cameroon (Gonwouo & Rödel, 2008; Herrmann, Babbitt, Baber, & Congalton, 2005). Similarly, frog species harvested from the wild contribute to the local supply chain including markets and restaurants in the Democratic Republic of Congo (Sandra Altherr, Goyenechea, & Schubert, 2011). Large tadpoles of endemic species such as *Conraua* sp., *Trichobatrachus* sp. and *Astylosternus* sp. are also harvested and traded for consumption (Gonwouo & Rödel, 2008; Mohneke, 2011). Despite the importance of these small wild animals, assessments of the value chains of which they are a part are scant, especially in many Central Africa regions.

Edible Insects

There are a considerable number of reports on the need for forest conservation using edible insects. They are important sources of food in arid and semi-arid areas of Africa and in the great sandy deserts of Australia (Yen, 2009). Traditional consumption of edible insects and small terrestrial invertebrates is common in one third of the world's population, mainly in Asian, African, Central American and South American cultures. Globally, more than two thousand identified arthropods are eaten (Arnold van Huis, 2018). Over 500 species of edible insects are reported for Mexico (Ramos-Elorduy, Pino-Moreno, & Martínez-Camacho, 2012) and 324 species of insects from 11 orders are documented as either edible or associated with entomophagy in China. People also feed insects to livestock and indirectly consume them (Feng *et al.*, 2018). People throughout higher income countries in Europe and North America are contemplating using of edible insects as an alternative, more sustainable source of protein than animals (Mlcek, Rop, Borkovcova, & Bednarova, 2014) **(Figure 3.47)**.

Globally 92% of insect species used by people are harvested from the wild (Alan L. Yen, 2015). Edible insects are often harvested by women and minority groups (A. van Huis & Oonincx, 2017; Arnold van Huis, 2018; Arnold van Huis *et al.*, 2013), but not exclusively. Insects are often harvested by hand. Some examples of harvest techniques are included here. The most common technique to harvest swarming termites and edible grasshoppers *(Ruspolia differens)* is using light sources at night. In Central African countries, women listen to trunks of the palm trees to check whether larvae of the palm weevil (*Rhynchophorus* sp.) are ready to be harvested (van Huis & Oonincx, 2017; van Huis, 2018). This also happens in Colombia, but it is usually the men who search and find the larvae in palm trees (*Oenocarpus bataua, Oenocarpus bacaba* in most cases). In many cases they cut down the palm (Mesa & Galeano, 2013) to harvest the insects. In the Venezuelan Amazon, the Jöti people manipulate *Oenocarpus bacaba* palms in order to increase abundance of their favorite palm weevil, *Rhynchophorus palmarum* (Choo, Zent, & Simpson, 2009). In the Asia Pacific, tarantulas (*Haplopelma* sp.) are harvested out of tropical forests. Yen and Ro (2013) observed that skilled spider hunters are able to harvest several hundred spiders a day, although how this is done is undocumented. Only female spiders are cooked and eaten. This may be because the females are larger. The income from selling spiders for food and medicine is substantial enough that this can be considered an important subsistence practice. Although reports suggest a decline in the population around Skun and other provinces is observed, direct causality from human harvesting has not been proven. There is little additional information available on the biology or population status of this species.

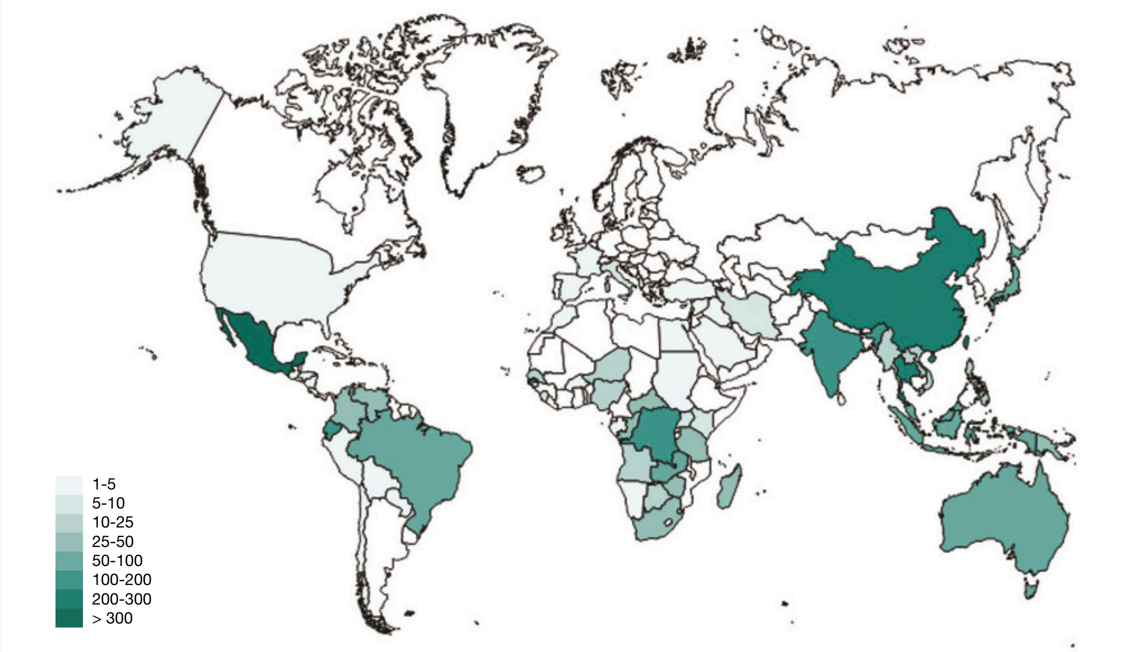


Figure 3 47 **Recorded number of edible insects, by country.**

This map is directly copied from its original source (Tiencheu & Womeni, 2017) and was not modified by the assessment authors. The map is copyrighted under license CC BY 3.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

The life cycle and host plants of edible caterpillars are well understood by local communities and this knowledge is communicated orally over generations. A survey of 39 ethnic groups, covering 21.4% of the all-ethnic groups in the Amazon basin, identified 115 edible insects with 131 local names. An additional 384 local names of edible small invertebrates could not be identified, indicating that local traditional knowledge was richer than the scientific understanding at the time (Paoletti, Buscardo, & Dufour, 2000).

Traditional land owners have, in most cases, developed harvesting protocols and habitat management practices that ensure sustainability (Yen, 2009). Traditional regulation of caterpillar harvesting in northern Zambia involves several aspects. Local people monitor development and abundance of edible caterpillars, changes in caterpillar habitats, protection of host plants and moth eggs against late bush fires and temporary restrictions on harvest of edible caterpillars (Mbata, Chidumayo, & Lwatula, 2002). Local knowledge also involves an understanding of processing to remove toxins that make inedible insects edible.

In agricultural systems, chitoumou *(Cirina butyrospermi)* are harvested. The time of harvesting, eating and selling of these caterpillars (so called 'chitoumou wakati') varied greatly in different areas and from year to year. Women consider caterpillars and shea nuts to be their primary income sources (Payne, Badolo, Cox, *et al.*, 2020; Payne, Badolo, Sagnon, *et al.*, 2020). Harvesting caterpillars has increased food security, although this is often from increased income from sale of fresh or dried caterpillars, rather than direct consumption.

Insects on the whole are vulnerable to overharvesting, habitat destruction, pesticides and other pollution and to climate change (Arnold van Huis *et al.*, 2013). For instance, habitat destruction has an impact on the availability of edible caterpillars *(Eucheira socialis)* in mountainous regions of Mexico. Problems can also arise when there are market demands that encourage non-specialist harvesters to harvest. In Australia, the use of edible insects by traditional indigenous owners has decreased significantly since European settlement. This is due in part to the displacement of indigenous people, the loss of traditional knowledge and language, and the adoption of a European diet. The harvest of edible insects, particularly in relation to nature-based tourism, now has implications for overharvesting in Australia (Yen, 2009). This is also the case of escamoles *(Liometopum* spp.) in Mexico where edible ant larvae with a high market value were affected when non-local people harvested them for profit (Ramos-Elorduy, 2006).

During the last five years the scientific interest and knowledge on insects as food has grown exponentially (van Huis, 2020). The industrial sector is increasingly engaged in rearing, processing and marketing of edible insects. The use of insects as human food (or as food supplements) or for feeding poultry and fish can contribute to more energy-efficient food production and promote environmental protection. An assessment conducted by the FAO concluded that insects represent a potential sustainable food source to address global food security concerns (van Huis *et al.*, 2013). However, insects could pose several microbiological and chemical health risks, which must also be considered (Imathiu, 2020).

3.3.3.2.4 Recreational hunting

Recreational hunting refers to practices where the purpose of the hunt is for the hunter's own personal use and enjoyment as opposed to harvesting for commercial or subsistence use (which are dealt with in section 3.3.3.2.3). Hunting is broadly considered as one way in which nature contributes to human wellbeing in a variety of context specific ways (Díaz *et al.*, 2018) and recreational hunting may be associated with a range of values and motivations, including food, social and cultural motivations, sport and exercise. As in all forms of hunting, there is a high degree of multi-functionality (*sensu* Fischer *et al.*, 2013). For example, a Scandinavian moose hunter may hunt in order to secure a year's supply of wild meat, in order to enjoy time exercising outdoors in the forest during autumn, to enjoy time spent socializing with family members or friends that make up his hunting team, to maintain the cultural tradition of harvesting natural resources by hunting in a forest, to help regulate the size of the moose population so that damage to commercially harvested tree species and traffic collisions is kept to acceptable levels, and for the possible chance to bring home a "trophy" set of antlers. Depending on if the hunter is a landowner, he/she may also have commercial interests via the sale of meat or hunting licenses (Fischer *et al.*, 2013; Storaas *et al.*, 2001).

The range of values associated with recreational hunting is reflected in the many terms linked to recreational hunting in the literature, including *inter alia* sport hunting, hunting tourism, safari hunting, trophy hunting, and big game hunting, or the use of terms associated with the hunting of particular species like deer hunting or duck hunting. Although these terms are sometimes used as synonyms, there is no agreed typology and the same terms can have different meanings in the literature, which can confound any attempt at synthesizing the evidence on sustainable use. The International Union for Conservation of Nature Red List uses the term 'sport hunting' for hunting where the end use is for the "collection and preservation of dead specimens for personal pleasure" (IUCN, 2020a). This definition is close to the definition of trophy hunting (see following paragraph) but differs from other interpretations where the term sport hunting/shooting is meant to differentiate it from market or commercial hunting and therefore covers a broader range of end uses. For example, grouse shooting in Scotland and England is regarded as sport shooting (Tharme, Green, Baines, Bainbridge, & O'Brien, 2001). This is an important distinction when trying to identify and interpret data sources for this assessment. The definition of recreational hunting used here encompasses all forms of hunting where the primary purpose is not subsistence or the commercial harvest of animals.

The term "trophy" hunting is a non-technical label that has been used for hunting practices where one of the end products is a photograph and/or the preservation of the whole or part of the hunted animal (i.e., a "trophy'). Within the context of recreational hunting, trophy hunting is often used for hunting practices where client hunters pay high prices to shoot particular species or individuals with particular attributes, e.g., large horns. There are therefore certain ecological, social and economic considerations that differ from other forms of recreational hunting.

There is a large amount of academic literature on the sustainability of recreational hunting and active management strategies for maintaining this practice. However, only a limited number of these studies contain well-argued, data-driven evidence. A recent assessment of recreational hunting (Di Minin *et al.*, 2021), using a similar protocol to IPBES assessments, identified 1342 relevant references but still concluded that "despite the extensive literature on recreational hunting, the evidence to address some of the most pressing academic and societal questions is still limited". Crucially, this included a paucity of evidence on critical policy relevant questions about when recreational hunting is sustainable and who benefits from it. One consequence of the limited information is that conclusions often reflect the value system, community status ("outsiders" *versus* "locals"), and professional background of the authors (Houdt *et al.*, 2021; Mkono, 2019; Nordbø, Turdumambetov, & Gulcan, 2018). Despite the limitations of the available literature and the challenges with assessing recreational hunting as a form of sustainable use, some of the key points raised in the literature are discussed further in this section.

The section first outlines differences in approaches across IPBES geographic regions and then examines evidence for various aspects relating to the sustainability of recreational hunting.

An overview of recreational hunting across IPBES regions

There is no global database of countries where recreational hunting occurs but several sources indicate that it is widespread. Species assessed for the International Union for Conservation of Nature Red List, and where sport hunting has been identified as a use, come from all major IPBES regions. Academic studies of recreational hunting have been conducted in 147 countries (Di Minin *et al.*, 2021) indicating that the practice takes place in a large number of countries spread across all IPBES regions.

There is considerable variation in the way that recreational hunting is governed and administered in different regions, especially relating to whether recreational hunting is allowed, whether it is regulated, who owns the wild species (government or private), who owns the land where the hunt takes place (private, public or communal lands), who can hunt (residents vs foreigners), how the hunt is managed (with an outfitter or community involvement), whether the use is purely personal or the hunted animal can be sold, who issues the licenses, whether there are bags or quotas for target species, what monitoring systems are in place, and whether the revenue from hunting is retained by landowners. These factors all have important implications for assessing sustainable use. It is not possible to provide a detailed analysis for all countries but some of the major aspects relating to each IPBES region are presented below.

AMERICAS

There are important policy differences regarding recreational hunting across the Americas. The practice is mostly not encouraged in Central and South American countries and legislation to prohibit recreational hunting exists in at least Colombia, Costa Rica and Brazil. Some South American countries allow recreational hunting of introduced animals (Argentina) and recreational hunting has been recorded as a use for at least 39 species of birds and mammals endemic to the region (IUCN Red List 2021). Despite prohibitions on recreational and other forms of hunting in South America, it is regarded as widespread and under-researched (Petriello & Stronza, 2020). An analysis of online videos showed that recreational hunting occurs frequently in Brazil (El Bizri, Morcatty, Lima, & Valsecchi, 2015) and is regarded as a part of local culture (Bragagnolo *et al.*, 2019).

In contrast, recreational hunting of wild animals is allowed in Canada, United States of America and Mexico where there also are active communities of hunters. In Canada there are an estimated 1.3 million hunters (Conference Board of Canada, 2018) whereas in the United States of America there were 11.5 million hunters in 2016, down from 37.8 million in 2001 (U.S. Department of the Interior, 2017). Recreational hunting occurs across large parts of Canada and the United States of America where the practice is allowed on private and public lands. The United States of America Department of Interior noted that hunting was permitted in “76 areas managed by the National Park Service, 336 national wild species refuges and 36 wetland management districts managed by the United States of America Fish and Wildlife Service, and over 220 million acres (890 000 km^2) of managed public lands” (U.S. Department of the Interior, 2017).

In the United States of America, regulated recreational hunting has been an integral part of the North American model of wild species conservation, providing social and political support as well as financing for wild species management activities (Arnett & Southwick, 2015; P. Mahoney & Geist, 2019). The early phase of North American wild species management concerned halting and reversing wild species decline, but more latterly the focus has been to manage populations within a ‘social carrying capacity’ (Heffelfinger, Geist, & Wishart, 2013). Wild species in the United States of America “owned” by state governments and hunting, are administered by State Fish and Wildlife Departments on both public and private land. However, it is estimated that >60% of hunting days occur on private land, which can present challenges in prescribing the legal relationships between publicly owned wild species and privately owned land (Freyfogle & Goble, 2019). The financing, management and governance of this land is under-studied (Poudyal, Bowker, Green, & Tarrant, 2012). Hunting is generally open to residents, with low priced hunting tags providing access to most prospective hunters. The sale of wild species meat and other products is illegal, and exchange is usually personal. Hunting revenues form part of a publicly managed and funded system where part of the budgets for all fifty State Fish and Wildlife Agencies is derived from user fees, including hunting and fishing licenses and federal excise taxes on hunting/fishing equipment (Arnett & Southwick, 2015). Through the Pittman-Robertson Act (Federal Aid in Wildlife Restoration Act of 1937), there is an 11 percent excise tax on the sale of firearms and ammunition products. The funding paid into the Wildlife Restoration Trust Fund provided an average of 751 million United States dollars annually from financial year 2012 to 2018 (P. Mahoney & Geist, 2019). Total expenditures on hunting decreased from 36.1 billion United States dollars in 2011 to 26.2 billion United States dollars in 2016, in line with declines in the number of hunters (U.S. Fish and Wildlife Service, 2016).

AFRICA

Africa is the only continent that retains its full spectrum of Pleistocene wild species (Ripple *et al.*, 2015) but there are substantial differences across Africa in the abundance of wild species, the way that wild species is managed, whether hunting is allowed, and the conditions regulating recreational hunting. Recreational hunting is not permitted in Kenya whereas it is allowed in many other African countries. Recreational hunting is recorded as a use for at least 90 species of mammals and birds across Africa (IUCN Red List 2021), and recreational hunting opportunities are advertised on the internet for at least nine countries in Southern, East and West Africa.

In African countries where recreational hunting is allowed, large areas of land may be managed partially or exclusively for hunting, especially for high paying clients. The area managed for recreational hunting, or where recreational hunting occurs, comprises as much as 26% in some countries, e.g., Tanzania (Di Minin, Leader-Williams, & Bradshaw, 2016) and has been estimated to be 1,394,000 km^2 for all of Africa (Lindsey, Roulet, & Romañach, 2007) and separately as 140 000-170 000 km^2 in South Africa (Taylor, Lindsey, Nicholson, Relton, & Davies-Mostert, 2020) and 288 000 km^2 in Namibia (Lindsey, 2011). The revenues from hunting have been estimated at 217 million United States dollars per year for seven Southern African countries (Di Minin *et al.*, 2016) and these revenues have been credited with funding ‘rewilding’ of commercial and communal farmlands in some Southern African countries where land conversion has been reversed or avoided by allowing regulated hunting and other uses of wild species (Child, 2019; P. Lindsey, 2011; W. A. Taylor *et al.*, 2020). In the case of South Africa, hunting is estimated to contribute 64% of income on lands that are managed for wild species compared to live sales (28%) and nature-basted tourism (8%) (DEA, 2015).

Several park agencies in Africa are at least partially funded by hunting revenues, although the percentage of revenues used to fund conservation agencies may be considerably less than what accrues to private companies managing recreational hunting (Di Minin *et al.*, 2016).

EUROPE AND CENTRAL ASIA

Hunting is an integral part of the cultures and traditions of European rural society and there are estimated to be over 7 million hunters across the continent (Brainerd, 2007). The governance of hunting is often situated within the broader context of biodiversity conservation and recognizes that Europe is a biocultural system with blurred boundaries between nature and culture and wild and domestic systems (John D. C. Linnell, 2015).

Some form of recreational hunting has been recorded as a use for at least 88 species of mammals and birds from across Europe (IUCN Red List 2021). In terms of European Union legislation, 82 species of birds are allowed to be hunted in the European Union (Hirschfeld, Attard, & Scott, 2019) and 13 species of mammals and seven birds have been regularly recorded in hunting bags from Central Europe (Reimoser & Reimoser, 2016). Some species such as Red deer have been valued game species for millennia (John D. C. Linnell, 2015). The recorded volumes of animals hunted every year varies from a few individuals to several million: in the bags from nine countries in Central Europe, six species comprised >100 000 individuals and wild boar exceeded one million per annum (Reimoser & Reimoser, 2016); the estimated bags for birds across Europe was 52 million (Hirschfeld *et al.*, 2019) per year. The trend in some countries is for hunting of fewer species but for an overall increase in the biomass of hunted animals **(Figure 3.48)**.

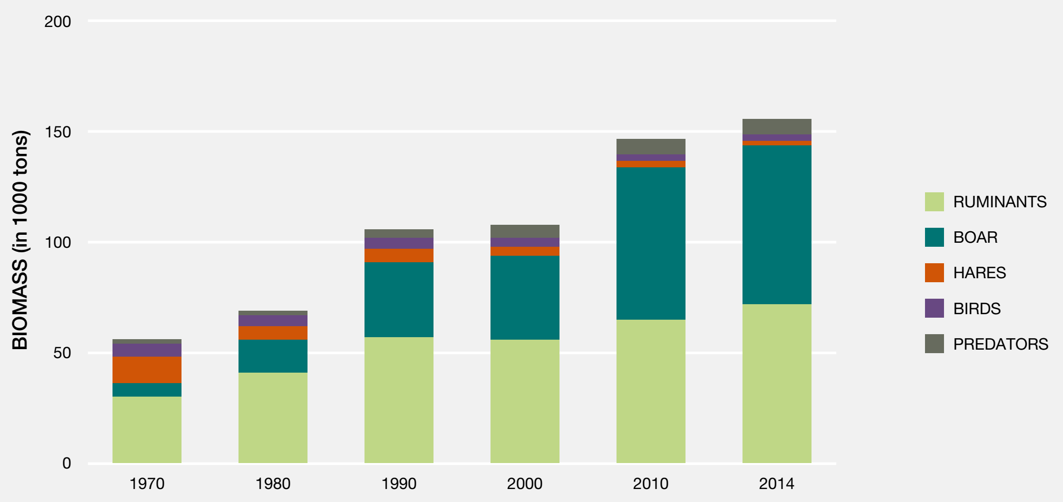


Figure 3 48 **Composition of harvested biomass (for nine European countries) in 1000 tons.**

Source: (Reimoser & Reimoser, 2016) under license CC BY 4.0.

The increase in biomass could be explained by the increase in the number of harvested ungulates which amount to approximatively 7 million every year (Linnell *et al.*, 2020). Hunting of large carnivores may also be allowed with the aim of reducing human-wildlife conflict, maintaining stable populations, and building public support for carnivores.

Despite the apparent increase in hunting bags of some species over the past 120 years (Reimoser 2014) populations of wild ungulates have increased across Europe (Linnell *et al.*, 2020) and this has also facilitated the recovery of large carnivores (Linnell *et al.*, 2020; Popescu, Artelle, Pop, Manolache, & Rozylowicz, 2016). Wildlife populations have tended to increase in Eastern Europe since 1990, especially in countries with reforms on the management of land and wild species (Bragina *et al.*, 2018). Hunters in Europe have been credited with providing monitoring data that supplements other forms of citizen science for wild species monitoring in 32 European countries (Cretois, Linnell, Grainger, Nilsen, & Rød, 2020).

There is also a long history of hunting and use of wild animals by people in Central Asia. The professional hunting economy that existed up to the 1950s gradually disappeared and was replaced by a growing number of amateur hunters. During the Soviet period, strict protected areas were imposed and some species were recovered through hunting bans (e.g., the nearly extinct saiga population). Hunting was controlled by central authorities. However, dramatic habitat loss and over-exploitation of wild species outside protected areas increased the threat to ungulates and other wild species, especially when trade liberalization after the Soviet era coincided with economic hardships and the weakening of state controls and capacities (Damm G.R., 2008). Unregulated hunting of species like markhor, combined with widespread and unregulated use of wild species for multiple purposes, has resulted in unsustainable use where poaching and sale of game meat became normal, and ungulates were reduced by poaching and rapidly increasing livestock populations (Blank & Li, 2021). The hunting sector is generally managed by government organizations through a permit system and wild species ownership remains centralized. This has replaced ancient kin-related ownership of hunting grounds, and some of the challenges associated with sustainable use of wild species have been ascribed to the lack of enforcement by state agencies and the loss of local systems of control (Blank & Li, 2021).

ASIA-PACIFIC

There is limited information on recreational hunting in Asia and the Pacific although it is recorded as a use for at least 100 resident or migratory mammal and bird species across all subregions (IUCN Red List 2021). The number of recorded scientific studies of recreational hunting is very low across the region, particularly for South Asia and Southeast Asia (with fewer than 10 publications) and to a slightly lesser extent for Northeast Asia and Oceania (Di Minin *et al.*, 2021). Recreational hunting in New Zealand and Australia focuses primarily on introduced or feral populations. New Zealand has hunting zones specifically set aside for recreational hunting.

Recreational hunting and sustainable use

Several studies have pointed out that an assessment of sustainable use needs to consider the social (including institutional and economic) and ecological factors affecting sustainable use (Fischer *et al.*, 2013), and be aware that sustainable use relating to recreational hunting is highly context specific (Di Minin *et al.*, 2021) **(Figure 3.49)**. This section examines evidence relating to the ecological, social and economic dimensions of sustainable use as it relates to recreational hunting.

Ecological aspects of sustainable use

The ecological and biological metrics used to assess sustainable use vary considerably but typically include the impact on population numbers. For bird and mammal species assessed for the International Union for Conservation of Nature Red List, and where sport hunting is identified as a use, 51% (n=620) have a declining population trend (IUCN Red List 2021). This implies that recreational hunting may not be biologically sustainable for these species. However, there are several limitations to the use of Red List data at the species level which would affect this conclusion. First, almost all the assessed species are subjected to multiple threats across different sites of which recreational hunting may only be a minor threat or a threat in only some areas of its range, so it is important to understand the context in which recreational hunting occurs. Second, the same species can be subjected to subsistence, commercial and recreational hunting and it is often not possible to disaggregate the effects of these different types of hunting.

An analysis of >1000 publications specifically focusing on recreational hunting (Di Minin *et al.*, 2021), identified 35 species that had been studied across multiple sites and these data provide a better understanding of population trends across sites. The results showed that only one species declined consistently across all sites, 11 (33%) species showed population declines in some sites but not others, and 23 (66%) species showed no decline or the results were inconclusive. These results highlight the extent of variation between sites. The study noted the geographical and taxonomic bias in published results with most of the studies focusing on a small number of mammal species mostly in Africa and North America. The paucity of evidence for many species and across other IPBES regions is important because the International Union for Conservation

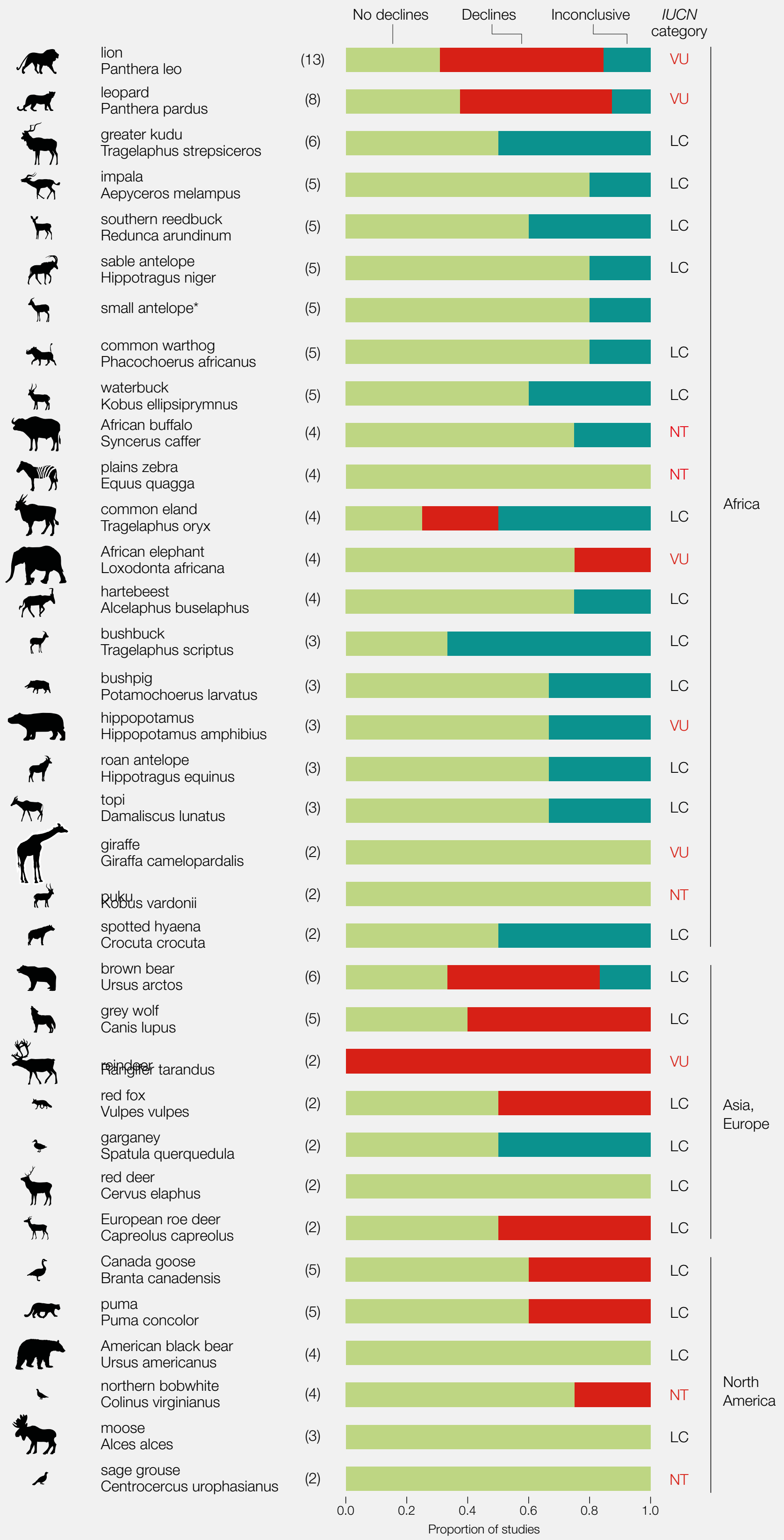


Figure 3 49 **Impact of recreational hunting on the population abundance of targeted species.**

Depicted is the proportion of studies that found inconclusive evidence, evidence of population declines, or evidence of no population declines. Number of studies is indicated in parentheses next to species name; only species included in more than one study are included. Abbreviations: LC: Least Concern; VU: Vulnerable; NT: Near Threatened. *Small antelope refers to steenbok Raphicerus campestris, oribi Ourebia ourebi, grysbok Raphicerus sharpei, duiker Cephalophus sp. or Sylvicapra grimmia, and dik-dik Madoqua kirkii. Source: (Di Minin *et al.*, 2021) under license CC BY-NC-ND 4.0.

Table 3 13 **Examples of populations of wild mammals that have recovered in areas where hunting management is in place even though global trends may be decreasing.**

(this does not mean there is an absence of continued threats)

Species name or taxonomic group	International Union for Conservation of Nature species status & global trends	Region or country	References
Black rhino *(Diceros bicornis)*	CR -Critically Endangered, increasing	Africa	(Challender & Cooney, 2016; CITES, 2019; Rosie Cooney *et al.*, 2017; NACSO, 2019)
White rhino *(Ceratotherium simum)*	NT – Near Threatened, decreasing	Africa	(Challender & Cooney, 2016; CITES, 2019; Rosie Cooney *et al.*, 2017; NACSO, 2019)
African lion *(Panthera leo)*	VU – Vulnerable, decreasing	Africa	(P. Lindsey, Balme, *et al.*, 2012; NACSO, 2019; Whitman, Starfield, Quadling, & Packer, 2004)
Different deer species (*Cervus* **spp.)**	LC – least concern, increasing	Europe (e.g., Germany), United States of America, Canada, Russia	(J D C Linnell *et al.*, 2020; Mustin, Newey, Irvine, Arroyo, & Redpath, 2012; Reimoser & Reimoser, 2016)
Bighorn sheep *(Ovis canadensis)*	LC – least concern, increasing	North America and Mexico	(Challender & Cooney, 2016)
Markhor *(Capra falconeri)*	NT – near threatened, increasing	Asia	(Rosie Cooney *et al.*, 2017)
Argali *(Ovis ammon)*	NT – near threatened, decreasing	Asia	(Rosie Cooney *et al.*, 2017)
Urial *(Ovis orientalis)*	VU – vulnerable, decreasing	Asia	(Rosie Cooney *et al.*, 2017)
Grey wolf *(Canis lupus)*	LC – least concern, stable	Some European countries	(Epstein, 2017)
Waterfowl	LC – least concern	North America	(M. G. Anderson & Padding, 2015; Hirschfeld *et al.*, 2019; P. Mahoney & Geist, 2019; Mustin *et al.*, 2012; Reimoser & Reimoser, 2016)
Mallard *(Anas platyrhynchos)*	LC – least concern, increasing	Europe, North America	(P. Mahoney & Geist, 2019; J. D. Nichols, Runge, Johnson, & Williams, 2007)
Greater white-fronted goose *(Anser albifrons)*	LC – least concern, unknown	Europe	(Hirschfeld *et al.*, 2019)
Phasianids e.g., black grouse *(Lyrurus tetrix)*	LC – least concern, decreasing	Europe	(Hirschfeld *et al.*, 2019)
Red-legged partridge *(Alectoris rufa)*	LC – least concern, decreasing	Europe	(Hirschfeld *et al.*, 2019)
Wild turkey *(Meleagris gallopavo)*	LC – least concern, increasing	North America	(Hirschfeld *et al.*, 2019)
European bison *(Bison bonasus)*	VU – vulnerable, increasing	Belarus	((Артеага В., 2019)
White-lipped peccary *(Tayassu pecari)*	VU – vulnerable, decreasing	South America	(Bodmer & Lozano, 2001)
Collared peccary *(Pecari tajacu)*	LC – least concern, stable	South America	(Bodmer & Lozano, 2001)
Paca *(Agouti paca)*	LC – least concern, stable	South America	(Bodmer & Lozano, 2001)
Agouti *(Dasyprocta fuliginosa)*	LC – least concern, stable	South America	(Bodmer & Lozano, 2001)
Polar bear *(Ursus maritimus)*	VU – vulnerable, decreasing	Canada	(Foote & Wenzel, 2009)
American alligator *(Alligator mississippiensis)*	LC – least concern, increasing/stable	United States of America	(Ruth Elsey, Woodward, & Sergio Balaguera-Reina, 2018)

of Nature Red List indicates that many more species across other IPBES regions are used for recreational hunting but there is no additional information to assess sustainable use of these species.

For those species that have been more intensively studied, there is evidence that mammalian game species with high reproduction rates, such as roe deer and wild boar, can tolerate more intensive exploitation and still maintain population numbers and structure as well as genetic diversity (Baldus, Damm, & Wollscheid, 2008; Challender & Cooney, 2016; J D C Linnell *et al.*, 2020; Loveridge, Reynolds, & Milner-Gulland, 2006; Tapper & Reynolds, 1996). As an example, populations of roe deer (Europe) and white-tailed deer (North America) have increased their range and density despite the intended use of hunting to reduce density-related human conflicts (Morellet *et al.*, 2007).

The evidence also shows that some populations of threatened species and those with low regeneration capacity have increased in numbers in systems where hunting is well managed **(Table 3.13)**. Attempts to combine hunting with the effective management and conservation of such species, has taken place in several IPBES regions. Note that the examples provided in **Table 3.13** apply only to the particular populations that were assessed, and not for the species generally.

In contrast, there is also evidence for populations where poorly regulated hunting is not sustainable and has contributed to local population declines that have reduced the number of animals that can be harvested sustainably, for example, some populations of lions and elephants in Africa (Fischer *et al.*, 2013; IUCN, 2016; Loveridge *et al.*, 2016; Mweetwa *et al.*, 2018; Packer *et al.*, 2009), brown bears in Northern Europe (Frank *et al.*, 2017), ungulates and Snow leopards in Asia (Rashid, Shi, Rahim, Dong, & Sultan, 2020).

Operationally, sound biological management is contingent on appropriate institutional, social and economic conditions. Scientists argue that biological sustainability of recreational hunting is highly connected with the proper regulation of the hunting system, including regular monitoring and adaptive management responses that adjust offtake to changes in population size (M. G. Anderson & Padding, 2015; Damm G.R., 2008; P. Mahoney & Geist, 2019; Souchay, Besnard, Perrot, Jakob, & Ponce, 2018). While these factors are important, they can also be achieved through local control and knowledge, and simple adaptive management systems (Goredema, Taylor, Bond, & Vermeulen, 2005). Some of the instances of unsustainable use have been associated with weak tenure, the centralization of revenues derived from hunting (Child, 2019) and breakdown of community governance without any effective replacement by state officials (Blank & Li, 2021).

Beyond population numbers, scholars have identified other biological and ecological issues that should be considered in the assessment of the sustainable use of recreational hunting. These include the indirect effects of hunting, which are often poorly known and therefore make it difficult or impossible to fully assess biological sustainability (for example Artelle *et al.*, 2018; Frank *et al.*, 2017; Macdonald *et al.*, 2017; M. N. Peterson & Nelson, 2017; Popescu *et al.*, 2016; Swenson *et al.*, 2017). In addition, all forms of hunting can have evolutionary and behavioral consequences for the target species, affect food chains, or alter herbivory, predation and other ecological processes (Fukushima *et al.*, 2020; Leclerc, Frank, Zedrosser, Swenson, & Pelletier, 2017). Selective harvesting of animals with particularly desirable phenotypes can also alter the distribution of traits in a population (Allen, Brent, Motsentwa, Weiss, & Croft, 2020; Coltman *et al.*, 2003; Crosmary *et al.*, 2013; Knell & Martínez-Ruiz, 2017; Milner, Nilsen, & Andreassen, 2007; Russo *et al.*, 2019; Wielgus, Morrison, Cooley, & Maletzke, 2013). Features such as body size or horn shape and size, may be linked to other fitness-related attributes, including physiological tolerances or disease resistance (Crosmary *et al.*, 2013; Knell & Martínez-Ruiz, 2017; Russo *et al.*, 2019).

Although these are important issues, the nature of available studies means that is not possible to make any firm conclusions regarding sustainable use based on these parameters (Di Minin *et al.*, 2021).

Social sustainability

Humans control their use of resources through formal or informal rules or institutions. The literature suggests that the primary variable affecting the sustainability or otherwise of recreational hunting is the governance of hunting systems (Cooney, 2017) and the quality and social legitimacy of relevant institutions (Fischer *et al.*, 2013). Analysis of a global dataset of utilized populations (not just for hunting) showed that utilized species declined more rapidly than unutilized species, but that where management systems were in place there was a positive impact on trends (McRae *et al.*, 2022). This broad analysis did not include institutional quality as an independent variable, and it is not possible to disaggregate the data for utilization under controlled *versus* open-access conditions, so it is not possible to assess the impact of management in more detail.

In an analysis of sustainable use, (AFischer *et al.*, 2013) fix citation format identified two aspects of institutional misfit that affect sustainability of recreational hunting: (i) conflicts between the functions of hunting as defined by the government and functions identified by local communities; and (ii) ecological functions embedded in formal institutions generated by non-local actors that are developed separately from, and in conflict with, the local institutions guiding the social and economic functions of hunting and land use more generally. One of the hypotheses is that hunting and the management of wild species become unsustainable when they are under-policed as open access resources and where wild species-based livelihoods are deinstitutionalized by land-use policies that favor agriculture farming (Bowles & Choi, 2013). These ideas have not been widely tested in hunting systems.

Legal, well-regulated recreational hunting has been shown in specific instances to play an important role in delivering benefits for both wild species conservation and for the livelihoods and well-being of indigenous and local communities living with wild species (Baldus *et al.*, 2008; Eklund T., 2017; C. Fischer, 2010). Investments from revenues generated through hunting on community conservancies have been used to improve local services such as water infrastructure, schools and health clinics, as well as providing meat for community members (IUCN, 2016; Naidoo, Weaver, *et al.*, 2016). Nevertheless, the evidence regarding these benefits across all areas where recreational hunting occurs is lacking.

Economic aspects of sustainable use

The economic literature on recreational hunting, specifically the generation and allocation of financial flows, tends to concentrate on two separate policy relevant questions. At a national level, total economic value is important because national policy makers are interested in economic growth, jobs and taxes and the revenue from hunting can therefore influence broader policy decisions affecting the sustainable use of wild species. At a local level, the policy question is whether the proportion of the value chain captured by the manager of land on which wild species occur is sufficient to enable reinvestment in the supply and management of wild species.

Recreational hunting has been considered an important economic activity by various scholars and stakeholders where it is credited with generating revenues and creating jobs in the land management and hospitality sector, as well as providing income and other important economic and social benefits to indigenous and local people in rural, remote and/or otherwise marginal areas (Conference Board of Canada, 2018; R. Cooney, 2017; Di Minin *et al.*, 2016; Sánchez-García *et al.*, 2021). Economic impacts of recreational hunting can be measured in terms of gross output (revenue), sales, income, employment or value-added benefits, and a summary of the data is provided in **Table 3.14**. While these measures are not always comparable, the table provides an indication of economic values.

Prices paid for hunts vary from hundreds to hundreds of thousands of United States dollars **(Table 3.15)**, and globally create a substantial revenue flow from developed

Table 3 14 **Hunting economic output.**

Abbreviations: OECD: Organization for Economic Cooperation and Development, EUR: euros, USD: United States Dollars.

Country	Gross revenues	People employed	Number of hunters	Reference
Finland	EUR 0,23 billion	100	304,245	Bioeconomy.fi, 2017)
Sweden	The annual gross hunting value is estimated to be in the neighborhood of USD 460 million	More than 12,000	300,000	(Mattsson, 2008; Mensah & Elofsson, 2017)
Austria	EUR 0,475 billion	More than 157 thousand	123,283	OECD.stat 2019
France	EUR 3,6 billion	25,800	150-200	(P. A. Lindsey et al., 2007)
Germany	EUR 1,6 billion	More than 617 thousand	368,664	OECD.stat 2019
United Kingdom	EUR 3,2-5,5 billions	12,000-74,000	600,000	(Mensah & Elofsson, 2017)
United States of America	USD 7,978,472 million	57,251,937	11,500,000	(U.S. Fish and Wildlife Service, 2016)
Russia	USD 518 million	More than 5587 thousand	2.8 million	(Braden, 2014)
South Africa	EUR 0,341 billion	17,000	76000	(Saayman, van der Merwe, & Saayman, 2018)
South Africa (“trophy” hunting alone)	USD 181 million			(Snyman *et al.*, 2021)
Canada	USD 13,2 billion	107,000	More than 50,000	(The Economic Footprint of Angling, Hunting, Trapping and Sport Shooting in Canada, 2019)
Sub-Saharan Africa	at least USD 201 million per year	More than 150,000	More than 100,000	(Di Minin *et al.*, 2016)

Table 3 15 **Indicative information on the species hunted, the number of individuals and the costs of trophy hunts in different countries.**

Abbreviations: DKK: Danish Krone, EUR: euros, USD: United Staes Dollars.

Country	Main hunted species	Individuals hunted/year	Cost of the trophy	Reference
United States of America	Deer, wild turkey, elk	More than 6 million	USD 2,659	(Bergstrom, 2008; Munn, Hussain, Spurlock, & Henderson, 2010)
Finland	Moose	49,667		(Bioeconomy.fi, 2017)
Kyrgyzstan	Snow leopard	Average of 25	EUR 7,000-10,000	(Eklund T., 2017)
Middle Europe	Red deer	-	EUR 10,000-15,000	(Bioeconomy.fi, 2017)
United Kingdom of Denmark	Red deer	Approx. 25,000 red-deer	DKK 7,000-25,000	(Bioeconomy.fi, 2017)
Germany	Red deer	9-12	EUR 1,000 without antlers, up to 5,000 with antlers	(Bioeconomy.fi, 2017)
Zambia	Lechwe, Hippopotamus, Leopard	300		Science Direct/Statista Charts, (P. Lindsey, Balme, *et al.*, 2012)
Tanzania	Leopard, Hippopotamus, Elephant	7034		Science Direct/Statista Charts, (P. A. Lindsey *et al.*, 2007)
Botswana	Elephant, Leopard, Lechwe	2500		Science Direct/Statista Charts, (P. A. Lindsey *et al.*, 2007)
South Africa	Impala, Warthog Kudu	53,885		Science Direct/Statista Charts, (P. A. Lindsey *et al.*, 2007)
Zimbabwe	Elephant, Leopard, Chacma Baboon	11,318		Science Direct/Statista Charts, Lindsey *et al.*, 2012(P. A. Lindsey *et al.*, 2007)
Mozambique	Crocodile Elephant	900		Science Direct/Statista Charts International (Sheikh & Bermejo, 2019)
Namibia	Zebra, Chacma Baboon, Leopard	22,462		(P. Lindsey, Balme, *et al.*, 2012; Sheikh, Bermejo, & Procita, 2019)

to developing countries, as well as from urban to rural areas within countries (Booth, 2010; Di Minin *et al.*, 2016; IUCN, 2016; Sánchez-García *et al.*, 2021). Besides spending money on hunting equipment, guns, ammunition, transportation, clothing, and meat processing, hunters typically also spend large amounts of money on permits, guide and outfitting services and travel (Lindsey *et al.*, 2007; U.S. Fish and Wildlife Service, 2016), contributing to the economies of the areas where this practice occurs, for example, on communal conservancies in Namibia (NACSO, 2015; NACSO & MET, 2018; Schmitt & Rempel, 2019).

From a production perspective, recreational hunting is regarded by scholars in this area as different from other forms of harvesting. First, the commodity value is only one of many values which collectively exceed the value of the raw commodity. Second, the process of hunting is considered a benefit to the production system, whereas with harvesting it is a production cost (Child, 2019). This is expected to give the multi-value approach to managing lands for wild species use, including recreational hunting, an economic comparative advantage over simple commodity production, and therefore provides an avenue to keep natural lands intact (Child, 2019). However, these economic advantages may not be realized due to the tendency to associate property rights with domestic species but not wild ones (Bowles and Choi 2013). It should be noted that this perspective also focuses on recreational hunting in comparison with other more commercial activities such as production forestry. It is not meant to be a direct comparison with the wide range of practices reported on in other parts of section 3.3.

Large areas of land are managed for the production of recreational hunting. For all of Africa, this was calculated as 1 394 000 km^2 (Lindsey *et al.*, 2007), which includes 288 000 km^2 of freehold land in Namibia (Lindsey, 2011) and between 170 000 and 205 000 km^2 (14-17% of total land area) in South Africa (Taylor *et al.*, 2020). Figures for other areas comprise at least 890 300 km^2 in the United States of America (Bureau of land management areas, US Dept of Interior 2017) and 1 780 km^2 managed as Recreational Hunting Areas in New Zealand (Fraser & Department of Conservation, 2000), noting that in New Zealand these areas are designated for hunting introduced land mammals and that larger areas were designated for commercial hunting.

The key species that generate the largest proportion of income through recreational hunting tourism in Africa are: elephants in Mozambique, Namibia and Zimbabwe, African buffalo in Tanzania, and sable antelopes *(Hippotragus niger)* in Zambia (P. A. Lindsey *et al.*, 2007). With the exception of rhinoceroses (*Ceratotherium simum* and *Diceros bicornis*) in Namibia and South Africa, and exceptionally large elephant trophies, lions generate the highest revenue per hunt (24,000–71,000 United States dollars) of any species in Africa **(Figure 3.50)**. Prices for lion hunts have been particularly high in Tanzania, and were also high in Botswana prior a hunting moratorium placed in that country (up to 140,000 United States dollars per hunt) (Lindsey *et al.*, 2012).

Legal, well-regulated recreational hunting can therefore support conservation by contributing to the preservation of the target species and the habitat in which it lives (Baldus *et al.*, 2008; Eklund T., 2017; Fischer *et al.*, 2013) (for discussion of this form of management as a driver of sustainable use, please refer to Chapter 4).

For emotional and ideological reasons hunting is often excluded as an option for income generation by international conservation non-governmental organizations and certain international funders. Some species are indeed so rare, endangered or sensitive that they are not suitable for even strictly managed and regulated hunting use. However, if wild species and protected areas are not successful resources and options for alleviating poverty, conservation efforts could be undermined. Total protection and trade bans can lead to a major devaluing of wild species because there are no longer economic incentives to protect them (Baldus *et al.*, 2008; Rosie Cooney *et al.*, 2017; NACSO, 2019). For example, it was estimated that if lion hunting were banned, areas across Southern Africa and outside of national parks (approximately 59,500 km^2) currently set aside for lion

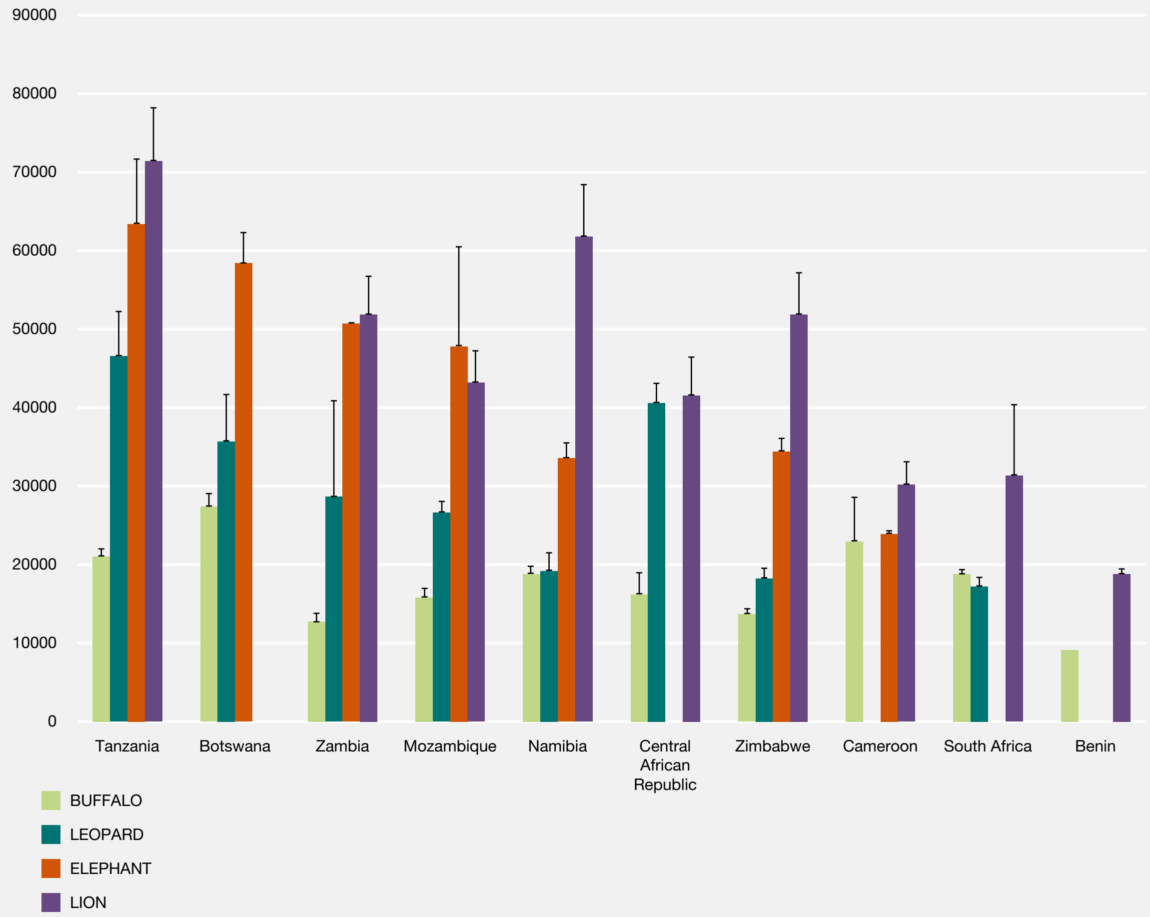


Figure 3 50 **Mean price for the cheapest trophy hunting packages (daily rates and trophy fees) for each of four key species.**

Source: (Lindsey, Balme, *et al.*, 2012) under license CC BY 4.0.

habitat could be converted to other uses such as agriculture (P. Lindsey, Balme, *et al.*, 2012). It is unlikely these areas would be incorporated into existing protected parks due to lack of funding (P. Lindsey, Balme, *et al.*, 2012).

Canned hunting

"Canned hunting" is a non-technical label that refers to the practice of placing captive-bred, semi-domesticated, and exotic animals within relatively restricted outdoor enclosures for the sole purpose of having the animals "hunted" and killed by paying clients (Graves, Mosman, & Rogers, 2012). "Canned hunting" represents a very small proportion of world hunting (IUCN, 2016) and is not a conservation strategy (Bilchitz, 2016; Williams, Loveridge, Newton, & Macdonald, 2017; G. C. Young, 2007). The practice has resulted in negative environmental and political consequences relating to recreational hunting and is regarded as a potential source of zoonotic diseases (HSI/HSUS, 2016; P. Lindsey, Alexander, *et al.*, 2012; D. W. Macdonald & Willis, 2013; Organ, Decker, & Lama, 2016; Somers & Hayward, 2012; B. K. Williams, Johnson, & Wilkins, 1996).

This is a highly contentious practice but mainly involves animals that are bred in captivity and therefore does not fall under the definition of wild species used in this assessment. In scientific and policy analyses, canned hunting needs to be separated from "ranched" wild species production, which involves the management of wild populations across extensive areas. In 2004 the World Conservation Congress, noting strong opposition to all forms of "canned hunting", accepted that well-managed recreational hunting has a role in the managed sustainable extractive use of wild species, and condemned the killing of animals in small enclosures where they have little or no chance of escape or where they do not exist as free ranging (IUCN, 2004). The International Union for Conservation of Nature encouraged the media and decision-makers to distinguish between canned hunting of confined animals and trophy hunting of free-ranging animals (IUCN, 2016).

3.3.3.2.5 Science and education

Scientific gathering is a tightly regulated and highly controlled activity. It brings benefits to conservation, management and science, can help diagnose or monitor the health of a population, species, or ecosystem and, as a result, protect certain species of animals from other causes of decline (Remsen, 1995; Sikes & Paul, 2013; Winker *et al.*, 2010). It can also have detrimental effects. Documented cases of decline due to removal of animals for scientific purposes usually involve large vertebrates (Gibbons *et al.*, 2000). For small mammals, responsible specimen gathering and removal have little impact on populations and have several benefits for science (Hope, Sandercock, & Malaney, 2018). However, recent studies indicate that harvest of voucher specimens for bats research is harming fragile populations (Russo *et al.*, 2017). For many invertebrate species, collection for scientific research is fundamentally important for species identification. Currently extraction of wild animals for scientific and educational purposes faces a series of economic and social pressures, including budget cuts and shortfalls (Suarez & Tsutsui, 2004), high harvesting cost (Enrique *et al.*, 2020), ethical considerations and significant and costly compliance procedures like those from the Convention on International Trade in Endangered Species of Wild Fauna and Flora for the cross-border exchange of specimens (Roberts & Solow, 2008).

Systematized repositories of life in all of its forms are cornerstones of quality research and education in many areas of science and innovation (National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Institute for Laboratory Animal Research; Roundtable on Science and Welfare in Laboratory Animal Use, 2019; Winker *et al.*, 2010). Schools, universities, and research laboratories use biological collections to teach concepts of evolution, ecology, taxonomy, physiology, biogeography, conservation, and more. Museum collections, while historically significant, have been greatly reduced by limiting numbers, even if species are common, as financial costs and ethics of maintaining and building these collections have changed. Larger series collected historically have been profoundly important in establishing both presence of absence, and providing evidence on historical population levels. This has been especially important with amphibians (Mahoney & Rueschemeyer, 2003). Biological collections also connect the public to nature and science, bolstering lifelong learning (Graham, Ferrier, Huettman, Moritz, & Peterson, 2004; Hill *et al.*, 2012; MacFadden, 2019; National Academies of Sciences, 2020; Suarez & Tsutsui, 2004). In some cases, digital technologies are able to successfully replace extractive practices for scientific and educational purposes.

In many countries, legislation improves animal welfare by setting minimum standards and currently covers all taxonomic groups of vertebrates and cephalopods. In European Union countries the use of wild animals is largely prohibited (Hartung, 2010). In the United States Institutional Animal Care and Use Committees (IACUC) are based at colleges and universities and follow national standards to conduct evaluations of animal care and use, including ethical and properly implemented care of wild animals by researchers. Permit-granting agencies are also in a position to place severe restrictions on the number of specimens that may be taken by scientists (Remsen, 1995; Russow & Theran, 2003; Silverman, Suckow, & Murthy, 2000). Currently, there is a tendency for reducing animals in experimentation and replacing animals for artificial models or digital simulators (Robinson *et al.*, 2019; Soulsbury *et* *al.*, 2020; Volker D., 2006). The potential harm to animal populations should be balanced with anticipated benefits (Brønstad *et al.*, 2016; Russow & Theran, 2003). Stricter controls can be detrimental to building conservation knowledge (Hochkirch *et al.*, 2021).

The impact on wild populations of scientific extraction of specimens is usually, but not always, small relative to other causes of mortality including natural mortality, hunting, collisions (e.g., road kill, bird death due to glass windows and communication towers, etc.), and habitat loss or alteration (Erickson, Johnson, & Young, 2005; Remsen, 1995; Rocha *et al.*, 2014; Winker *et al.*, 2010). For example, the entire vertebrate specimen collection of Museum Victoria (Australia), houses less than 200,000 specimens harvested within Victoria over the past 150 years (Clemann *et al.*, 2014). In comparison, duck and quail hunters in Victoria are estimated to have killed 638,000 native birds as of 2012 (Moloney & Turnbull, 2012). It should be noted that museum collections, unlike game hunting, aim at covering a much broader biodiversity, and hence may also exploit small, rare, or endangered populations unlikely to be targeted by hunters (Donegan, 2009).

The use of animals in human biomedical research has been of particular focus, more so for ethical considerations than for whether or not extraction of individuals for medical research is a sustainable form of use. Members of the Callitrichidae primate family (marmosets and tamarins) have been used since 1960s as biomedical research subjects because of their small size, wide availability, and relatively inexpensive costs. They are extracted mostly from wild populations in South American countries such as Brazil, Colombia, Peru, and Venezuela. In the 1960s and 1970s the Oak Ridge Associated Universities had the largest tamarin/marmoset population in the United States of America, housing about 550–650 animals (National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Institute for Laboratory Animal Research; Roundtable on Science and Welfare in Laboratory Animal Use, 2019).

Due to the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the export of wild primates for biomedical research from Central and South America decreased significantly from 200,000 in the 1950s and 1960s to 5,000 specimens after 1975 when the Convention on International Trade in Endangered Species of Wild Fauna and Flora was enacted (Fialho, Ludwig, & Valença-Montenegro, 2016). High export levels have led to declines of some species, such as the cotton-top tamarin *(Saguinus oedipus)* (National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Institute for Laboratory Animal Research; Roundtable on Science and Welfare in Laboratory Animal Use, 2019). The cotton-top tamarin, as well as most marmosets and tamarins, are listed under Appendix I of the Convention. Thus, current import controls will favor wild populations, even though it does make it harder for researchers to acquire marmosets (National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Institute for Laboratory Animal Research; Roundtable on Science and Welfare in Laboratory Animal Use, 2019).

Today, marmosets as model organisms are attracting so much research interest that their demand far outstrips the already limited supply. Currently, 10–15 institutions are developing small marmoset colonies (of 20–60 animals each) for neuroscience studies. The growing focus on transgenic work has led to the development of some larger colonies (250–350 animals). If the field continues to grow, some facilities may establish much larger colonies (up to 1,000 animals) for line maintenance and characterization (National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Institute for Laboratory Animal Research; Roundtable on Science and Welfare in Laboratory Animal Use, 2019).

According to the United Nations World Conservation Monitoring Centre and the Convention on International Trade in Endangered Species of Wild Fauna and Flora trade database, reported exports of live macaques (for example, long-tailed macaques for research purposes) from six Southeastern Asian countries were more than 25,000 in 2019. While many animals are bred in captivity for scientific research, there are still significant extractions from wild populations to provide breeding stock. When the illegal trade is factored in (which often relies on legal trade to launder animals into the trade) coupled with unreliable or absent data on wild population numbers, this overall trade may be unsustainable.

The high demand for research animals has resulted in the manipulation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora to ban imports of wild primates and birds into the United States of America and the European Union in order to bolster profit generated through commercial captive breeding programs. This raises all sorts of ethical issues (especially with the Convention on Biological Diversity) about the ability of indigenous and other peoples in range states to use their natural resources for economic development. The *ex situ* commercial captive breeding industry economically favors extinction of wild populations in range states that can potentially compete with them (Kasso & Balakrishnan, 2013).

The second-largest use of amphibians, after food, is for teaching and medical research. Frogs and salamanders are used as model organisms in medical research and are one of the classics for teaching animal biology at universities all over the world (Smith, Wassersug, & Tyler, 2007). The use of amphibians to aid advancing science has led to a number of significant scientific breakthroughs, and several Nobel prizes in physiology or medicine have benefitted from studies involving frogs, the last of which pertain to stem cells in regenerative medicine (Rossant & Mummery, 2012). According to studies on small lizards in Central America, many reptile populations are resilient to standard herpetological gathering (intensive gathering in short-term) (Poe & Armijo, 2014). Current sustainability efforts can potentially focus on reducing and replacing the use of animals in research and teaching with scientific alternatives emerging from innovative education and medical technologies. Using common and widespread species or animals raised in facilities for such activities would promote sustainability (Coleman, Carpenter, & Dunphy, 1996).

The killing of critically endangered birds and reptiles for scientific reference has caused debate and ethical dispute in the last two decades (Collar, 2000; Donegan, 2009). It was argued that the scientific gathering of voucher specimens is linked to the decline or loss of Mexico's elf owl *(Micrathene whitneyi soccorroensis)*, but others ascribe the extinction to invasive species (Minteer, Collins, Love, & Puschendorf, 2014; Rocha *et al.*, 2014).

3.3.3.2.6. Medicine and hygiene

The 2019 version of the International Union for Conservation of Nature Red List reports 1,660 species of animals have medicinal uses. Most known species (~77%) are chordates in terrestrial habitats (~72%). Globally, animals used for medicine comprise a relatively narrow subset of all animals, but they do occur across diverse taxa, habitats, and geographies. At least about 62% (n = 1025) of species have multiple uses. The most common additional use is food for human consumption, which approaches half (~46%, n = 769). Geographic hotspots of medicinal species occur in South America, Southeast Asia, India, and the tropical regions of Africa. Although not previously examined, geographic areas of prominent medicinal use (and threats to their use) likely occur where so-called human development is low (Short & Darimont, 2021).

Across varied geographies, threats to medicinal animals are more closely related to overall ecosystem degradation than human use. Among species with known population trends (n = 839), the highest proportion have a decreasing trend (~63%, n = 525), whereas about 30% (n = 254) are stable, and only about 7% (n = 60) have increasing populations. Primary threats are related to agriculture and aquaculture (~45% of species, n = 143) and biological resource use (~44%, n = 142), which includes exploitation for medicine, food, clothing, and other uses (Short & Darimont, 2021).

There are many examples of surveys that have documented the diversity of animals used in traditional medicine, some are highlighted in the section below.

Species of global interest

Amphibians and reptiles are used in traditional medicine or as part of cultural beliefs all over the world, resulting in harvest of these animals from the wild (Gorzula, 1996; Hocking & Babbitt, 2014; Schlaepfer, Hoover, & Dodd, 2005; UNODC, 2016). Alves *et al.* (2013) found that 331 species (284 reptiles and 47 amphibians) are used as part of traditional folk medicines around the world. The use of secretions, especially those of Bufonids that contains numerous active molecules, is one of the reasons they are desirable (Rodríguez, Rollins-Smith, Ibáñez, Durant-Archibold, & Gutiérrez, 2017). Insects are also used as medicinal resources all over the world (Costa-Neto, 2005).

Pangolins (four species in Asia and four species in Africa) are the most heavily traded wild mammal in the world (UNODC, 2016). Their various body parts, especially their scales, fetuses, blood, bones, and claws are largely used in traditional medicines (Boakye, Pietersen, Kotzé, Dalton, & Jansen, 2014; Mohapatra, Panda, Nair, Acharjyo, & Challender, 2015; Soewu A Durojaye & Sodeinde A Olufemi, 2015). Harvesting of two Asian species of Pangolins is largely driven by demand from China. This, in combination with additional threats related to habitat decline, are affecting the sustainability of use. These species are listed as critically endangered in the International Union for Conservation of Nature Red List (Heinrich *et al.*, 2016). With declining Asian pangolin populations, a shift in trade from Asian to African pangolin species has been suggested. As a result, the total number of incidents involving Asian species declined since 2000, yet they were still being traded in large volumes (more than 17,500 estimated whole Asian pangolins were traded between 2001 to 2014) despite a zero-export quota for commercially traded wild sourced Asian species (Heinrich *et al.*, 2016). The United States of America is also a significant largest importer of pangolins and their products (UNODC, 2016).

EUROPE

The traditional use of animals as a source of medicine is relatively low in Europe. However, Benitez (2011) reported 26 different animals provided 61 distinct medicinal uses in Western Granada Province, Andalusia (Spain). The high number of uses is due to the fact that some animal species are involved in more than one preparation method, sometimes with different parts used.

AFRICA

In Benin, 87 mammal species have been reported as traded for medicinal purposes including some vulnerable, endangered and threatened species (Djagoun, Akpona, Mensah, Nuttman, & Sinsin, 2013). El-Kamali (2000) identified 23 animal species whose products were commercialized for traditional medicine purposes in Central

Figure 3 51 **Word cloud of the use categories derived from species used in animal-based medicine in South Africa.**

The size of the words in the figure is proportional to the number of times the uses were mentioned. Source: (Vivienne Linda Williams & Whiting, 2016) © 2015 Elsevier Ireland Ltd., license number 5153130663118. CC-BY NC.

Sudan. Sodeinde and Soewu (1999) recorded the use of 45 medicinal species in Nigerian markets. Simelane and Kerley (1998) showed that 44 species (eight reptiles, six birds, 30 mammals) were sold in 19 herbalist shops in the Eastern Cape Province of South Africa. Cunningham and Zondi (1991) examined the trade in animals for medicinal uses in KwaZulu-Nata Province and reviewed the literature reports for South Africa, recording at least 79 species of vertebrate (18 reptiles, 16 birds, 45 mammals), excluding domestic mammals and various marine invertebrates and fishes. A total 132 species of vertebrates (21 reptiles, 32 birds, 79 mammals) were reported by Ngwenya (2001) to be traded across KwaZulu-Natal Province, with 50 species highly demanded by the costumers. These were vultures, chacma baboon, green mamba, Southern African python, Nile crocodile, puff adder, striped weasel, and black mamba. Whiting *et al.* (2013) identified 147 vertebrate species that were traded in all South African traditional medicine markets. This represented around 63% of the total number of documented wild species. Recently William *et al.* (2014) reported 354 bird species (from 205 genera, 70 families, and 25 orders) used for traditional medicine in 25 African countries.

In numerous societies of Western and Central Africa, body parts of great apes (chimpanzee, gorilla, bonobo) are used for medicinal and/or ritual purposes. These practices usually operate according to the principle of analogy: the quality and value of the foodstuff is incorporated by the person who ingests it (Epelboin, 2012; Leblan, 2017). For instance, in Guinea, consuming the right arm of a chimpanzee will protect children from disease and make them good hunters, because monkeys are considered as violent and powerful beings (Leblan, personal observation). Scientists point out the unsustainability of such practices and the need for conservation strategies (Sá, da Silva, Sousa, & Minhós, 2012 on Guinea-Bissau). However, given the widespread interest in these species, it is also a matter of global debate.

Williams and Whiting (2016) reported 301 uses of animal parts for 122 broad-use categories **(Figure 3.51)** across South Africa. They used a word cloud to report their findings for visual impact. Although the study was conducted in South Africa, the categories of uses reported paint a picture of the health needs of the consumers of animal-based medicine elsewhere. 'Strength' (e.g., home strength, imbuing physical strength and overcoming fear) stands out as a dominant use, followed by protection to ward off evil spirits from within a person or from their residence.

LATIN AMERICA

A recent literature review on animal-based medicine recorded at least 584 wild species (13 taxonomic categories) as being used in the entire continent of Latin America (R. R. N. Alves, Rosa, Albuquerque, & Cunningham, 2013). The authors even speculated that this number might be underestimated given the limited number of studies on the theme, highlighting the conservation implications of the wild species use in medicine. Surveys carried out in 15 Brazilian cities reported that at least 180 animal species are traded for medicinal purposes (R. R. N. Alves & Rosa, 2010). In the State of Bahia, in Northeast Brazil, 50 insect species were reportedly used for medicinal purposes (Costa-Neto, 2005).

Didelphis. marsupialis has an undeniable cultural significance for local communities in the Amazon, both in terms of food and medicine. it is also designated as the best wild meat in the region. It is hunted by men, but the preparation of meat and medicinal oil are tasks mainly performed by women. The current study focused on riverine communities, who reportedly hunt the "common opossum" in morning or at night. They have a variety of techniques including handmade traps called "mundé", made from locally gathered wood and vines. However, this technique is declining because riverine people themselves believe that "mundé" does not select animals and it is harmful. Based on structured and semi-structured interviews with the local community, Barros and Azevedo (2014) found that this activity has not negatively affected the local populations of *D. marsupialis*. Some respondents stated that there is a decreased number of animals, other respondents argued that there is an increased number of opossums in the region. A third group said that the common opossum is a species that has a good reproductive capacity (it is a "mineral animal"), therefore, they think the population remains stable. Scientific studies suggest consumption of this species should be the subject of further studies, as this marsupial species has been described as a reservoir for parasites that cause severe disease.

ASIA

Use of wild terrestrial animals for medicinal purposes is widespread throughout Asia. Ashwell and Waltson (2008) recorded at least 47 animal species being traded for medicinal purposes in Cambodian markets, while Van and Tap (2008) recorded 100 different medicinal products from 68 animal species traded in Ho Chi Minh City, mainly sold as dried products (either the whole animal or parts) soaked in rice wine, or as a gel product which remains after boiling animal remains slowly in water.

The rhinoceros horn cut from live individuals are used in traditional Chinese medicine to dispel heat, detoxify blood, but were split over other purported medicinal properties, including its ability to treat cancer (Cheung, Mazerolle, Possingham, & Biggs, 2018). In 2018, the import and export of rhinoceros and their products will continue to be strictly prohibited; the sale, purchase, transportation, carrying and mailing of rhinoceros and their products are strictly prohibited; rhino horn and tiger bone are strictly forbidden to be used as medicine (http://www.china.com.cn/news/2018-12/13/content_74271446.htm).

3.3.3.3 "Non-lethal" terrestrial animal harvesting

Non-lethal uses of wild animals include all use forms that do not result in the death of animal through killing, contrary to lethal uses which take the life of animals. Non-lethal uses include ornamental use, scientific research, pets, green hunting, and religious and cultural practices and can benefit food security, economy, industry, and result in conservation. Traditional non-lethal uses of wild animals at local scales occur among indigenous communities, although biodiversity conservation and poverty alleviation remain a challenge in tropical biodiversity hotspots (Tranquilli, 2014).

3.3.3.3.1 Decorative and aesthetic

Natural fibers have important properties and are used as luxury goods and handicrafts that sell for better prices and generate higher profits for the community. Vicuñas *(Vicugna vicugna)* are a species which has received considerable attention regarding its sustainable use. Its hair produces one of the finest natural fibers in the world and is highly valued to make luxury fabric and clothing. The vicuña is the most representative wild ungulate of the high Andes of South America. In 1965, at its low point, the population of vicuña was estimated at only 6000, having collapsed from 1 million animals 25 years prior. Current population size is about 460,000-520,000 individuals, but they went through a serious and long-term overexploitation for 500 years. The recovery has benefited from a series of conservation actions, including the early prohibition of hunting and trade, establishment of the National Council of South American Camelids (Consejo Nacional de Camélidos Sudamericanos, CONACS), corral programs on community land and the practices of capturing and live shearing wild animals to earn high profits from selling the fiber. The benefit to society and the natural world of these efforts was the survival of a charismatic animal in its historical landscape (Sahley, Vargas, & Valdivia, 2007; Wakild, 2020). The restoration of depleted wild populations of vicuñas has reinstated the species in the ecosystem, and has allowed the development of sustainable use programs that directly assist the livelihoods and well-being of local people, and provides options for further economic development linked directly to successful conservation.

3.3.3.3.2 Food and beverage: honey

Wild honey is an important source of nutrition and medicine, and contributes to the income of local communities in many parts of the world. Wild honey harvesting is practiced by men and women belonging to many indigenous peoples and local communities. The harvest, filtration and preservation of wild honey relies in many parts of the world on rich traditional knowledge and its continued transmission across generations.

Wild honeybee local knowledge and traditional skills are key to sustainable use. In Lizongole, Mozambique wild honey gathering is typically carried out by groups of five to seven men sometimes called honey hunters (Ribeiro, Snook, Vaz, & Alves, 2019). Honey hunters have a mutualistic interaction with the honey guide bird *(Indicator indicator)* that directs men to trees containing honey. There they burn dried sticks to initiate fire and the felling of trees. Honey hunters apparently fell up to 560 trees per year. Impacts on tree populations vary among the 12 species killed for honey and are considered as a diminishing resource. Non-destructive traditional practices based on tree climbing are recommended (N. S. Ribeiro *et al.*, 2019). In Asian countries including India, the harvesting of wild honey from tall forest trees is done using bamboo baskets and bamboo ladders, and climbing trees with a smoke torch (Deori, Deb, Singha, & Choudhury, 2017). In the Southeastern United States of America tupelo honey production has been part of rural livelihood practices for several generations, and is carried out according to local ecological knowledge of both the trees *(Nyssa ogeche)* and the bees (Watson, 2017).

This non-lethal use of wild bees is widely proposed by local conservation stakeholders and is generally integrated into most of management plans of worldwide protected areas. It constitutes a sustainable alternative which provides a long-term income source to local people (Syampungani *et al.*, 2020). However, in many areas the required traditional knowledge is threatened due to changes in the related socio-economy, as more young people choose to work in the cash economy. For example, only 24% of the 251 local community members surveyed in Palawan Philippines could correctly identify the giant honeybee (Matias, Borgemeister, & von Wehrden, 2018).

3.3.3.3.3 Recreation: green hunting

Green hunting occurs with tranquilizer dart guns and the animals are released alive. This is typically performed for veterinary procedures or translocation, and has been suggested as an alternative to lethal forms of hunting (Greyling, McCay, & Douglas-Hamilton, 2004). Green hunting is cheaper and less harmful compared to traditional hunting and while immobilized, the animal can be micro-chipped or have tissue sampled (Greyling *et al.*, 2004). However, as green hunting is as of yet not a significant recreational activity, there is insufficient information on the status, trends and/or impact of the activity with regards to its potential impact on sustainable use of wild terrestrial species.

3.3.3.3.4 Pet and zoo trade

There are two distinct, but related, aspects to the live animal trade: the pet trade and the zoo trade. An array of live animals, eggs, and taxidermy are targeted by buyers worldwide for private collections and zoos or as exotic pets. Examples include reptiles, such as chameleons and tortoises; birds such as parrots and falcons; and mammals, such as tiger cubs and apes (ROUTES, 2022).

Zoological gardens and zoos represent *ex situ* conservation of wild animals for research and educational activities, tourism and recreation. The zoological parks basically exchange or buy/sell animals from each other, rarely do they buy specimens coming from the wild.

Wild animals are maintained in captivity for visual observations by the public. In an increasingly urban world, the ability of people to have contact with animals through zoos and pets adds significantly to the positive values people attribute to wild species – a prerequisite for their active engagement in conservation (Fukuda *et al.*, 2011). They constitute the ideal sites for environmental education, and therefore may have secondary level benefits for sustainable use due to a better educated public. In these cases, animals may progressively lose their wild instinct through a long-term habituation process. Given relatively few captive-bred animals do get released back into the wild, where they can make a significant contribution to *in situ* conservation, the role of encouraging people to value wild species positively is arguably the biggest conservation benefit that flows from zoos and exotic pet ownership.

The global pet trade is a large and complex industry. Pets are widely kept in many countries with 46% of United Kingdom of Great Britain and Northern Ireland and 62% of United States of America households estimated to have pets, supporting a multi-billion-dollar industry dedicated to their care and feeding (Human Society of United States, 2014; Pet Food Manufactures Association, 2014). Pet owners not only display more positive attitudes toward animals (Daly & Morton, 2009; N. Taylor & Signal, 2009), but also engage in more animal-related activities such as bird watching and viewing nature documentaries (Bjerke, Østdahl, & Kleiven, 2003). Pet owners are also more inclined to join and support animal welfare and environmental organizations (R. Bennett, 2003). As specified in the 2016 World Wildlife crime report: "In a range of countries, the capture and sale of wild-caught pets can be a way for rural communities to make money and for urban communities to express a link to the natural heritage of their countries. Display of these wild species can also draw tourists – exotic birds or even primates may be strategically positioned in front of restaurants for example, or wild species may be shown for a fee as a roadside attraction. International trade in exotic species has also become big business. Most of this involves relatively common species, but dedicated collectors may pay thousands of dollars for protected specimens, captive bred or supplied from the wild. Much of this trade involves birds, reptiles, and fish – populations that may prove difficult to monitor. The trade of tropical fish for aquaria and freshwater turtles and tortoises for terraria involves millions of individuals annually, and the share of this trade that comes from the wild is not always clear. About one quarter of all commercial live animal exports permitted under the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 2013 were declared as wild sourced, with most involving species of birds, amphibians, or reptiles prized in the pet trade. In terms of total live animals, the most commonly exported were map turtles" (Vereinte Nationen, 2016).

From the 1980s to the present, approximately 12 million live internationally protected parrots were reported in international trade, according to the Convention on International Trade in Endangered Species of Wild Fauna and Flora export data. Most were either wild-sourced or of unknown origin (62%). Trade trends have been strongly influenced by national controls in key destination markets (UNODC, 2016). In 1992, the United States of America passed the Wild Bird Conservation Act, which sharply reduced the number of parrots and other wild birds imported to the United States of America. In 2005, the European Union banned the import of wild birds due to concerns about bird flu transmission (Vereinte Nationen, 2016). Both acts radically changed the international live bird market.

The pet-trade in wild frogs and amphibians concerns a minority of the recorded importations or exportations compared to other taxonomic groups of vertebrates. An analysis of trade data reported in the Convention on International Trade in Endangered Species of Wild Fauna and Flora database showed that trade in amphibians has increased in the last years, with ~ 40,000 animals exported per year globally as part of the trade of captive-sourced live animals (Harfoot *et al.*, 2018). This has resulted in a decrease in wild sourced exports since 2000. At the same time, these numbers may be underestimates due to mislabeling of specimens as captive-bred which may in fact be wild-caught (Auliya *et al.*, 2016). For example, between 2013 and 2018, the United States of America alone imported 3,655,620 live amphibians for the pet trade, belonging to 283 species (Mohanty & Measey, 2019).

The Asian houbara bustard *(Chlamydotis macqueenii)* is listed as Vulnerable by Birdlife International (2004) due to global population decline of 35 per cent over the last 20 years. The principal cause of declines has been hunting by Arab falconers (Collar *et al.*, 2017; Seddon & Launay, 2008; Tourenq *et al.*, 2004), and associated poaching of live birds, especially from Pakistan, for training of falcons in the Arabian Peninsula. However, Saudi Arabia has taken necessary steps to conserve dwindling populations of Houbara Bustards. The goal of houbara conservation in Saudi Arabia is to restore self-sustaining populations of resident breeding birds protected within a network of protected areas, but which may one day support sustainable falconry in hunting areas outside reserves (Gelinaud, Combreau, & Seddon, 1997; Seddon, Knight, & Budd, 2009; van Heezik & Ostrowski, 2001).

Unfortunately, not all species can be bred in captivity and some consumer countries do not have access to captive bred animals, so demand for wild animals persists. The harvest of live specimens, in many cases, involves significant mortality during capture, transport and holding. Many wild animal species controlled under current policies remain unsustainably traded to supply the international pet markets, with rare and endemic species most threatened (Auliya *et al.*, 2016; E. G. Frank & Wilcove, 2019; R. O. Martin, 2018; R. O. Martin *et al.*, 2014; Ngo, Nguyen, Phan, van Schingen, & Ziegler, 2019). Even with existing international regulations, the majority of species in exotic pet trade are not protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora, leaving international trade mostly unregulated and unmonitored (Janssen & Shepherd, 2018). In particular, species with small wild populations and/or small areas of occupancy, including island populations, are highly prone to overexploitation and decline due to the exotic pet trade (S. Altherr & Lameter, 2020; Flecks *et al.*, 2012; Lyons & Natusch, 2013). The high demand by specialized collectors for a "new" (i.e., only recently scientifically described) or rare species has caused intense collections in the wild, shortly after type localities were published – which is why an increasing number of scientists warn against publishing type localities (Lindenmayer & Scheele, 2017a; Maron, D.F., 2019). The sustainability of this form of consumer-driven use is unclear.

Additional issues related to the pet trade are: (i) some common methods of animal harvest for commercial trade result in destruction of habitats and shelters (see for example, Goode, Horrace, Sredl, & Howland, 2005) and (ii) the exotic pet trade has been identified as a pathway for the spread of invasive alien species (Shivambu, Shivambu, & Downs, 2020; Soule, 1990; Warwick & Steedman, 2021).

3.3.3.4 Emerging issues: terrestrial animals harvesting for integrated species and habitat management

Hunting is not only done for food and other products, but can also be an important component of wild species management (Linnell *et al.*, 2020; Winker *et al.*, 2010), and can be an important part of sustainable management practices for the wild species and their habitats. Wild species management is defined as the application of science-based and local knowledge in the stewardship of wild animal populations (including game) and their habitats in a manner that is beneficial to the environment and society (IUFRO, 2017).

Wild species are managed for several reasons, such as: (i) to reduce a range of human-wildlife conflicts; (ii) to prevent over-population and thus reduce related socio-economic and ecological threats; (iii) to maintain desired structure of game species populations (e.g., sex, age, morphology, etc.); (iv) and to support ecosystem functioning and resilience, including control of invasive and alien species.

There are many ongoing debates within conservation and management science concerning the best models for human-nature interactions (Cornicelli, Fulton, Grund, & Fieberg, 2011; Linnell *et al.*, 2020). Wild species management institutions designed to regulate hunter impacts on wild species and wild species impacts on human interests go back centuries in various forms, although the modern tradition appeared in North America and Europe in the early 20th century (e.g., Leopold, 1933). Management for hunting may involve the introduction of alien species, habitat modification, artificial feeding and the intensive control of predators, all of which can have widespread ecosystem effects.

Wild species management institutions motivated and funded by hunting activities have led to the dramatic recovery of many species of game (roe deer, red deer, white-tailed deer, moose, wild boar, brown bears, black bears, mountain lions, wild turkeys, the American Alligator) across North America and Europe to the extent that their populations are today higher than they may have been for centuries (Gross, 2008; Joanen *et al.*, 2021; Linnell *et al.*, 2020; P. Mahoney & Geist, 2019; Ripple *et al.*, 2014). The population levels of game species that are optimal for commercial hunting can at the same time be detrimental for forest regeneration and biodiversity conservation and lead to conflicts between different groups of actors and management goals. These high populations have secondary effects including changes in animal and plant community structure and function and spread of diseases (Gortázar, Acevedo, Ruiz-Fons, & Vicente, 2006; Mustin *et al.*, 2018). Human-wildlife conflicts often include damage to agriculture, disease transmission, traffic collisions, etc.

Trends in increasing populations for several popular game species has had detrimental effects on non-game species, both because of competition for resources and they are pursued by hunters as 'vermin' that threaten game populations (Denny, Latham-Green T., & Hazenberg R., 2021; Gross, 2008; Linnell *et al.*, 2020; Ripple *et al.*, 2014; Teichman, Cristescu, & Darimont, 2016). In the 20th century, large predators' populations were almost exterminated in North America and Western Europe (Ripple *et al.*, 2014), which caused multiple cascade effects to ecosystem functioning, such as "mesopredator release" effects (Brashares, Prugh, Stoner, & Epps, 2013; Prugh *et al.*, 2009; Soule *et al.*, 1988). Growing numbers of ungulates and other desirable game species (Grant, Mallard J., Leigh, S., & Thompson, P. S., 2012; Kuijper *et al.*, 2013) resulted in habitat alterations and degradation (Grant *et al.*, 2012; Kuijper *et al.*, 2013; Theuerkauf & Rouys, 2008), increased levels of infanticide among certain species (Swenson *et al.*, 2017) and hybridization (Salvatori *et al.*, 2020). Presently, populations of most large predators are maintained at a socially acceptable maximum and are even decreasing in certain parts of Europe (Fernández-Gil *et al.*, 2016; J D C Linnell & Cretois, 2018; Niedziałkowski, Sidorovich, Kireyeu, & Shkaruba, 2021; Virgós & Travaini, 2005). In the United Kingdom, one of the most criticized management actions of grouse hunting is population control of raptors (Denny *et al.*, 2021).

Killing of people and domestic stock by predators is a serious human-wildlife conflict. Most predator populations were historically subject to severe depletion and sometimes eradication to the point of extinction. However, societal perspectives on wild species have changed over time, and now conservation actions are focused on rebuilding populations. If successful this often results in a need for additional management of the conflicts which then arise from larger predator populations. The result is that many wild species require ongoing, active management to negotiate the human-wildlife interface (Arroyo-Quiroz, García-Barrios, Argueta-Villamar, Smith, & Salcido, 2017; Lute, Carter, López-Bao, & Linnell, 2018). Saltwater crocodile populations in Australia have followed this pattern (Saalfeld, Fukuda Y., Duldig T., & Fisher A., 2016; G.J.W. Webb, 2014; Grahame J W Webb, 2021). Recovery of their populations has largely been tolerated due to the economic benefit derived from commercial skin and meat production, egg collection and tourism (Fukuda *et al.*, 2020; Joanen *et al.*, 2021). Wolves in Southeastern Norway and the French Alps in Europe, and the Midwestern and Western

United States of America have similarly rebounded after strict protection in recent decades, leading to conflicts between pro-wolf and anti-wolf "camps" that highlight different aspects of the wolf recovery history in attempts to influence management (Ruid *et al.*, 2009; Skogen, Mauz, & Krange, 2008; Smith & Peterson, 2021). Although economic valuation through nature's contributions to people is a popular approach to address such issues, it is likely to fail with regard to wild species management (Linnell *et al.*, 2020) because so many of the costs and benefits of wild species conservation are of an intangible nature, and not conducive to economic valuation. In addition, the distribution of costs and benefits vary widely by spatial scales (Linnell, 2015) and within different value domains (Arias-arévalo, Gómez-baggethun, Martín-lópez, & Pérez-rincón, 2018).

These complex trade-offs challenge governance structures. When decisions are likely to be controversial, it is essential that decision making processes maintain broad societal legitimacy by balancing inputs of diverse experts, key stakeholders and the public before making transparent decisions. It is important to consider not only the direct practical and economic impacts of human-wildlife conflicts but the wider social, cultural and political context within which these impacts occur and which co-constitute sustainable use (e.g., Linnell & Cretois, 2018; Linnell *et al.*, 2020; Lüchtrath & Schraml, 2015; Skogen, Krange, & Figari, 2017). In order to attend to the increasing diversity of conflicting interests and objectives, existing management structures would require greater transparency, scientific robustness and social legitimacy. The integration of all these elements is more likely ensure successful co-habitation among humans and wild species can continue (Carter & Linnell, 2016).

Finally, eradication of invasive alien species, including invasive wild animals, is globally acknowledged as a key management option for mitigating the impacts they cause to biological diversity, economy and human well-being (Courchamp *et al.*, 2011, p. 2011; Genovesi & Carnevali, 2011; Simberloff, Parker, & Windle, 2005). Most of these eradications have been done on islands and involved vertebrates (Genovesi, 2005), but there are also examples of successful eradications of invertebrates, including fruit flies from Nauru (Allwood, Vueti, Leblanc, & Bull, 2002), mosquito *Anopheles gambiae* from Brazil (Davis JR & Garcia R, 1989), and the Asian Gypsy Moth in North America (Elkinton & Liebhold, 1990). In Europe, rats (*Rattus* spp., 67% of all eradications) and rabbits were the most common target species (Genovesi, 2005). Although effective, possible cascading ecological effects of eradications must be taken into account (Courchamp *et al.*, 2011, p. 2011).

3.3.4 Logging

3.3.4.1 Introduction

Logging practices differ widely around the world. These include felling of individual wild trees, selective timber-harvesting, clearcutting and variable retention harvesting. The broader the group of forest users, the more likely logging needs to be reconciled with other uses and services, which support very diversified and complex livelihood strategies (Zenteno, Zuidema, de Jong, & Boot, 2013). This section assesses the status and trends of logging in the relation to the sustainable use of wild tree species. Due to the relative complexity of grouping all logging practices together, in this introduction several topics relevant to logging are briefly introduced. This includes the formal definition from Chapter 1, the issue of plantation vs. natural forests, and how forests are classified and forest management defined. A more detailed overview of the global status and trends of forests and forest management is presented in the following section (3.3.4.2). Section 3.3.4.3. is a review of timber products and uses structured similarly to the other uses sections in section 3.3. Finally, emerging issues are discussed in section 3.3.4.4. Direct and indirect drivers of use and sustainable use are discussed in detail in Chapter 4.

The review on key aspects of sustainable use focusing on logging practices relies heavily on meta-analyses carried out by either independent academic scholars or in affiliation to forest-based research departments or institutions including the FAO, the Center for International Forestry Research and the International Tropical Timber Organization (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Due to the peculiarities of the forest management and logging practices across and within the same biomes and regions, the analyses are further supplemented with a limited number of country specific case-studies. A review of the available relevant scientific literature is also included. Reports from national forest management departments, case study reports and academic theses at both masters and doctoral levels were also used as appropriate (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651).

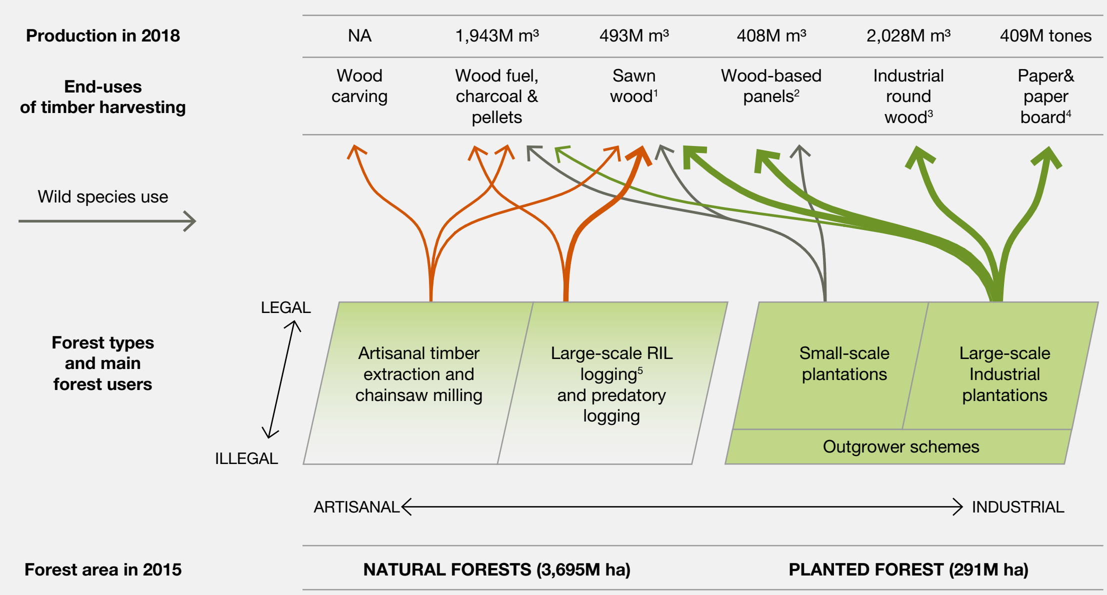
Logging is defined in this assessment as the removal of whole trees or woody parts of trees from their habitat. Logging generally results in the death of the tree, but also includes cases in which it may not, such as coppicing. Harvesting of non-woody parts of trees, such as fruits, bark or leaves, is considered under gathering (See Chapter 1 for definition, 3.3.2 for gathering). Logging is a key aspect of forest management, guided by site-specific requirements and prescriptions set out in forest management (and harvest) plans or through long-standing practices. It occurs in varying land tenure conditions including private, communal, and public ownership, and in forests ranging from simple (few dominant species) to complex (multiple species). The practice can be carried out formally or informally at small to large scales, for different uses, and for subsistence and commercial benefits **(Figure 3.52)**.

Timber is obtained from both natural and planted forests **(Figure 3.52)**. Estimates suggest plantations provide one third to one half (500-800 million m^3) of global industrial round wood (Jürgensen, Kollert, & Lebedys, 2014; Siry, Cubbage, & Ahmed, 2005), meaning that natural forests are still the major sources of timber globally. Widespread adoption of tree planting for industrial purposes began in the 1960s (Bull *et al.*, 2006; Evans, 2009; McEwan, Marchi, Spinelli, & Brink, 2020; Szulecka, Pretzsch, & Secco, 2014) to generate mainly industrial roundwood and reduce deforestation (FAO, 1967). However, while there are projected increases in the extent and volume of wood that will be produced from plantations (Armesto, Smith-Ramirez, & Rozzi, 1999; C. Brown, 2000; FSC, 2012), their relative contribution is projected to decrease as demand increases (Carle & Homgren, 2008). Thus, the pressure on existing natural forests is expected to greatly increase in the coming decades, starting with the areas with easiest access.

Forests are classified under four climatic domains. The largest domain is tropical, constituting 45% (1834 million ha) of the world's forests, followed by boreal (27%) (1110 million ha), then temperate with 16% (666 million ha) and lastly the subtropical domain that constitutes 11% (449 million ha) of the world's forests (FAO, 2020a) **(Figure 3.53)**. For the purposes of this assessment, tropical and subtropical are at times referenced together and temperate and boreal are at times referenced together.

Widespread changes in forest types are more evident in tropical forests (Fearnside, 2004; Malhi & Phillips, 2004; Root *et al.*, 2003), which are more sensitive to climate changes (Hughen, Eglinton, Xu, & Makou, 2004) and have been greatly affected by loss of forest cover and forest degradation. These changes affect the ability of species to migrate and can lead to extinction of some species (Pounds *et al.*, 2006; Pounds, Fogden, & Campbell, 1999). The subtropics contain some of the most prominent biodiversity hotspots in Latin America, Australia, and South Africa, however many forest tree species exist in highly fragmented environments and are at particular risk of extinction (Locatelli, Brockhaus, Buck, & Thompson, 2010).

Temperate forests are the most extensively altered forest biome due to global change factors, with a smaller fraction of original vegetation remaining compared to boreal and tropical forests (Reich & Frelich, 2002). More changes in vegetation type are anticipated over the next 70-100 years



(1) Encompasses planks, sleepers (cross-ties), beams, joists, boards, rafters, scantlings, laths, and boxboards
(2) Comprises plywood, particleboard
(3) Is all roundwood used for any purpose other than energy. It comprises pulpwood, sawlogs and veneer logs
(4) Comprises of graphic papers (newsprint, printing and writing paper) and other paper and paperboard.
(5) RIL = Reduced Impact Logging

Figure 3 52 **Flow diagram of timber products from natural and plantation forests.**

Based on Global Forest Products: Facts and Figures 2018 (FAO, 2019a) under license CC BY-NC-SA 3.0 IGO.

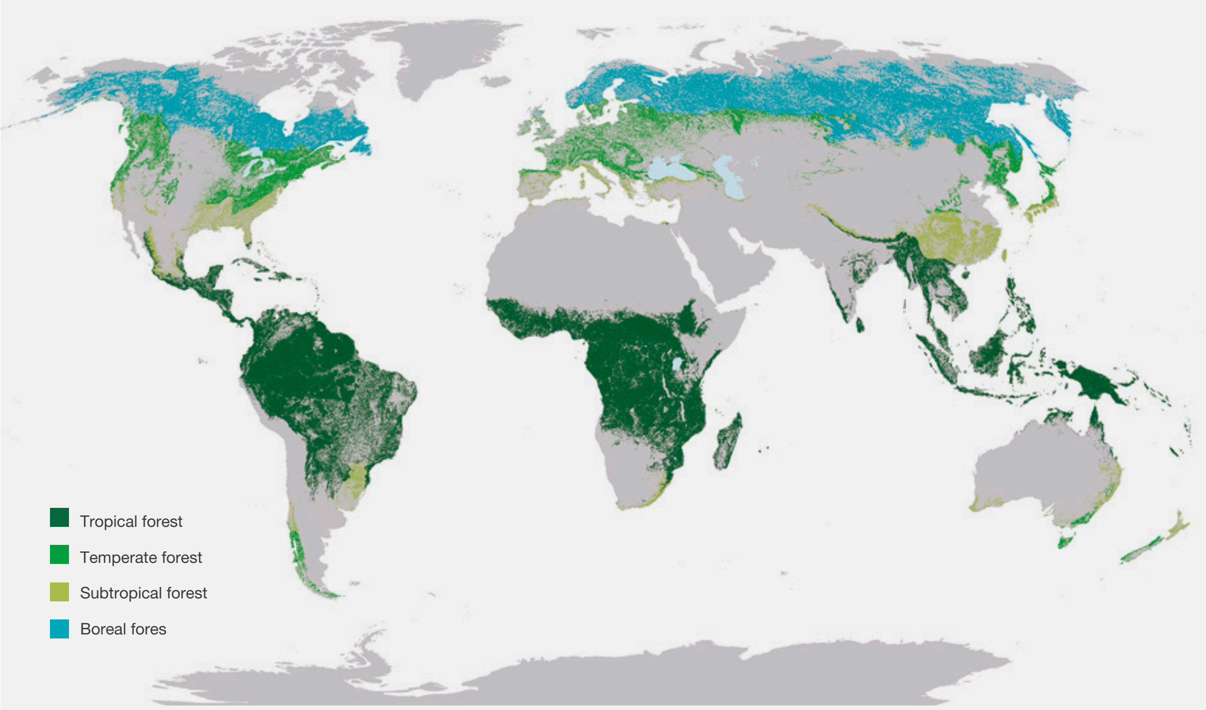


Figure 3 53 **Global distribution of forests sub-divided by climatic domains.**

Red: tropical, purple: subtropical, green: temperate, and blue: boreal.

This map is adapted from its original source (FAO, 2020a) and is copyrighted under license CC BY-NC-SA 3.0 IGO. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

(Locatelli *et al.*, 2010), though with a high degree of uncertainty due to interactions among increased fire, invasive species, pathogens, and storms (Virginia H. Dale *et al.*, 2001). It is reported that temperate and boreal forests are expanding northwards, a trend expected to continue due to climate change (Chamberlain, Emery, & Patel-Weynand, 2018; Locatelli *et al.*, 2010). Models suggest boreal forests will also undergo increased fires, increased insect and disease infestations, altered stand composition and structure. Declines in old-growth forests and conversion of southern-central dry forests to grasslands are also predicted due to climate change over the next several decades (Locatelli *et al.*, 2010).

3.3.4.2 Global trends and overview

Logging and trade in timber products has increased over the last several decades due to land use change including conversion to agricultural lands, transition to timber plantations and urban development, leading to deforestation and forest degradation (Estrada, Garber, & Chaudhary, 2019; Hosonuma *et al.*, 2012; Kissinger, Herold, & De Sy, 2012; Miller, Mansourian, & Wildburger, 2020; Ngansop, Biye, Fongnzossie, Forbi, & Chimi, 2019). According to the Food and Agriculture Organization of the United Nations (2020a), forests decreased from 32.5 percent to 30.8 percent of the global area between 1990 and 2020, representing a net loss of 178 million hectares (FAO, 2020a) **(Figure 3.54)**. Africa had the highest net loss of forest area between 2010–2020, with a loss of 3.94 million hectares per year, followed by South America with 2.60 million hectares per year. Asia showed the highest net gain in forest area in the period 2010–2020 (FAO & UNEP, 2020), however this is attributed to expanding already extensive plantation forests (Paradis, 2020; Sloan, Meyfroidt, Rudel, Bongers, & Chazdon, 2019; Szulecka *et al.*, 2014) **(Figure 3.54)**.

Primary forests, which are defined as naturally regenerated forests of native species (FAO, 2018c) have reduced by 81 million ha. since 1990, though the rate of loss decreased by over 50% between 2010–2020. Forests with high ecosystem integrity remain in Canada, Russia, the Amazon, Central Africa, and New Guinea (Grantham *et al.*, 2020). Ecosystem integrity here refers to the degree to which a system is free from anthropogenic modification of its structure, composition, and function (Parrish, Braun, & Unnasch, 2003). The majority of remaining forest areas have moderate to low forest ecosystem integrity as a result

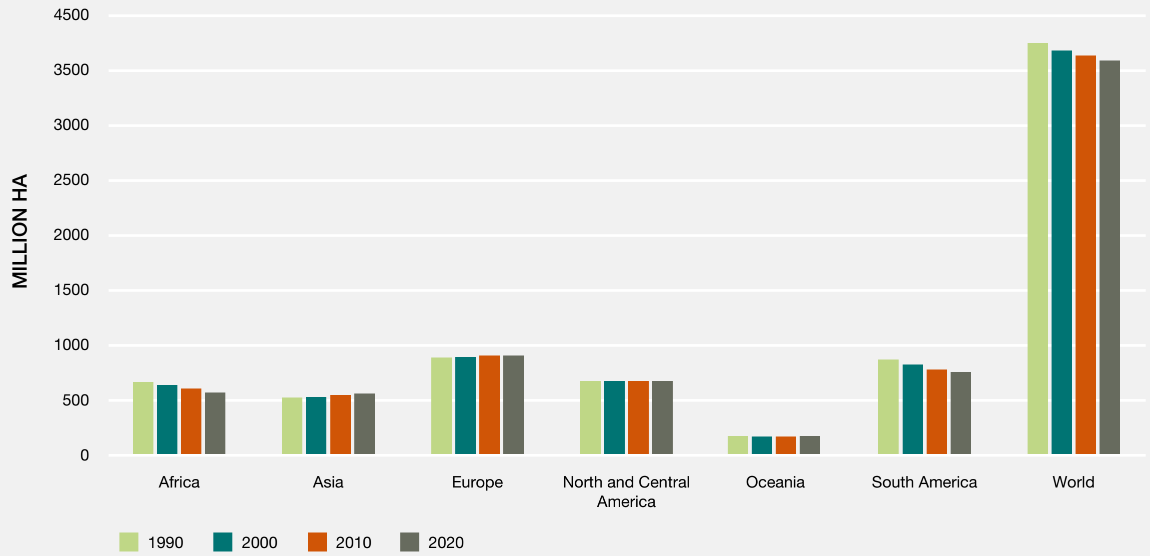


Figure 3 54 **Forest area by region, from 1990 to 2020.**

Data from the Global Forest resource assessment (FAO, 2020a) under license CC BY-NC-SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453095.

of human use of forest systems, affecting the capacity of forests to provide benefits. This degradation can be a precursor to outright deforestation (Grantham *et al.*, 2020; McNicol, Ryan, & Mitchard, 2018).

Planted forest cover increased by 123 million ha between 1990 and 2020, although rates of increase have slowed since 2010 (**Figure 3.55**, also see Supplementary material Table S3.2). In 2020, plantations and other planted forests equaled 294 million ha (7%) of the world's forest cover. Asia has the largest proportion of planted forests, 135 million ha, which constitute 22% of the region's total forest cover. Approximately 44% of plantation forests feature introduced species. Native species are mainly planted in North and Central America (96%) and Asia (68%) while the percentage of plantation forests comprised of native species are 30%, 23%, 22% and 3% in Africa, Europe, Oceania and South America respectively (FAO, 2020a).

Forest management objectives can be categorized under production, protection of soil and water, conservation of biodiversity, social services, multiple use, and other uses **(Table 3.16)** (FAO, 2020a). Approximately 1.15 billion ha., accounting for 31 percent of the world's total forest area is managed for production purposes, that is for timber, fiber, bioenergy and/or wild plants and fungal products. The area has however slightly decreased by 1.22 million ha between 1990 and 2020 with some fluctuations. Decreases in production forests occurred in Europe, Asia and most significantly in Africa (from 109 to 91.4 million ha) with a corresponding decrease in forest area. North America and Oceania had slight increases in forest area under production during the same time period. Concurrently, approximately 749 million ha (22% of total forest area) of forest globally are designated primarily for multiple use. This total decreased by 70.7 million ha between 1990 and 2020 in all regions except Asia and Europe (FAO, 2020a).

Selective harvesting is one of the dominant logging practices that contributes nearly 15 percent of global timber needs (P. A. Martin, Newton, Pfeifer, Khoo, & Bullock, 2015; Poudyal, Maraseni, & Cockfield, 2018). Selective harvesting can be low impact timber-harvesting when it involves harvesting 1-2 species and 1-2 individuals per hectare. It can be moderate when 5-15 species are harvested and 1-3 individuals per hectare (Uhl *et al.*, 1997). The practice is done on a large scale through mechanized tree extraction or on a small scale through manual extraction (Rendón-Carmona, Martínez-Yrízar, Balvanera, & Pérez-Salicrup, 2009). The practice can also be carried out by local people who hand harvest wood in exchange for staples, while large distant companies do the wood processing.

Globally selective logging is practiced on about 20.3% (3.9 million km^2) of humid tropical forests (Asner, Rudel, Aide, Defries, & Emerson, 2009). Selective logging is considered unsustainable when it is carried out the conventional way without measures to reduce damage to the residual forest stand. It is considered sustainable when specific planning and techniques are used to minimize damage to the residual stand. Several of these techniques are included in guidelines which are referred to as Reduced Impact Logging (RIL) (Arets *et al.*, 2011; Dykstra & Heinrich, 1996; Pinard, Putz, Tay, & Sullivan, 1995; F. E. Putz, Sist,

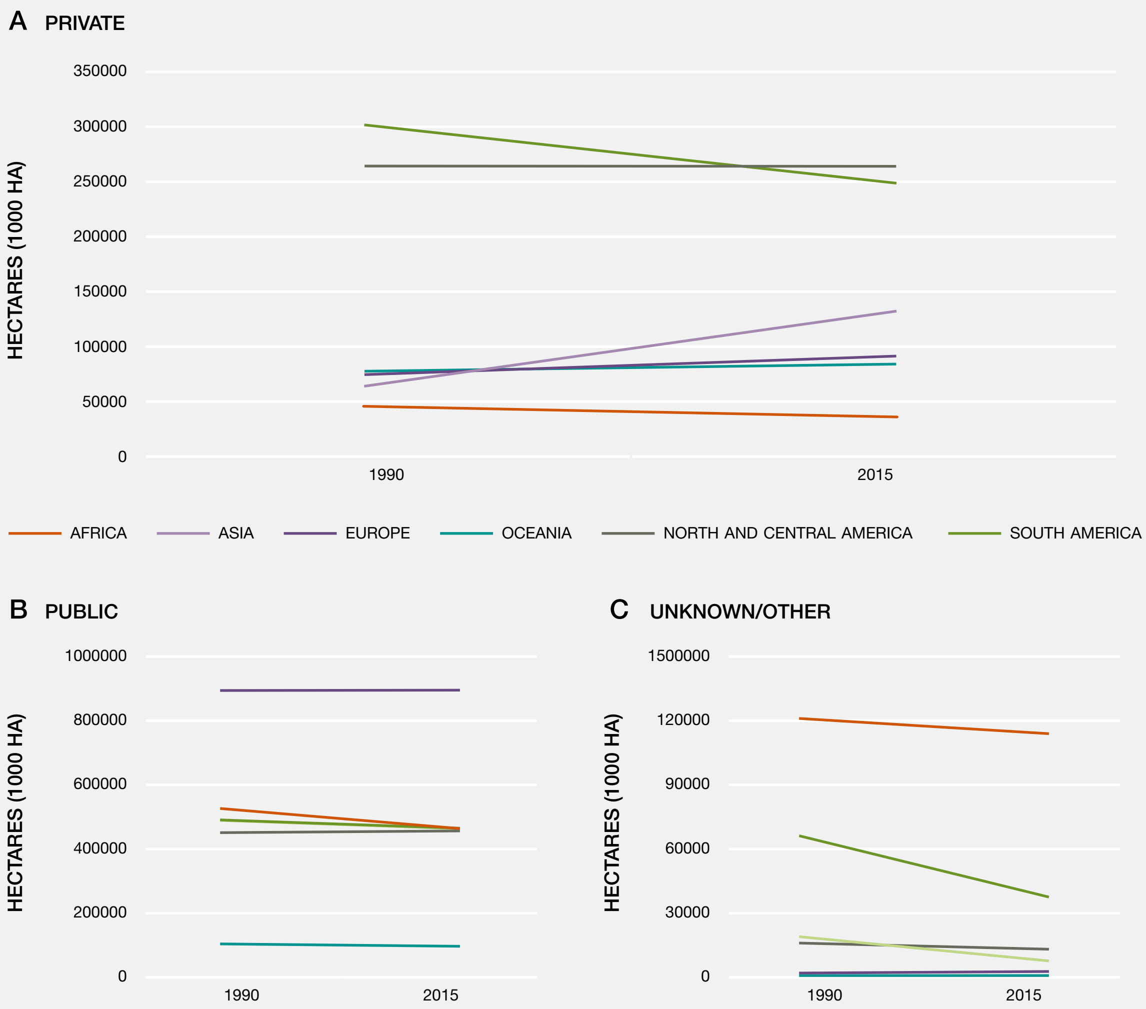


Figure 3 55 **Changes in global planted forest cover between 1990–2015.**

(A) Changes in privately owned forest land. The figure shows an overall four percent (4%) increase in privately owned forest lands, with decreases in Africa and South America, no change in North and Central America, and increases in Asia, Europe and Oceania. **(B) Changes in publicly owned forest land.** Figure shows an overall decrease of four percent (4%), with decreases in Africa, Asia, Oceania and South America, no change in Europe and a slight increase (1%) in North America. **(C) Changes in forest land with unknown ownership.** Figure shows an overall decrease of 22% in forest cover on lands with unclear ownership. Large decreases are observed in Asia and South America with lesser decreases in Africa, North and Central America. There was a slight increase in Oceania and a larger increase in Europe. Source: Global Forest resource assessment (FAO, 2020a) under license CC BY-NC-SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453095.

Fredericksen, & Dykstra, 2008). Reduced impact logging is implemented at the operational level by planning skid trails, practicing carefully controlled felling and skidding, and reducing damage to soils and residual trees (Sist and Ferreira, 2007). Implementation of reduced impact logging is still limited (Arets *et al.*, 2011; P. A. Martin *et al.*, 2015) and conventional logging practices continue to dominate (F. E. Putz, Dykstra, & Heinrich, 2000). Among the major factors hindering adaptation of reduced impact logging is the expense in comparison with conventional timber-harvesting (F. E. Putz *et al.*, 2000, 2008). In addition, evidence that reduced impact logging achieves the desired objectives is also contradictory. Some studies do suggest a reduction in the negative impacts of logging activities when reduced impact logging guidelines are followed (Bicknell, Struebig, Edwards, & Davies, 2014; R. Pereira, Zweede, Asner, & Keller, 2002; Putz *et al.*, 2012; T. A. P. West, Vidal, & Putz, 2014). However, other studies suggest that positive effects of reduced impact logging are in fact more closely related to differences in harvesting intensity (Griscom, Ellis, & Putz,

Table 3 16 **Forest area (1000 ha) designated primarily for production, and annual change, 1990–2020.**

Source: Global Forest resource assessment (FAO, 2020a) under license CC BY-NC-SA 3.0 IGO.

	Year				Annual change		
	1990	2000	2010	2020	1990–2000	2000–2010	2010–2020
Forest area	4236433	4158050	4106317	4058931	-7838	-5173	-4739
Planted Forests	170061	210662	261958	292587	4060	5130	3063
Forest area with long-management plans		1757831	1855538	1990865		9771	13533
Forests in protected areas	437 821	499 853	600 845	629 139	6 203	10 099	2 829
Forest designated for Production	1 135 826	1 112 657	1 097 126	1 134493	-2 317	-1 553	3 737
Forest designated for multiple use	809 181	780 458	750 728	738 464	-2 872	-2 973	-1 226

2014; Johns, 1992; Picard, Gourlet-Fleury, & Forni, 2012; Sist, 2000; Sist, Fimbel, Sheil, Nasi, & Chevallier, 2003; Sist, Nolan, Bertault, & Dykstra, 1998). Reduced impact logging provides guidelines to reduce environmental impacts of logging, however its lack of specificity regarding intensity can sometimes result in perverse effects. Therefore, more research is recommended to clarify whether reduced impact logging should be practiced in a way which incorporates harvesting intensity (Martin *et al.*, 2015).

Low intensity harvesting that is recommended in reduced impact logging may encourage expansion into previously unlogged areas in order to distribute the impact more widely (Martin *et al.*, 2015). In addition, the recovery rate of commercial trees after reduced impact logging is very low. One study in tropical rain forests, revealed that only 50% of the commercial stand was predicted to recover after a period of 30 years, creating a major reduction in stock for the next harvesting cycle in that area. This is not compatible with sustainable yield production on a long-term basis (Sist & Ferreira, 2007). Sist and Ferreira (2007) suggest that more sophisticated silvicultural systems are required to ensure sustainable management of the forests on a long-term basis. There is evidence suggesting that reduced-impact logging practices, if actually employed, could increase future timber yields (Griscom *et al.*, 2014; Johns, 1992; Picard *et al.*, 2012; Sist, 2000; Sist *et al.*, 2003, 1998). There is not much change on the ground in spite of these recommended practices (Putz, 2018).

The status of illegal logging and associated timber trade as well as its trends in harvesting practice, constitute complex and serious challenges in the sustainable use of wild species (J. Liu, Yong, Choi, & Gibson, 2020). Although illegal timber trade and unsustainable logging that threaten sustainable use are rampant and not well documented, it is promoting large-scale forest destruction, especially in the tropics (Laurance, 2004). The Illegal timber trade is highly international, which may result in substantial loss of large old trees. Owing to the higher prices of timber in India and China, smugglers are motivated to export timber from Nepal to the Tibetan Autonomous Region of China (Chaudhary, Uprety, & Rimal, 2016); and Nepal-India border (Chaudhary *et al.*, 2016).

Regarding data on logging, a common understanding is that it is hard to obtain accurate data on the scope of illegal logging. Scientific studies as well as reports present conflicting views on whether illegal logging is declining or not (Kleinschmit, Mansourian, Wildburger, & Purret, 2016). According to Hoare (2015), there has been important progress made in reducing illegality in the forest sector over the last decades. However, another report published three years earlier claims that illegal logging has remained high in many regions, even increased in some areas, and become more advanced with better organized activities also comprising criminal activities (Nellemann, International Criminal Police Organization, & GRID--Arendal, 2012). China (importing more than 50%, of total illegal export value), Vietnam, India, the European Union, Thailand and the United States of America are among the major importers of illegal timber accounting for 84% of the total value of imports. Southeast Asia (mainly Cambodia, Laos, Myanmar Indonesia and Malaysia), the Russian Federation, Papua New Guinea and the Congo Basin (Democratic Republic of Congo, the Republic of Congo and Cameroon are among the main exporters with Southeast Asia accounting for 55% of the exports (Chaudhary *et al.*, 2007).

There has also been an observed geographic shift in illegal logging and related timber trade. Illegal logging in Brazil, Indonesia and Malaysia has declined in recent years (Hoare, 2015). After decades of conservation efforts, forests along the China-Russia border have been recolonized (Wang *et al.*, 2016). In recent years the smuggling of timber as well as other forest resources has declined along Nepal-China and Nepal-India borders due to improved monitoring and collaborative transboundary conservation (Chaudhary *et al.*, 2016; personal communication with Bishnu Lama, indigenous people and local community member and chairman of the Namkha rural municipality – Humla District, Nepal, December 2020). However, Russia, other Southeast Asian countries (e.g., Cambodia, Laos and Myanmar), Papua New Guinea and some African countries have also witnessed increases in illegal forest activities (Guan *et al.*, 2016). Russia (primarily in its Far East region) is one among rising timber producer countries and exports timber mainly to China (Guan *et al.*, 2016). China has become the world's largest importer of tropical timber since a ban on domestic logging was implemented in 1998. It is also a key processing country, for example, it is the leading manufacturer of furniture worldwide, occupying 40 percent of the global market share (Richer, 2016); much is exported to the United States of America and Europe (Tacconi *et al.*, 2016).

Commercial logging is illegal in Afghanistan which leaves a massive smuggling industry to satisfy international demand. Local communities have lost control over the resources on which they depend for their survival, and forest resources are now largely used for immediate profit by organized crime syndicates and traders (Milbrandt & Overend, 2011). Additionally, poor forest management, lack of incentives for reforestation, lack of community involvement and awareness, and agricultural and urban encroachments on forest land also contributed to the severe decline of forest cover in Afghanistan (Milbrandt & Overend, 2011). The results have been that rangelands have deteriorated, forests have been felled, and wild species populations have greatly diminished from uncontrolled hunting and habitat degradation (UNDP, 2014).

In 2006, an executive order that was issued by then President Hamid Karzai banned illegal timber-harvesting and felling of trees and shrubs in natural forests in Afghanistan. After that, Afghanistan's Forest Management Law, passed in 2012, declared natural forests and woodlands as public property owned by the national government. The law also has a provision to support community-based forest management, allowing indigenous communities to utilize and manage the forest in collaboration with the Department of Natural Resources. However, the deterioration of overall law and order situation in Afghanistan means that the 2012 forest law has only been partially implemented.

Curbing illegal timber extraction and trade poses special challenges because of the need for cooperation among sovereign states. In order to support producer countries, bilateral arrangements have emerged, either between neighboring countries or between primary export and import countries (Kleinschmit *et al.*, 2016). Imports of illegal tropical hardwood timber in China with the republic of Congo, Ghana, Papua New Guinea, Laos, Brazil and Malaysia; India with Brazil, and Paua New Guinea; Japan with Republic of Congo, Cameroon, Malaysia and Paua New Guinea; and South Korea with Malaysia are considerable (Z. Guan, Chen, Xu, & Liu, 2020). Bilateral actions that also include transboundary cooperation have been initiated at the national level (Tacconi *et al.*, 2016). Besides scientists, transboundary conservation deserves more attention from policymakers too (Liu *et al.*, 2020). Policy in one country can easily have a major impact in other countries. For example, some research suggests that logging bans in Thailand and China have led to increased logging and forest loss in the neighboring countries including Lao People's Democratic Republic, Cambodia, Indonesia, the Russian Far East and Mongolia (Fisher, Maginnis, Jackson, Barrow, & Jeanrenaud, 2008). Hence, there is need to further strengthen international cooperation and domestic legislation in order to control the imports of illegal timber, enhance the protection and cultivation of forest resources and reduce dependence on imported timber (Guan *et al.*, 2020).

The spread of illegal logging and other forest crimes into protected areas occurs because valuable timber is still available in commercial volumes (Wardojo, Suhariyanto, & Purnama, 2001). Timber felling in protected areas in Indonesia involve multiple stakeholders, including local people, logging companies, military personal and forestry officials (Barber & Talbott, 2003; Hiller *et al.*, 2004; Laurance, 2004; McCarthy, 2002; Ravenel, 2004; Robertson & van Schaik, 2001). Illegal logging provides immediate income for local communities and may aid in day-to-day survival (Schroeder-Wildberg & Carius, 2005). In some places illegal forestry activity is a function of local livelihood context such as reduced income from farming (Yonariza & Webb, 2007).

3.3.4.3 A stratified typology on sustainable use of wild species in logging

Forests are owned either publicly by the state for the benefit of the citizens or privately by individuals, local, tribal and indigenous communities, or business entities and institutions. The proportion of forests under public ownership has declined, while those under private ownership increased between 1990 and 2015. In all regions, public administration holds management rights to most of the publicly owned forests. Globally, individuals own most privately owned forests, followed by local, tribal and indigenous communities and the least are owned by business entities and institutions (FAO, 2020a) **(Table 3.17)**.

Table 3 17 **Management of forest area under private and public ownership.**

Source: Global Forest resource assessment (FAO, 2020a) under license CC BY-NC-SA 3.0 IGO.

Region/ subregion	Area of forest in three types of private ownership, by region, 2015 (1000 ha)			Holders of management rights to public forests, by region, 2015 (1000 ha)				
	Individuals	Local, tribal and indigenous communities	Business entities and institutions	Public administration	Individuals	Local, tribal and indigenous communities	Business entities and institutions	Unknown/ other
Africa	824	15599	1978	378849	0	7104	41485	844
Asia	7196	3900	1742	323232	45	30245	1275	40052
Europe	50946	2535	11691	641273	1	1324	244003	809
North and Central America	129468	45579	59723	389302	202	5570	54882	2956
Oceania	160	37551	0	6728	0	0	278	0
South America	0	3491	144	435192	2014	7173	5925	3
World	**188592**	**108655**	**75279**	**2174576**	**2263**	**51416**	**347848**	**44664**

Features of logging activities vary depending on the specific contexts in which they develop. Land tenure, the level of access to public infrastructure (e.g., roads, energy, health, education) and proximity to markets are all important structural conditions. Ecological conditions including stand composition, seasonality, and soil types also affect harvesting conditions. In all these cases, logging may apply technologies that range from artisanal, often manual and carried out with or without permits by individual small-scale millers, to industrial operations with highly mechanized large scale tree removal. To try to account for these variables, the status and trends of logging operations have been analyzed using a three-element typology which generally corresponds to the scale of volume harvested and size of harvest area **(Table 3.18)**. Specific actors have also been associated with these categories. In increasing volume and area, these are identified as: (1) smallholder, (2) community and (3) industrial logging operations:

1. **Smallholder forestry**, where logging is undertaken by individuals or family groups in lands on which they hold individual private access to forests and timber

2. **Community logging or community forestry**, where logging is organized and carried out collectively in forests stocking on community lands, using either artisanal techniques or externally supported reduced impact logging with heavy machinery

3. **Industrial Logging**, where individual companies holding individual or long-term concession rights conduct either conventional or reduced impact logging.

These logging operations are further differentiated by key aspects of use, identified here as harvest regime, governance, and economy:

1. **Harvesting regime** refers to the species harvested, species characteristics which affect volume of harvest such as growth and regeneration rates, and the techniques and equipment used.

2. **Governance** refers to different forms of access to forests and timber. It also refers to individual and collective rights, which range from diffuse and well-defined customary rights to full formal ownership of private lands and long-term usufruct rights in public lands. Legality is also considered a governance issue.

3. **Economy** refers to ways in which benefits are accumulated by actors. These include subsistence needs, and produce goods for the formal and informal economies. There are differential distributions of benefits depending on the form of capital accumulation and capital distribution.

3.3.4.3.1 Smallholder Logging practice

Estimates suggest that 1.3 billion people live in or around the world's remaining forests (Chao, 2012). These include right holders with individual and collective access to forests, either formal or informal. Rights holders may include individual landowners, indigenous traditional communities, local communities with established land tenure and historical access, and naturalized immigrant communities (for example from settler colonial expansion). In many cases

Table 3 18 **Typology of logging systems.**

Actors = Social entities organizing logging operations. **Harvest regimes** = equipment used, volume harvested, species, age class, size, return interval, regeneration, etc. **Governance** = customary and formal norms (including cultural knowledge and principles), rules, and regulations, management plans. **Economy** = subsistence, informal trade, formal trade; harvest to consumption value chains, distribution of benefits, and capital accumulation.

	Actors	Harvest regime	Governance	Economy
Aggregate	All	3.3.4.2	3.3.4.2	3.3.4.2
Smallholder	Individual or collective	3.3.4.3.1.	3.3.4.3.1.	3.3.4.3.1.
Community	Collective	3.3.4.3.2.	3.3.4.3.2.	3.3.4.3.2.
Industrial	Individual or corporation	3.3.4.3.3.	3.3.4.3.3.	3.3.4.3.3.

different individuals and communities may co-exist in the same locations. For example, in the Brazilian Amazon, traditional dwellers are comprised by *caboclos* or local people who descended from immigrants who followed the several waves of resource exploitation into the region and mixed with indigenous residents (Adams, Murrieta, Neves, & Harris, 2009). In the north central United States of America, the indigenous Menominee and Ojibwe peoples manage their tribal forests independently of the surrounding state and federally owned lands (Mausel, Waupochick, & Pecore, 2017; Ronald L. Trosper, 2012; Waller & Reo, 2018). Naturalized communities and migrants are more recent arrivals into forest zones who settled spontaneously or followed government-sponsored programs (B. M. Fernandes, 2004). In Southeast Asia, immigrants followed state-driven immigration programs but also followed the development of plantations that attracted rural labor to forest landscapes (Budidarsono, Susanti, & Zoomers, 2013). All these local groups undertake some type of small-scale logging, along with landless people trying to make a living, a portion of which may carry out logging operations on smallholder lands through different arrangements.

Smallholder plot sizes range widely across world regions. Plots in more remote areas tend to have more independent logging activities. For example, 60% of family forest owners in the United States of America have an area ranging between 0.4-4.0 ha (Snyder, Butler, & Markowski-Lindsay, 2019). Many smallholder farmers in the Amazon have access to larger pieces of land of up to roughly 100 ha (Siegmund-Schultze, Rischkowsky, da Veiga, & King, 2007) (Budiman, Fujiwara, Sato, & Pamungkas, 2020). In the Amazon, the more remote farms are, the higher the probability that they still have some primary forest remnants stocking their property. These remote farmers often operate more independently regardless of the status of their tenure (Serra, 2020). In the Amazon, most of the forests on the land occupied by immigrant smallholders are already degraded from fires or former harvesting by commercial loggers. Smallholders may harvest trees from their plots, but, due to the immense logistical and legal challenges, this is rarely carried out for commercial purposes. Accordingly, for most farmers, forests are a reserve for agricultural land, or provide materials for subsistence needs (e.g., fences, fuel wood) (Pacheco, 2009). If marketable timber is still available, they may also extract trees for commercial purposes when quick cash is needed (Pokorny, 2013). While smallholder farmers selectively extract high-value timber from remnant forests, they may also sell timber that originated from secondary forests emerging in agricultural fallows, often to local markets. At the same time, growing trees is an essential component of most smallholders' production systems (Hoch, Pokorny, & de Jong, 2012). Accordingly, over time, landscapes occupied by smallholders develop complex land-use mosaics that include swidden fields, fallows, agroforestry plots and forest patches (Denevan & Padoch, 1987; Padoch & Pinedo-Vásquez, 2006).

The small-scale logging industry is characterized by stakeholders that may or may not have a felling permit, often use chainsaws (sometimes mobile saw) for felling and processing in the forest, have smaller numbers of trees per operation, often produce lower quality sawnwood for national market and neighboring countries and is largely informal (Cerutti & Lescuyer, 2011). In addition to chainsaws, winches and canoes with outboard motors are often used when water transport is involved. Chain saw milling requires a relatively small investment as the equipment is readily available and inexpensive to buy or rent, is portable and efficient (Pinard *et al.*, 2006). Among the products of chainsaw milling are boards and planks for personal use, those that are sold directly to the market, and blocks or scantlings that are further processed in sawmills (Wit, van Dam, Omar Cerutti, Lescuyer, & Mckeown, 2010). The logging team consists of a few individuals who could be part of an entitled community or recruited from elsewhere, and they may own their own equipment or operate equipment owned by others (Salo, Sirén, & Kalliola, 2013). They harvest significantly smaller volumes of timber. The practice is usually very selective, concentrating only on the most valuable commercial species such as, in the tropics, mahogany, cedar, teak and *tornillo (Cedrelinga catanaeformis).* Chainsaw systems persist especially in areas with more rugged terrain. Across the United States of America, one-third to over three-quarters of loggers used chainsaw felling (Conrad, Greene, & Hiesl, 2018). Wherever possible, small-scale chainsaw millers target large trees to maximize their output (Cerutti & Lescuyer, 2011).

Wood production by small-scale chain saw operators can be for personal use (Snyder *et al.*, 2019) and to supply domestic markets (Rozemeijer & Aggrey, 2011). In some instances, the wood is for social or community purposes and not sold or exchanged (Lesniewska & McDermott, 2014). When entering into formal markets, the timber is usually purchased by middlemen at cheaper prices who then sell it to the timber industries (Salo *et al.*, 2013). The industry is rapidly growing in tropical countries (Hoare, 2015), representing approximately 30-40% (in Guyana, Republic of Congo, Democratic Republic of Congo and Uganda), more than 50% (in Ghana, Cameroon and Peru), and almost 100% (in Liberia) of total timber trade (Wit *et al.*, 2010). However, wood for timber is only a small part of the total domestic market, with most locally traded wood in the tropics being used for fuel or made into charcoal (Wit *et al.*, 2010).

In many Amazonian countries (e.g., Bolivia, Peru, Ecuador), smallholders are allowed to extract timber from their properties for commercial purpose, yet they have to obtain permits, often through simplified processes including simpler management plans (Cerutti & Lescuyer, 2011) **(Box 3.15)**. That said, few smallholders, such as those in the Peruvian Amazon, have secured formal property rights (Cronkleton & Larson, 2015). For those with formal usufruct rights to households occupying forest lands, they may be able to register a formal forest management plan to carry out selective timber-harvesting (Robiglio, Acevedo, & Simauchi, 2015). In spite of the options allowing for the use of simplified plans, only a small portion of smallholders formally apply for forest permits (Pacheco, Mejía, Cano, & de Jong, 2016).

Informal logging by smallholders provides thousands of jobs in Central African countries. In the Congo Basin, countries have embraced forest policies that mainly targeted the sustainable management of timber in large-scale timber-harvesting concessions targeting export markets and overlooked small-scale production. Yet small-scale chainsaw milling, which is chiefly informal, has undergone rapid development to meet the domestic demand for cheap timber in Central African countries and other nearby countries, as well as the interests of stakeholders all along the chain of custody (Eba'a Atyi *et al.*, 2016). Over the last decade, in Central Africa, the annual volume of timber from informal chainsaw milling consumed domestically or unofficially exported to nearby countries is greater than that of timber from the industrial sector (Guillaume Lescuyer & Cerutti, 2013). In Cameroon, around 45,000 people find their main employment in this sector (Cerutti & Lescuyer, 2011). In the cities of Congo, the Central African Republic and Gabon, more than 1,000 people have jobs directly linked to the sale of small-scale timber production (Guillaume Lescuyer, Cerutti, & Robiglio, 2013).

Small-scale chainsaw milling is an important source of income for rural stakeholders, and accepted by urban consumers (Guillaume Lescuyer *et al.*, 2017), who gain access to materials at prices three to four times lower than those from industrial timber (Guillaume Lescuyer *et al.*, 2013). In remote areas, smallholders, when in need to harvest and sell timber often face distorted market conditions, mainly for two reasons. They may suffer from elevated transport costs, due to long distances, bad roads, and small quantities, or, to avoid logistical challenges depend on intermediaries or sawmill operators that tend to underprice the timber (Pacheco, 2012). In locations closer to the markets, smallholders who still dispose on forests, are better engaged to extend market networks managed by

Box 3 15 Smallholder logging in Ucayali, Peruvian Amazon.

There are approximately 440,000 smallholder producers (i.e., plots <115 hectares) in Ucayali region in the Peruvian Amazon, with approximately 80% holding less than 20 hectares of land (Robiglio *et al.*, 2015). It is estimated that mosaic production systems of these smallholders cover more the 4.5 million hectares in the Peruvian Amazon, with approximately 90,000 ha under fallow-forestry (Sears, Pinedo-Vasquez, & Padoch, 2014). Farmers in the Ucayali region of Peru produce 950,000 m^3 of sawn wood annually (Sears, Cronkleton, Polo Villanueva, Miranda Ruiz, & Pérez-Ojeda del Arco, 2018). This is based on production of 38 m^3 ha^{-1} of sawnwood on a stand of 7 years. Smallholder farmers extract timber from remnant standing forests but also from secondary forests growing from fallows. The main product from the fallow-forestry system is small dimension lumber from *Guazuma crinita* (Sterculiaceae) and *Calycophyllum spruceanum* and Rubiaceae (Sears *et al.*, 2014).

In tropical regions, forest concessions occupy more than 20% of public forests in west and central Africa and Southeast Asia and about 4% in Latin America. In the tropics 15% of forests are managed by communities (Arts & de Koning, 2017). All these communities manage forests through different socio-ecological systems with very peculiar characteristics that are associated with traditional knowledge and community identity.

intermediaries who organize the extraction in response to orders from end-buyers in the cities (Mejia, Pacheco, Muzo, & Torres, 2015). Main markets are for construction such as in Central Africa (Eba'a Atyi *et al.*, 2016), and the furniture industry such as in Jepara district, Indonesia **(Box 3.16)**. In some places in the Amazon, the broader value chain for small-dimension lumber supports hundreds of other actors involved in the harvest, transport, transformation, and wholesale activities within marketing networks stretching from remote areas of the Amazon to major urban centers in Peru's coast and highlands (Pokorny, 2013; Sears *et al.*, 2018).

In the Amazon, for most smallholders, primary forests play only a little role for income generation, whenever wood products such as firewood, poles, or for construction are regularly used by the families (Porro *et al.*, 2014). In addition, forest fallows have a potential to generate income if the production areas are located near to roads and markets. In such conditions, farmers benefit from additional incomes from selling wood ranging from $35 to $1870 United States dollars per hectare (Hoch *et al.*, 2012; Sears *et al.*, 2014), with multiplier income effects associated with the processing. In Central Africa, chainsaw milling also constitutes an important source of employment for rural population, which translates into a relatively regular income stream on the lack of other job opportunities (Eba'a Atyi *et al.*, 2016).

In the Amazon, much timber harvest takes place at the scale of individual households, even within communal properties granted to indigenous communities (Cronkleton & Larson, 2015). The smallholders may harvest the timber themselves with chainsaws and then process the log to produce planks, which are easier to transport, they hire specialized loggers (Pokorny, 2013). Yet, this informal practice is generally penalized by law, except in some countries like Ecuador (Sears *et al.*, 2014). In some cases, smallholders sell standing timber to professional loggers that have better connection with sawmills, which often approach a larger number of farmers so to compensate for the use of heavy machinery (Mejia *et al.*, 2015). In the Peruvian Amazon, commercial harvest of fallow timber is done with a chainsaw portable mill with a circular saw set up on the farm for *in situ* primary transformation. It is often the case that the rough-hewn planks are planed into the finished product in either lumber yards or workshops in the urban centers.

Systems for permitting are quite different and greatly vary in many countries in temperate zones, where land tenure systems tend to be more closely regulated with regards to private vs. public ownership. In cases of private ownership, there is variation in the freedom to decide the amount of timber to harvest, approvals required to harvest and freedom of owners to perform the actual harvesting (Nichiforel *et al.*, 2018). Freedom to decide the amount of timber to harvest can be based on a framework of general silvicultural restrictions (e.g., Norway, Austria, United Kingdom of Denmark, Ireland, Latvia, Portugal and Sweden) and size/quantity provided for in the legislation. For example, in France the forest owners maximumly harvest 50% of the standing timber on their property in comparison to

Box 3 16 The furniture industry in Indonesia.

Furniture is an important industry within the forest-based sectors for several reasons. First, micro, small and medium enterprises play a significant role in creating employment. The furniture sector provides direct employment to approximately 500,000 individuals (Munadi, 2017). Second, the industry contributes significantly in terms of foreign exchange. In 2019, Indonesia exported 1.7 billion United States dollars from the furniture exports (Bank Indonesia, 2020). Third, the furniture industry also represents Indonesian identity in international markets since Jepara is a furniture producing district with global recognition as furniture and woodcraft center (Pujiati, 2017).

Ironically, the performance of the industry at the national level is not well-known, and national estimates regarding the size of the industry are based on limited data. The most valuable data comes from the Central Statistical Agency, which reported that by 2019, there were 145,000 furniture micro, small and medium enterprises in Indonesia (wooden and nonwooden-based), representing about 3.3% of the total sample of 4.4 million micro, small, and medium enterprises (BPS, 2020). A Ministry of Industry report shows that wooden-based furniture producers represent about 80% of the total furniture producers (Munadi, 2017; Pujiati, 2017). From this information and the Central Statistical Agency data, there was an estimated 116,000 wooden-based furniture producers in Indonesia.

A survey of furniture producers in Jepara and Pasuruan in 2020 by the Center for International Forestry Research (Dermawan, 2020) estimated that one producer uses about 71 m^3 of wood annually. Multiplying this number with the estimated total national producers, the wood consumption by the furniture industry in Indonesia could reach approximately 8.2 million m^3 of wood. A high segment of wooden furniture in Indonesia uses teak as the primary raw material. Teak is mainly available in Java and some areas in other islands, such as Sulawesi. With the mean annual increment of 10 m^3/ha/year (Kallio, Kanninen, & Krisnawati, 2012), meeting the need for 8.2 million m^3 of wood would require approximately 820,000 hectares of teak forests.

Estonia, where one can harvest 20m^3 per year and Bulgaria where one can harvest 10m^3 per year. These ranges are a result of forest management planning in combination with owners' decisions. In some cases, such as in Finland and Netherlands, more restrictions apply. In other countries owners are generally required to ask for approvals and adhere to the conditions of approval (Bulgaria, Greece, Romania). Approvals may be required when forest management plans do not apply (e.g., France and Czeck Republic) or when there are special circumstances such as exceeding a given size of clear cut. There is little regulation on private forests in the United Kingdom of Denmark, and in Estonia no formal approval is required for personal use. In the majority of the countries, forest owners have the freedom to cut down trees without any restrictions, others restrict the quantity an individual can harvest by him/herself (for example in Romania where owners can harvest less than 20m^3 without a permit). Several countries in Eastern Europe only grant licenses to individuals with harvesting skills, and others such as Greece require the owner to contract a special firm for harvesting (Nichiforel *et al.*, 2018).

Ecological impacts of small-scale logging range from minimal to long-term. In Central Africa, when smallholder logging is driven by demand, chainsaw millers may penetrate deeper into the forest, and apply more effective tools such as portable saws in order to meet with a growing urban demand (Cerruti *et al.*, 2017). Fallow-forestry allows the use of timber and other non-timber forest resources, while providing multiple contributions to people to regenerate soil fertility and conserve biodiversity (Pattanayak & Sills, 2001; Pyhälä, Brown, & Neil Adger, 2006). In such systems, smallholder farmers often conserve scarce timber species, such as *Cedrela odorata, Swietenia macrophylla,* and *Dipteryx* spp.), among others (Putzel, Padoch, & Ricse, 2013).

Due to the individualized living schemes of small-scale farmers in the Amazon, there are not many social impacts of forest management. However, natural and planted forests are frequently affected by accidental fires caused during field preparation, which further reduces the attractiveness of forest investments (Hoch *et al.*, 2012) and may lead to conflicts. Less frequent are wood robbery, and forest tenure conflicts in the remoter, less accessible forest parts of smallholder properties. Although not often discussed, smallholder logging often does not involve women in the operations, which may lead to some unequal distribution of benefits in the households undertaking logging, although women develop other activities in the farm and gardens (Colfer, 2005).

Thousands of households manage forest fallows and trees as part of their customary livelihoods strategy that meets both subsistence and income needs (Pokorny & De Jong, 2015). Smallholder logging is only sustainable when it is done for subsistence or at low intensities. It constitutes a complementary activity that is shrinking over time due to the expansion of agriculture. Even with forest fallows and re-growing secondary forest, tree species composition and tree growth are affected from soil degradation caused by agricultural uses and fire.

3.3.4.3.2 Community Logging practice

Community forest management involves the use and management of forests by communities. While community forestry often involves the management of large areas of forest relative to the average size of that managed by individual smallholders, the areas are still small relative to most industrial estates (100s of hectares compared with 1000s of hectares). Furthermore, the focus on multiple use management is strong in both community and smallholder forestry compared with the focus on timber production in industrial estates.

Forest areas that are owned or managed by local communities have been increasing in the last decades and account for up to 15% of total forest area worldwide (513 million hectares) (Putraditama, Kim, & Baral, 2021). Collective forest tenure reforms in countries such as China (Yiwen, Kant, & Long, 2020) and Indonesia (Putraditama *et al.*, 2021), although criticized in terms of effectiveness (Yiwen *et al.*, 2020), are likely contributing to this upward trend in community forest area. The trend in moving away from industrial forestry towards landholder-based forest management and community forestry may be due to increased support for community forests as a form of sustainable development.

From an ecological perspective, indigenous, low-intensity forest use has little negative impact on forest ecosystems (Gómez-Pompa, Whitmore, & Hadley, 1991). The effects of informal, more intensive timber harvest by the community in more forested landscapes in the Amazon and Central Africa, are limited to the easily accessible parts of the forests, where, after a while, the valuable species tend to disappear (Ferreira, Cunha, & Parolin, 2014). The environmental damage becomes stronger with the involvement of professional loggers, as they have the means for investments into infrastructure and heavy machinery. Although logging may be highly selective, the damage to the forest could be immense as it damages the remaining stand and changes its structure and tree composition in the long run (de Avila *et al.*, 2017). However, the basic ecological functions of the forest remain as long as it is not converted for agricultural purposes.

Independently of the type of ownership or management goals, community forest management has been supported across the globe by governments and donors as a way of combining socio-economic development with forest conservation. Transferring responsibilities from public (e.g., governments) or private (e.g., companies) entities to forest communities is believed to create conditions for better conservation and more sustainable use of forest ecosystems, as well as fostering social well-being and gender equity (Nandigama, 2020). There has been a high level of support for community forests managed under communal property rights, which suggests participatory engagement in common property resource management promotes environmental sustainability through improved livelihoods for the rural poor (Bluffstone *et al.*, 2018; Okumu & Muchapondwa, 2020; Ostrom 2008, 2009) and decreases the costs of management (Gutiérrez-Zamora & Hernández Estrada, 2020; Nandigama, 2020; Shumsky, Hickey, Johns, Pelletier, & Galaty, 2014). Community forests also increase local resilience and enable better disaster preparedness for emergencies ranging from earthquakes to the COVID-19 pandemic (Gentle *et al.*, 2020).

Communities can have full, partial, or no formal ownership of the forests they manage. In the cases that communities hold ownership of the forest land, they often share forest management responsibilities, including its costs and benefits, with governments, non-governmental organizations, etc., via different legal arrangements (Hyde, 2016). The mechanisms that transfer rights to use and management of forests from public or private land to communities greatly vary across the world. Legal arrangements range from the forestry regime of "baldios" in Portugal or the "montes comunales en mano commum" in Galiza/Spain (Carvalho Ribeiro, Sónia Maria, 1998; Skulska, Duarte, Rego, & Montiel-Molina, 2020), and the "van panchayats" in the Himalayas (Thakur *et al.*, 2020). In Mediterranean European countries, the existence of common property institutions and community forests in particular dates to at least a thousand years (Cullotta *et al.*, 2015; Skulska *et al.*, 2020).

Community forest management is also associated with use of forests in indigenous reserves or designated sustainable use areas including for example the sustainable use extractive reserves, some of which were created over the last decades, granting conditional local use rights on state lands for vast areas. In South America, often communities also manage land through forest concessions. Forest concessions are defined as a formal legal agreement signed with a concessionaire for the occupation and use of a territory. In these agreements, space units are demarcated for the use and management of ecosystems for specific uses and for a fixed time. There are at least 122 million hectares of tropical forests under concessions, equivalent to 14% of the world's public forests some of which are managed by forest communities.

The industry is operated by small and medium forest enterprises which are largely left out of the forest statistics, planning and management, and yet it is growing rapidly in many tropical countries (Hoare, 2015). The small and medium forest enterprises are characterized by low level capital, informally trained workers and having potential for value addition (Osei-Tutu, Nketiah, Kyereh, Owusu-Ansah, & Faniyan, 2010). The industry contributes directly to the local economy in the form of improved livelihoods and cheap lumber for urban consumers. Small and medium forest enterprises are the main, additional or alternative income sources for a greater proportion of the local population as compared to the large-scale formal forest subsector in countries where the forestry sector is among the major income earner (Cerutti & Lescuyer, 2011; Osei-Tutu *et al.*, 2010). This is because small and medium forest enterprises tend to accrue wealth locally, empower local entrepreneurship and seek local approval to operate (Osei-Tutu *et al.*, 2010). Small-scale enterprises tend not to be adapted to landlocked, low population density, remote markets and high transportation, costs but can compete and replace forest concessions when public road infrastructures allow them easier access to the market (Karsenty, Drigo, Piketty, & Singer, 2008) **(Box 3.15)**.

Globally, about 15% of tropical forests are managed by communities (Arts & de Koning, 2017), many managed by indigenous peoples and local communities. As of 2020, indigenous peoples and local communities in Africa, South America and Asia, customarily managed at least 31% of land area corresponding to 571 M hectares (Khare, White, & Frechette, 2020). As of 2016, in Latin America nearly 33% of forests (232 million ha) were under some type of collective tenure regime owned by communities, most of which are of indigenous peoples, and another 8% of the area had been designated for their use. An important portion of these forests are used for meeting subsistence needs, but few of the communities undertake commercial logging operations, formally or informally. Traditional forest management for subsistence uses tends to be informed by traditional knowledge and customary local regulations (Gibson, McKean, & Ostrom, 2000). In turn, community forestry for commercial purposes is informed by management plans that are based on scientific forestry with no obvious role for indigenous knowledge. Often, these plans are inspired by large-scale industrial timber-harvesting schemes.

Since informal management schemes are considered by some to be ineffective or degrading, the management of forests by communities on the basis of the Reduced-Impact-Logging principles and formally authorized management plans has been widely promoted given assumptions that it would lead to sustainable outcomes in terms of biodiversity and local income. Accordingly, hundreds of initiatives across the tropics have promoted community forestry, in some cases also labelled as social forestry or collaborative forest management (Hajjar *et al.*, 2021).

The most developed cases of community forest management in Mesoamerica include Quintana Roo, Mexico, and Peten, Guatemala (see Supplementary material Box S3.1), as well as community forestry in the Amazon including Brazil, Bolivia, Peru. In Central Africa, community forestry has mainly developed in Cameroon, and to a lesser extent in Democratic Republic of the Congo. Especially in Latin America, the promotion of community forestry was accompanied by the formal recognition of tenure rights to indigenous peoples (RRI, 2015), which has been understood as a critical condition for achieving positive outcomes (Baynes, Herbohn, Smith, Fisher, & Bray, 2015).

In developed countries, community forestry is less well established than in developing countries (Bullock & Hanna, 2007). Charnley and Poe (2007) reported only 2% community and indigenous ownership of forests in developed countries in comparison with the approximately 14% of community and indigenous owned forests in developing countries. Community forestry began to be implemented in the 1990s in Canada as a result of public controversies surrounding large-scale industrial forestry, and as of 2007 existed in Ontario, Quebec, and British Columbia **(Box 3.17)**. In the Canadian context, forests remain state property but communities receive key management rights and responsibilities. In the United States of America community forestry initiatives have been supported through joint efforts across private, tribal, and public lands across the country. Despite widespread support for increased public participation in environmental decision-making in the United States of America, there has been resistance from the government and environmental groups to yielding actual control over land to local communities. Thus, in the United States of America collaborations between state and federal forest management agencies and local communities has been more common (Charnley & Poe, 2007).

The specific outcomes of community forestry initiatives largely depend on the biophysical conditions, tenure right situation, community characteristics, and the type of intervention. For the majority of cases, positive environmental and income-related outcomes are reported, but the need for formalization and the related bureaucratic and technical requirements negatively affect forest access and resource rights (Hajjar *et al.*, 2021) and the attractiveness for the local resource users (Pokorny, 2013). Accordingly, the long-term success of community forestry initiatives largely relies on continuous external support, but only in some limited cases (Pokorny, Johnson, Medina, & Hoch, 2012).

Box 3 17 **Community forestry on public lands in Canada.**

Community forestry has been a legally recognized form of forestry governance in Canada for over 50 years. While area in community forestry is small compared with industrial tenures, it makes important contributions to community development and diversifying the beneficiaries of forestry (Bullock & Hanna, 2007; McIlveen & Rhodes, 2016; Teitelbaum, 2016).

Three provinces in Canada have institutionalized forms of community forestry on public land: British Columbia, Ontario, and Quebec. Since 1998, British Columbia has granted 25-year renewable licenses to more than 50 organizations and indigenous communities under the British Columbia Community Forest Agreement (Government of British Columbia, 2020). British Columbia also has a tenure specific to indigenous communities, the First Nations Woodland Licence (Government of British Columbia, 2020).

Quebec was the second province to adopt a community forestry policy. Although implementation has been slow (Ministère des Ressources naturelles et de la Faune, 2011), a number of community forests have been created across the province (Bissonnette, Blouin, Bouthillier, & Teitelbaum, 2020; Teitelbaum, Beckley, & Nadeau, 2006). Many are located in proximity to small rural communities and are run by municipal or regional governments (Chiasson & Leclerc, 2013). A handful have also been allocated to indigenous communities and are largely run by the band council.

The province of Ontario has a network of county and municipal forests, as well as forests owned and managed by Conservation Authorities (Teitelbaum & Bullock, 2012). Under this model, forestlands are owned outright by local government entities and have strong authority over management decisions. In contrast, the provinces of Quebec and British Columbia retain considerable control over management decisions such as allowable timber cut, wild species management and gathering. Community forestry entities in Quebec and Ontario also face substantial administrative burdens from a regulatory system designed for much larger operations (Ambus & Hoberg, 2011; R.L Trosper & Tindall, 2013).

Timber harvesting is a main objective for many community forests and, in at least one case, generates significant employment in its region of British Columbia (McIlveen & Rhodes, 2016). However, there is considerable diversity in management values and priorities, with some strongly focused on protection of ecological functions and nature's contributions to people. Some community forests have diversified their activities through development of recreation and/or alternative forest products. For example, one community forestry initiative in Quebec developed an innovative approach combining timber and wild blueberry production. Revenues have been sufficient to support research on optimal conditions for co-habitation of trees and blueberries (Fournier, 2013).

Traditional forest management for subsistence uses tends to be informed by traditional knowledge and customary local regulations (Gibson *et al.*, 2000). In turn, community forestry for commercial purposes is informed by management plans that are based on scientific forestry with no obvious role for indigenous knowledge. Often, these plans are inspired by large-scale industrial timber-harvesting schemes.

In the Amazon, there are four general schemes of community timber harvesting: (1) traditional harvesting of forest products aimed to meet subsistence needs; (2) locally devised schemes to carry out commercial timber harvesting; (3) harvesting agreements between communities and loggers; and (4) formal community forestry on the basis of legally authorized management plans as described above (Sabogal, de Jong, Pokorny, & Louman, 2008). The species, volumes, areas, and management schemes of the forest operations vary strongly between and within these schemes and the context under which they occur. A key contextual factor is tenure. For example, some indigenous people and communities have been granted collective tenure, and others hold collective rights in extractive reserves, yet others have not been recognized with customary collective or individual tenure, which affects the community's possibility to legally use timber.

Informal logging operations tend to be highly selective of high-value species such as for example *Swietenia macrophylla, Manilkara huberi, Mezilaurus itauba, Handroanthus serratifolia*. While traditional logging practiced by communities works with motor-manual practices and concentrates on small areas up to 20 hectares with extraction volumes of around 50m^3 in the entire area, formalized community forestry operations may cover extraction areas of up to 1,000 hectares and volumes extracted range from 5-20m^3 per hectare. In accordance with Reduced-Impact-Logging principles, many in the Amazon region follow formally approved management

Box 3 18 **Coomflona in Flona Tapajos, Para, Brazil.**

Tapajós National Forest is a government-owned land with community use designated as protected area with sustainable use of natural resources. Located in the state of Pará, in the Brazilian Amazon, Tapajós National Forest occupies an area of 527,319 ha of mostly dense tropical forest characterized by the dominance of large trees under a climatic regime of high temperatures and intense precipitation distributed throughout the year (Humphries, Andrade, & McGrath, 2015; IBAMA, 2004; Silva, de Carvalho, & Lopes, 1985). Over 24 forest-based communities are based in the area. Approximately 500 indigenous people and 5000 local people live within Tapajós National Forest. They have diversified livelihood strategies which include agriculture, non-timber forest products, timber, and fishing (Andrade, de Carvalho, ilva-Ribeiro, & Dantas, 2014; ICMBio, 2015).

Tapajós National Forest residents founded a local timber cooperative, the Mixed Cooperative of the Tapajós National Forest (Coomflona) to manage tropical timber resources. The members include 150 forest residents from the 24 communities. With few exceptions, Coomflona hires external labor for work such as lawyer, forest engineer, and forestry machinery operators. The access to forest is collective, since every cooperative-member has the right to vote and make decisions over forest resource management. Decisions are made during general assemblies, held during the first three months of the year, and a cooperative executive committee operationalizes management decisions (Espada & Vasconcellos Sobrinho, 2019; Humphries, 2016).

Coomflona has a permit to manage timber with non-onerous (zero-cost) concession from the federal government, and every year it has to submit an operational plan to get the approval from the government to execute timber-harvesting operations. Currently, the total timber harvest area covers 44,000 ha, and represents 8% of the total area of the Tapajós National Forest. Annually, Coomflona now manages an area of 1,500 ha, which has steadily increased since its first year of timber-harvesting operations in 2006. They manage for a cutting cycle of 30 years (Espada & Vasconcellos Sobrinho, 2019; Humphries, 2016). Coomflona implements reduced impact harvesting techniques, removing 3 to 4 whole trees per hectare. The main log extraction equipment in a skidder, and around of 30,000 meters cube of roundwood are harvest every year (Humphries *et al.*, 2015).

Coomflona, with the support of its partner organizations, achieved several notable accomplishments. First, the cooperative has secured financial resources for forestry operation costs, critical in community forestry. Second, the cooperative created an innovative system of funds in which to allocate net profit from timber sales to benefit timber workers, their families, and communities, and beyond, local people that do not participate directly in the cooperative. Third, Coomflona invested in a portable sawmill and small-scale carpentry to verticalize timber production, aggregate value to timber products, expand market strategies, and engage additional community members in timber production. Fourth, Coomflona has established long-term and strong partnerships with diverse organizations. Fifth, Coomflona has become a model for other community-based groups aiming to manage timber resources in sustainable-use protected areas, as in the cases of extractive reserves. Sixth, Coomflona is running timber management with good practices considered in the forestry sector; the Forest Stewardship Council certification, for instance, certifies that Coomflona is maintaining forest health and ecosystem functions while provisioning both local social and economic benefits.

plans drawing on timber inventories and respect defined cutting cycles (Sabogal *et al.*, 2008). However, most frequently, timber on communal lands is harvested by local loggers on the basis of informal arrangements that pay the communities or the communitarian leader a lump sum for the right to harvest the forests. While these arrangements typically are unfair and often the logger doesn't hold his promise, it provides communities the opportunity for an easy income (Medina, Pokorny, & Campbell, 2009) (**Boxes 3.18** and **3.19**).

In protected areas an important timber management experience operated collectively by community-based enterprises takes place in the Mayan Biosphere Reserve, a protected area of 2.1 million ha established in 1990s (Radachowsky, Ramos, McNab, Baur, & Kazakov, 2012). A total of 12-community concession contracts (for areas ranging from 7,000 ha to 85,000 ha for a total of 390,000 ha) were signed between 1994 and 2001 (Stoian, Rodas, Butler, Monterroso, & Hodgdon, 2018). All concession contracts required collective organization: three forms emerged i) limited liability companies or civil societies *(Sociedades Civiles)*, ii) civil associations, and iii) cooperatives. Community concession contracts are legal agreements between the state and an organized group composed of members living in a given community. These

Box 3 19 **Ejido Petcacab-Quintana Roo, Mexico, drawn from (Wilshusen, 2005a, 2005b).**

Local communities own approximately 45% of Mexico's forests and have relative autonomy to manage them. Some of these communities have established community forest enterprises in order to generate benefits, such as jobs (Frey *et al.*, 2019). In the Mexican state of Quintana Roo, tropical forest ecosystems dominate the landscape. Forest types vary by soil, topography and local climate: medium-stature forests (15 to 25 meters) are present on well-drained soils, while shorter forests occur on seasonally inundated wetlands depressions. Mahogany *(Swietenia macrophylla)* and Spanish cedar *(Cedrela odorata)* were historically the most important commercial tree species, but in recent decades lesser-known tropical species have come to constitute around 70% of the harvest (Ellis *et al.*, 2015). As of 1992, the harvest was managed by four associations of forestry ejidos through community forest enterprises with a combined allowable cut of 10,580 m^3 per year of mahogany and cedar from 393,481 ha of permanent forest areas (Flachsenberg & Galleti, 1999). Up until 1983, logging was carried out first by small private concessionaires and later by a parastatal company, with wildly fluctuating annual volumes between 10,000 and 50,000 m^3. Beginning in 1984, community management produced a striking reduction and stabilization of harvests of mahogany and cedar going from 10,000 m^3 annually, a 78% reduction from the last five years of the parastatal to around 5,000 m^3 in 2018, and foresters consider this to be sustainable (Bray, 2020; Navarro-Martínez, Ellis, Hernández-Gómez, Romero-Montero, & Sánchez-Sánchez, 2018).

Petcacab is an ejido, a common property land grant in Mexico's agrarian system, inhabited by Mayan indigenous peoples. It is located in Central Quintana Roo, with an estimated population of 947 and 206 legal members of the ejido. The property regime is communal with a total land area of 46,000 hectares and permanent forest area of 32,500 hectares. Petcacab's community forest enterprise was initially organized in the mid-1980s with external support from the Forest Pilot Plan, supported by the Mexican government and German foreign assistance. Petcacab initially organized its community forest enterprise as an entirely community-administered operation, supervised by community authorities. However, due to concerns about corruption, in 1996 Petcacab reorganized its community forest enterprise to be administered by what are termed "work groups" or coalitions of community members based on family clans and individual families. Access to communal lands by community groups, approved by the community assembly, was permitted by a 1992 reform to agrarian law. By 2000, Petcacab had 11 work groups who each received a proportional share of the annual authorized volume, and essentially managed themselves as small, separate community forest enterprises or microenterprises.

All of the work groups operated under a single management program prepared by a professional forester and approved by the Mexican environmental agency. In the 2000s Petcacab had authorized harvest volumes of 1,499 m^3 of mahogany, 2,545 m^3 of tropical softwoods, 3, 927 m^3 of tropical hardwoods and 10, 328 m^3 of polewood, with a decline in the volume of mahogany in more recent years. Production is small-scale industrial, with the use of tractors and skidders for extraction and logwood is sold to a community sawmill or intermediaries. Harvests are regulated by Mexican forest and environmental laws and compliance is considered good.

The work groups sell both logwood and sawnwood, after processing at a community sawmill. Most timber is sold domestically in Mexico. Benefits go to the individual work groups, with little or no reinvestment in the community or the community sawmill. Harvests are conducted according to the management programs with little or no input from indigenous knowledge. Harvests of mahogany have declined in recent years but are considered sustainable at current more reduced levels. Socially, the work groups have allowed for increased incomes at the work group and household level, but with a corresponding decline in community investments in public goods. The apportionment of the authorized volumes to individuals has led to a market in the shares of authorized volumes and increasing economic inequality with the ejido as some members purchase others shares. Economically the work groups appear to be profitable, and the work group arrangements appear to be sustainable.

25-year concession contracts allowed concessionaire members rights to manage and extract timber and non-timber forest products recognizing also rights to implement nature-based tourism activities in protected areas. This system of community concessions in the Multiple Use Zone (MUZ) represents about 15% of the country's total forest cover, including national parks (IARNA/URL/ILA, 2006). The area under forest concessions covers more than 480,000 hectares. To date, nine community concession contracts remain active (around 350,000 hectares) (Stoian *et al.*, 2018).

Compared to Latin America and South Asia, relatively little information on Africa was available. In Central Africa, the number of communities formally embracing community forest management has greatly increased over the last twenty years as all countries have included this management option in their forest legal frameworks. There are now more than a thousand of them, about 90% of which are in Cameroon. However, most of the community forestry operations validated by the authorities are either inactive, as in Cameroon (G. Lescuyer, Cerutti, & Tsanga, 2016), or oriented towards conservation, as in the Democratic Republic of Congo (Bauer, 2016). In total, only about 150 forestry communities are authorized in Cameroon, and about a hundred are created or in the process of being created in both Gabon and the Democratic Republic of Congo. There are no regional statistics on timber production from community forestry in Central Africa. Yet, based on case studies in each country, a maximum of 50,000m^3 would be legally extracted from community forestry harvesting operations in the Congo Basin (Beauchamp & Ingram, 2011; Julve *et al.*, 2013). Due to inadequate regulatory texts that are costly to apply for (Cuny, 2011), the vast majority of community forests that exploit timber do so illegally, destined for domestic markets that do not require timber of legal origin. There are no statistics on these illegal practices, but numerous reports from Cameroon (Nzoyem, Vabi, Kouokam, & Azanga, 2010) and Gabon (Ondo, Medik, Mijola, & Boussougou, 2020) indicate that informal timber-harvesting from community forestry operations far exceeds the volume legally extracted.

Generally, South Asia's forest dependent communities are the ones who are also the more disadvantaged in the region. Two categories of forest dependent people are identifiable. First, those who are traditionally the forest communities residing in and around forest areas for generations, such as tribal communities in India. Altogether, the population of this group is estimated to be 150 million in the region (World Bank, 2005). Second, people who depend on forests for a variety of products and nature's contributions to people but do not directly reside inside or in the vicinity of the forest. There are around 400 million forest users in this category (Poffenberger, 2000). More recently, rapid rural and urban and even overseas migration of youths has led to change in the conventional patterns of forest dependence, with reduced use of forest products in livelihoods (Ojha *et al.*, 2017).

In terms of policy shifts, South Asia has notable community forestry initiatives in terms of scale and demonstrated outcomes, although the actual form and operational modalities vary greatly across the countries and sub-national regions. Likewise, a variety of local regimes of community forestry are found: formally handed over state forests, jointly managed forests, 'sacred groves' with cultural values, community plantations, and other forms of collective land use for trees and pastures. The beliefs and rituals linked to sacred groves have helped to conserve biodiversity, although they are under threat due to changing values and perceptions (see section 3.3.5).

Forest harvesting status and trends data for community forestry are not readily available for most countries in South Asia. Available evidence suggests all the countries and their sub-national authorities are struggling to optimize forest harvesting in a sustainable, efficient, and equitable way. A significant part of the forest landscape is under protected area management, and there have been participatory and co-management shifts in this regime too, especially since early 1990s. Studies show that such participatory shift in protected area management has resulted in more active use of resources, as found by a study in Bangladesh (K. Islam, Nath, Jashimuddin, & Rahman, 2019).

In Bhutan, conservation rather than sustainable use mindsets dominate forest management policy and programs, and strategies and methodologies to promote sustainable harvesting are slow to develop (Phuntsho, 2011). Despite having nearly 70% of area under forest, Bhutan has kept harvesting level to a minimum, favoring import of forest products. The most significant wood-based import item is charcoal. In 2012, Bhutan imported charcoal worth 16.8 million United States dollars, comprising 1.4 percent of total imports and 60 percent of wood-based imports (MoF 2013, cited in World Bank (2019). The first national forest inventory published in 2017 and provides detailed data and information on Bhutan's forests, showing the Bhutan is under harvesting its forest below the potential (World Bank, 2019). A bottom-up approach to forest management in Bhutan began after the 1979 royal decree that called for the involvement of local people in tree planting activities (Phuntsho, 2011). Bhutan's community forestry policy emphasizes protection, conservation and sustainable use of forest resources in the country, together with contributions to poverty reduction and local democratization (Phuntsho, 2011). The level of harvesting in community forestry is no different than the national scenario. Following the adoption of a more decentralized and people-centered approach to forestry in the early 2000s, the number of community forestry management groups has increased rapidly since 2007. By 2018, there were 781 community forest management groups involving 32,402 rural households managing 92,165 hectares (3.0 percent) of forest land (MoAF, 2018; World Bank, 2019). Although the government is supportive to the implementation of the community forestry program, community forest management groups continue to face administrative hurdles with regard to timber marketing, leading to under-harvesting of forest stock (Samdrup, 2011).

Community forestry in Nepal emerged in the mid-1970s and led to the devolution of management and user rights to forest user groups, largely as a shift in the approach to conserve the hill forests in the context of degradation and deforestation. During the last three decades Nepal's community forestry programme has evolved in terms of coverage and institutional innovation, supported through appropriate changes in policies and legislation. Substantial international support has also helped to sustain community participation. Community forestry has contributed to livelihoods of nearly one-third of the country's total population, improved forest conditions and biodiversity, and above all, developed itself as a self-sustaining system involving a strong base of policy champions, service providers, and critical action researchers. By the end of 2019, over 22,000 community forestry user groups had been registered across the country, with rights granted to manage nearly two million hectares of forest areas (about a third of total forest areas of the country. Community forests are vital components of environmental resilience and nature's contributions to people not only to the people close by but also to large populations downstream. Dissipating fears of desertification, community forestry has led to improvement in forest ecology, with 74% of the forest area managed by community forestry user groups reported as in "good" condition, compared to 19% in "degraded" condition (Kanel & Kandel, 2004). Community forestry user groups also compare favorably to government forests in terms of change in forest condition (Nagendra, Pareeth, Sharma, Schweik, & Adhikari, 2008). More recent empirical evidence confirms improved biodiversity outcomes from community forestry (Luintel, Bluffstone, & Scheller, 2018). Nepal has a strong legislation that allows communities to enjoy perpetual rights over designated community forest areas. Such perpetual and sustained rights of access to forests have been key for the success of community forestry in Nepal (Acharya, Adhikari, & Khanal, 2008). Though the land ownership remains with the government, the tenure of forest biomass is transferred to the community through a detailed approval process. Community forestry user groups retain 100 percent of revenues generated from their forest, but they have to allocate 25% of the income to forest development activities and 35% to programs that directly benefit the poorest households within the community forestry user group. The existing forest law provides communities with enough rights to choose their objectives of forest management and harvesting, but too often the actual practices of regulation and bureaucratic oversights hinder active management of forests beyond subsistence use. Nepal has achieved massive scale community forestry development in terms of enabling policy and institutional development, but the actual use of forest is less than 30% of the annual sustainable harvest level. Despite having 45% of the country's area under forests, the contribution of the forest sector to local and national economy has remained much less than the potential in Nepal (Banjade, Paudel, Karki, Sunam, & Paudyal, 2011; Chhetri, Lund, & Nielsen, 2012; Luintel, Bluffstone, Scheller, & Adhikari, 2017; Thoms, 2008). As the national mood has recently shifted towards active forest management, several attempts have been made to develop and scale up silviculture innovations. These have stimulated debates in scientific forest management, though outcomes on the ground have remained limited.

Community forestry in Sri Lanka has developed somewhat similarly to Nepal, but began in the 1990s. The community forestry project was initiated in Sri Lanka after a series of forest policy reforms and decentralization arrangements during the 1980s. Since 2003, the Department of Forest Conservation, a government department responsible for forestry in Sri Lanka, has been testing and trialing various approaches using the community forestry model (Ekanayake, Xie, Ahmad, Geldard, & Nissanka, 2020). Community-based forest management in Sri Lanka encompasses community-owned forests and agro-forests as well as government-owned forests managed by communities. Forests managed by communities produce timber and wood products in agroforestry systems, on agricultural lands and community lands including farmer woodlots and silvopastoral systems (De Zoysa, 2017). The home gardens, outside natural and planted forests supply more than 70% of the timber and 80% of the fuel wood in Sri Lanka (De Zoysa, 2017). Recent studies have shown that impact of community forestry development has led to positive outcomes on livelihoods (Ekanayake *et al.*, 2020).

In India, large scale shifts from state control of forest to joint management with local communities has led to a large area of forest being managed under joint forest management. Joint forest management covers more than 22 million hectares which is about third of the forest land in India, engaging 25 million people through 104, in 729 committees across more than 100,000 villages (Sundar, 2017). Like Nepal and Bhutan, a conservative approach to forest harvesting dominates forest management practices across all regimes of public forests.

India's average annual yield of forest is estimated as 85.65 million m^3, whereas the annual removal of only 5.85 million m^3, which is 6.82% (FSI, 2019). Total growing stock is estimated to be 5915 million m^3 and the growing stock of trees outside forest is 1642 m^3 (FSI, 2019, p. 117). Total forest coverage between 2010 and 2020 increased in India by 0.38% (FAO, 2020a). Timber production from public forest meets only the 3.35% of the total demand, while trees from outside areas officially classified as forests provide 45% of the demand (Ghosh & Sinha, 2016). It is suggested that community forests managed by indigenous people and local communities are more likely to harvest in sustainable ways than those managed by the government (Sundar, 2017). Despite government efforts to raise domestic productivity, India's overall timber production remains low. This is especially true for the tree species preferred by consumers such as teak, sheesham and pine (Norman & Canby, 2020). The International Union of Forest Research Organizations estimates that India was the third-largest importer of illegally logged timber in the world in 2016, after China and Vietnam (Kleinschmit *et al.*, 2016). While its own forests are under harvested, India is emerging as a major importer of timber (Vanam, 2019). The demand for timber is growing from the current gross value added of 606 billion United States dollars in 2011 (FAO, 2014a). However, restrictive policy and regulatory barriers inhibit community forestry groups from harvesting and selling surplus timber from their forests even when supported by sustainable forest harvesting protocols (Shyamsundar, Ahlroth, Kristjanson, & Onder, 2020). India's joint forest management is an arrangement for co-management between local communities and the Department of Forest. Typically, the joint forest management committee holds a joint account in the local public sector bank with the chairperson, vice-chairperson and the district forest officer or her nominee as joint signatories through which financial aid from donor and the government is channeled (Sundar, 2017). The district forest officer prepares forest management plans in consultation with the communities.

3.3.4.3.3 Industrial Logging practice

In practice there are three major types of industrial logging: (i) most frequently, so-called private concessions grounded on an agreement between a private landholder and the logger or by the landowner himself, mostly on a short-term basis and sizes of some few hundred to thousand hectares; (ii) government granted concessions in public forests (~1.5 M hectares by 2019) (J. R. Ribeiro, Azevedo-Ramos, & Nascimento dos Santos, 2020) based on a set of technical, financial, and administrative requirements, that comprise several ten thousand hectares for an entire timber-harvesting cycle; (iii) the legal use of timber from authorized forest conversion areas in private landholdings. Nearly all industrial logging is organized by sawmills to secure their supply.

Large-scale industrial logging involves felling large numbers of trees in areas of more than 50,000 ha. The loggers have felling permits, use heavy machinery, have a processing plant and sell a number of wood products including logs, sawnwood, veneer, plywood, and wooden floors, almost exclusively for export (Cerutti & Lescuyer, 2011). In the last three to four decades, industrial logging has been the major source of globally traded wood products (FAO, 2009). For example, in Papua New Guinea, large-scale industrial logging companies export approximately 90% of the logs harvested in the country (PNGF, 2009).

Large scale forestry operations occurring within managed forests and tree plantations were estimated to cover 26% of global forest area between 2001 and 2015 (mainly in America and Europe) (Curtis, Slay, Harris, Tyukavina, & Hansen, 2018). Within some tropical countries, a small number of large-scale companies who source much of their timber from small and medium sized enterprises dominate the export sector (Osei-Tutu *et al.*, 2010). Allocation of forests or trees for large scale industrial logging in public and large-scale privately owned forests is predominantly done through the provision of forest concessions (Vilanova, Ramírez-Angulo, Ramírez, & Torres-Lezama, 2012), which is a common legal tool among forest policy decision-makers (Karsenty *et al.*, 2008). Forest concessions have been carried out for hundreds of years in boreal, temperate and tropical public forests (Van Hensbergen, 2016). Forest concessions have been carried out in many of the Central African forests for over a century (since the colonial rule), and in South American countries for over three decades (Karsenty *et al.*, 2008). Within Latin America, Southeast Asia and West & Central Africa, forest concessions cover about 123 million ha accounting for approximately 14% of the publicly owned forests (Van Hensbergen, 2016).

Conventional logging is highly selective, sometimes concentrating on only one or two species. Selecting and felling trees often occurs without a complete inventory or thorough spatial planning. In large-scale conventional logging there may be issues with incorrect identification, poor labor conditions, insufficient training in best practices, and overly high felling rates. These conditions can lead to immense damage and economic losses (Piponiot *et al.*, 2019).

Since the 1950s, clear-cutting involves the use of heavy timber machinery (Boucher, Auger, Noël, Grondin, & Arseneault, 2017; Maleki, Nguema Allogo, & Lafleur, 2020; Mohr, Coppus, Iroumé, Huber, & Bronstert, 2013), which may lead to changes in tree composition and oversimplification of stand structure and species diversity (Boucher, Arseneault, Sirois, & Blais, 2009; Boucher *et al.*, 2017; Gustafsson, Kouki, & Sverdrup-Thygeson, 2010). These activities can have negative effects on wild plant and animal populations (Berg *et al.*, 1994; Gärdenfors, 2010; Hyvärinen, Juslén, Kemppainen, Uddström, & Liukko, 2019; Kålås, Viken, Henriksen, & Skjelseth, 2010). Log skidding, done with heavy machinery, can also be damaging if done during improper weather conditions or during the wrong season when soils are especially vulnerable.

Industrial logging is done with and without legally authorized management plans. A correct tracing of the logs to their point of origin varies widely so loggers may use management plans to justify harvesting adjunct areas technically not under the plan. The vast majority of sawmills in the tropics work with this kind of timber-harvesting. They have small teams of mostly non-local seasonal workers and use tractors for both the construction of access roads, secondary roads, and landings as well as for the skidding (Pokorny & Steinbrenner, 2005). Larger companies may also use skidders and stackers for loading. Sometimes machinery is owned by the sawmill, sometimes services are subcontracted. Transport distances from the forest to the sawmill may reach up to nearly 100 km (Pokorny & Steinbrenner, 2005). However, if the distance becomes too large, the saw lines are dismantled and rebuilt closer to the forest.

Alternative "sustainable forest management" schemes are meant to ameliorate several of the concerns raised regarding species identification, spatial planning, proper use of equipment, and proper application of management plans. More sustainable forest management is well planned so as to minimize damage on the remaining stand while effectively making use of costly heavy machinery. This includes infrastructure planning, spatial planning of harvesting operations, harvest planning based on an inventory of all commercially valuable trees, and skid-trail planning (Putz *et al.*, 2012).

In tropical and subtropical regions such harvesting is done by larger companies with the necessary human and financial resources and engaged in export activities often linked to Forest Stewardship Council (FSC) certification (Pokorny & Steinbrenner, 2005). Certification requires the demarcation of protected areas, and the timber-harvesting of a wider range of tree species, including the ones with lower commercial value, so as to reduce the pressure on the most valuable tree species (Putz *et al.*, 2008). The engagement of the certifier has positive effects on the quality of the operation, the treatment of the workers and the local resource users living around the management unit. However, certified companies tend to work as enclaves in the forest landscape and prefer to work with non-local workers. They prioritize fast timber-harvesting and hesitate to invest in the long-term security of the management unit once the area has been logged. These practices place the long-term sustainability of these certified operations in question.

Since the 1980s, variable retention forestry is being promoted as a sustainable forest management practice in temperate and boreal forests as opposed to clear-cutting (Fedrowitz *et al.*, 2014; Franklin, Berg, Thornburgh, & Tappeiner, 1997; Harkema & Scott, 2002; Kuuluvainen & Grenfell, 2012). It is a system in which key structural components of the original stand are retained at the time of logging through selection cutting, gap cutting and modifications of clear cutting, and become part of a new stand that regrows after logging (Franklin *et al.*, 1997; Gustafsson *et al.*, 2010; Koivula *et al.*, 2014; Koivula, Silvennoinen, Koivula, Tikkanen, & Tyrväinen, 2020; Puettmann, Messier, & Coates, 2009). Emerging research reveals that tree retention has the potential to reduce impacts of logging on forest biodiversity through creating favourable conditions that allow for complex and uneven forest structures similar to those of natural forests (Gustafsson *et al.*, 2020; Moussaoui, Leduc, Fenton, Lafleur, & Bergeron, 2019; Opoku-Nyame, Leduc, & Fenton, 2021). The practice is being adopted with rather modest retention levels ranging from 30 to 40% (Beese, Deal, Dunsworth, Mitchell, & Philpott, 2019; Scott, Neyland, & Baker, 2019). Though retaining small amounts of trees or patches is better than traditional clearfelling (Gustafsson *et al.*, 2020; Koivula & Vanha-Majamaa, 2020), only retaining a minor proportion of the volume of harvestable timber (often 1-10%) makes it practically impossible to avoid edge effects and random demographic effects on the forest stands. Maintaining more of the mature forest characteristics in production forests would require lower harvest intensities in some areas than is currently typical. Therefore, this low level of retention is still considered by some scholars as clear-felling (Fedrowitz *et al.*, 2014).

Prevailing retention practices have been reported to lack ecological credibility in safeguarding biodiversity and there are calls for their further development (Kuuluvainen, Lindberg, Vanha-Majamaa, Keto-Tokoi, & Punttila, 2019). Other studies have reported that it is not necessarily the level of retention of living trees, but rather, the microclimatic continuity, and maintenance and active increase of legacies such as existing coarse woody debris, very old trees, and tree species mixtures that significantly contribute to the conservation of forest species (Koivula & Vanha-Majamaa, 2020; Siitonen, 2001).

Diversification of silvicultural harvesting techniques is recommended to enhance specific structural or compositional elements and the diversity of species in forest stands. Either clear-cutting, partial cutting or selective cutting can be carried out to match variations in stand conditions and effects of natural disturbances, biophysical site characteristics and succession processes (Bergeron, Gauthier, Kafka, Lefort, & Lesieur, 2001; Harvey & Bergeron, 1989; Maleki *et al.*, 2020). Clear-cutting tends to allow cycling of early successional species into a single species dominant stand, while partial cutting and extended rotations can enable maintenance of a mixed species stand or stands that have some characteristics of older forests (Ruel, Fortin, & Pothier, 2013).

Post-logging forest restoration greatly relies on post logging seedling generation. The ability of a species to be sustained through rotations depends on the growth and reproduction of surviving adults, juveniles and seedling regeneration (smith *et al.*, 1997). However, many of the high-value timber species are nonpioneer light demanders whose seedlings occur at low densities in the forest understory due to limited shade tolerance (Grogan, Landis, Ashton, & Galvão, 2005; Gullison & Hubbell, 1992; Hall, Medjibe, Berlyn, & Ashton, 2003; Jones, 1956; Lamprecht, 1989; Medjibe & Hall, 2002; M Schulze, Vidal, Grogan, Zweede, & Zarin, 2005), such as wind-dispersed mahoganies and related genera in the family Meliaceae (Swietenia, Cedrela, Chukrasia, Entandrophragma, Khaya, Toona), Amburana, Cedrelinga, Couratari, Dinizia, Hymenolobium, and Tabebuia. These usually have limited post-logging regeneration (Dickinson & Whigham, 1999; Grogan, Galvão, Simões, & VerÍssimo, 2003; Gullison, Panfil, Strouse, & Hubbell, 1996; Schulze, 2003, p. 2003; Veríssimo, Barreto, Tarifa, & Uhl, 1995) and thus require adjustment in logging and silvicultural practices to promote their regeneration. To ensure sustained yield timber production from such timber species across the tropics, there are a number of silvicultural practices that should be taken into consideration (Grogan & Galvão, 2006).

Economically, timber-harvesting is most profitable for the traders, particularly if engaged in export markets. Conventional, particularly illegal, timber-harvesting, is also profitable for the owner of the sawmill, but also provides urgently required income opportunities for local people, not so much in the forest operations, but in the sawmills (Pokorny, 2013). The benefits of large-scale industrial logging to the local economy are usually limited (Gray, 1999) to some low-paid work, but loss of non-timber forest products which many local people often rely on for subsistence or livelihood diversification can have serious negative impacts (Adams, 2009). Benefits to the national economy are restricted, because while value is added to the timber when it is sawn and made into products, this typically takes place elsewhere (Adams, 2009). The main products obtained are round logs which are directly exported with very little in-country downstream processing. In instances where companies obtain concessions from private or community forests, these give royalties to the owners which depend on the tree species harvested. Nevertheless, large concessions seem to be a suitable tenure model in low-density areas where central or local governments are not capable of creating or maintaining adequate infrastructure to support regional economic issues and where only large-scale companies have the potential to do so (Karsenty *et al.*, 2008).

Social impacts are felt due to large amounts of migrant labor associated with industrial logging. A larger proportion of the workers in large-scale industrial timber-harvesting operations are permanent, but are brought from other regions and seldom become settled in a region. Concessionaires, especially including certified companies, have to effectively protect their management unit against informal harvest and encroachment. Accordingly, local resource users living in and around concessions suffer from restricted access to forest management areas. In Central Africa, the social impact of industrial timber-harvesting remains a contested issue. Taxation systems and services due to workers and the local populations are clear on paper, but there is limited transparency or availability of information about how much of the due amounts or promised services are actually paid into the State coffers or delivered locally. And while there seems to be a bit more clarity on the amounts of money that are collected and redistributed to local councils and villages, e.g., in Cameroon (Cerutti, Lescuyer, Assembe-Mvondo, & Tacconi, 2010) and the Democratic Republic of Congo (Tsanga, Cerutti, Bolika, Tibaldeschi, & Inkonkoy, 2020) much of the burden of redistributing benefits to local populations remains within the concessionaires themselves, which are not always willing or capable of playing that role (Cerruti *et al.*, 2017).

Ecological, economic and social sustainability can perhaps be achieved through continuous-cover forest management (e.g., Fedrowitz *et al.*, 2014; Franklin *et al.*, 1997; Kuuluvainen & Grenfell, 2012). This regime applies logging methods other than clear cutting and thus varies the amount and spatial distribution of retained trees, and the size of harvested openings. The logging methods include selection cutting, gap cutting and modifications of clear cutting, all characterized by maintaining a significant proportion of trees throughout the logging cycle (e.g., Koivula *et al.*, 2014; Puettmann *et al.*, 2009).

Experimental evidence suggests that even modest retention of living trees in harvested blocks is beneficial for biodiversity (Koivula & Vanha-Majamaa, 2020). Also, based on landscape preference research, retention methods may be preferred over clear cutting by citizens who use forests for aesthetic pleasure, recreation, hunting, or harvesting (see 3.3.4.4). Clear cutting decreases the aesthetic and recreational values of forests (e.g., Arnberger *et al.*, 2018; Karjalainen, 2006; Tyrväinen, Silvennoinen, & Hallikainen, 2017), whereas logging methods with a high amount of retained trees, such as selection cutting, are considered socially more acceptable (Putz *et al.*, 2008; Ribe, 1989). Citizens prefer forests with diverse tree ages, species, and sizes (Silvennoinen, Alho, Kolehmainen, & Pukkala, 2001; Silvennoinen, Pukkala, & Tahvanainen, 2002; Tyrväinen *et al.*, 2017) with not too densely spaced trees (Ribe, 1989; Silvennoinen, 2017).

Industrial logging is quite extensive in the tropics **(Box 3.20)**. It takes place legally on public and private lands, and illegally on public forests designated for conservation. Logging also occurs on indigenous people and local communities' lands and territories. Forest concessions have been widely used to allow companies to undertake large-scale timber-harvesting operations, yet these areas have been shrinking over time, particularly in the Amazon (e.g., Bolivia, Peru) and Southeast Asia (e.g., Malaysia and Indonesia). There are significant areas of public lands granted as concessions on all continents. In 2009, small properties accounted for 28% of production, medium-sized properties extracted 41% of wood and large properties supplied 31% of roundwood (Pereira, Santos, Vedoveto, Guimarães, & Veríssimo, 2010). Only 29% of production in 2009 came from areas owned or leased by the timber industries. The remainder (71%) originated in third party areas.

Throughout the tropics, forestry regulations commonly grant rights to industrial, large-scale, export-oriented timber-harvesting concessions. These concessions require management plans, which are presumed to maintain forest cover and biodiversity. All countries in Central Africa follow the concessionary model, with the Ministries of Forests granting rights and responsibilities to the concessionaire (i.e., a private entity is given permission to manage a public property) either through public auctions or directly. The duration of the contract varies. In the Central African Republic, the concession is granted for the entire lifespan of the company, in all other countries there exist legal temporal limitations to the contractual agreement, which is 15 years in Cameroon, Republic of Congo and Equatorial Guinea, 25 years in the Democratic Republic of Congo, and 30 years in Gabon (Cerutti, Nasi, & Center for International Forestry Research (CIFOR), Kenya and Indonesia, 2020). Timber-harvesting concessions comprise a total area of 50 million ha in the Congo Basin, of which about half had approved management plans by 2020 (Cerutti *et al.*, 2020). Management plans are generally based on a rotation period of about 30 years, with annual allowable cuts authorized for timber-harvesting each year by the forest administration.

Logging in the boreal and temperate forests is mainly industrial in scale (Safford & Vallejo, 2019). Approximately 90% of the forest in Fennoscandia, and perhaps 40% and 60% of Canadian and Russian forests, respectively are subject to industrial tree harvest (Gauthier, Bernier, Kuuluvainen, Shvidenko, & Schepaschenko, 2015). Prior to the 20th century, selective cutting was the dominant logging practice in the temperate and boreal forests. An intensive era of clear-cutting targeting mainly conifer trees began in the 20th century due to economic factors (Dupuis, Danneyrolles, Laflamme, Boucher, & Arseneault, 2020; Koivula & Vanha-Majamaa, 2020; Lundmark, Josefsson, & Östlund, 2013; Storaunet, Rolstad, Gjerde, & Gundersen, 2005). Clear-cutting continues to be the dominant logging

Box 3 20 Industrial logging in the Amazon.

In 1998, the Brazilian Amazon generated 10.8 million cubic meters of native wood. Twenty years later, only 57% of this volume was produced (~ 6.2 million m^3 (Lentini, Sobral, & Vieira, 2020). This was due to increasing competition with cheap supplies of forest products from tree plantations and contractions in the domestic market, as well as replacement with other materials such as plastics, steel and aluminum. An estimated 95% of the sawmills in the region are small family enterprises with very limited managerial capacity. Despite operations based on legally approved management plans, it is unclear whether this logging is sustainable. The extraction (cutting and skid trails) is performed mostly (61%) by third parties, while the rest (39%) is extracted by the processing industries themselves (D. Pereira *et al.*, 2010). The Amazon has more than 300 species of trees considered commercially valuable (Martini, Rosa, & Uhl, 1994). However, for decades the very same 15 to 20 species of commercial interest were harvested. Some of the most strained and consequently most pressured species are: *Hymenaea courbaril, Handroanthus sp, Apuleia leiocarpa, Goupia glabra Aubl., Manilkara alata, Himenolobium petreum, Couratari* sp., *Dinizia excelsa* (Lentini *et al.*, 2020). Manifold attempts to broadening this range have not been too successful. Only very few large companies have the interest and capacity to comply with the Forest Stewardship Council certification standard. It is estimated that less than a quarter of the timber produced in the Amazon is exported, as most of the timber is consumed in the big cities at the coast. Depending on the forest type and the market situation, between 10 to 25 m^3 per hectare is harvested. Increments of commercial timber are low around 0.5 to 1.5 m^3 per year and hectare, which mathematically result in harvesting cycles of around 25 to 35 years (Pereira *et al.*, 2010).

The regulations established in the Brazilian Amazon assume that a minimum harvest cycle of 25 to 30 years would guarantee the long-term sustainability of forest management. The legal requirements for industrial timber harvest include clarified tenure arrangements for the forest management unit, the formulation of a sustainable forest management plan, and annual operational plans. The volumes and products of harvested wood have to be reported in a document of forest origin (DFO) designed to accompany legally harvested wood at all stages of the transport and production chain (Waldhoff & Vidal, 2015). The regulations foresee two categories of forest management: 1) Low-intensity forest management, normally by local communities, with a maximum harvest volume of up to 10 m^3 per ha, a minimum harvest cycle of 10 years, and restrictions on the use of heavy machinery; 2) Complete forest management, which allows a maximum harvest volume of 30 m^3 per hectare and year, minimum harvest cycles of 25 to 35 years, and without machinery restrictions (Pereira *et al.*, 2010).

practice (Curtis *et al.*, 2018; Kålås *et al.*, 2010; Siitonen, 2001), although trials for partial cutting practices, such as retention silviculture have been established to test their operational and biological feasibility (Bose, Harvey, Brais, Beaudet, & Leduc, 2014). In clear-cutting, mature trees are usually completely removed, followed by regeneration through site preparation, sowing or planting, tending of the emerging cohort of even-aged trees, and often a relatively short logging rotation (Koivula *et al.*, 2020; Safford & Vallejo, 2019). An underlying rationale of clear-cutting is economic because it is seen as highly efficient and leading to sustained yields of timber (Koivula *et al.*, 2020). The concept of sustained yield has been criticized for only concentrating on the maintenance of timber stocks over time, while other forest resources that are protected with site-specific practices are not explicitly considered in the management plans, consequently leading to their decline (Berg *et al.*, 1994; Cyr, Gauthier, Bergeron, & Carcaillet, 2009; Luckert & Williamson, 2005).

Tree retention is an emerging alternative to clear cut harvesting, practiced on several continents including North and South America, Oceania, and Europe (Gustafsson *et al.*, 2020). Emerging research reveals that tree retention has the potential to reduce impacts of logging on forest biodiversity through creating favourable conditions that allow for complex and uneven forest structures similar to those of natural forests (Gustafsson *et al.*, 2020; Moussaoui *et al.*, 2019; Opoku-Nyame *et al.*, 2021). Though even leaving small amounts of trees or patches is better than traditional clear-felling (Gustafsson *et al.*, 2020), tree retention comprising a minor proportion of the volume of harvestable timber (often 1-10%), which makes it practically impossible to avoid edge effects and random demographic effects on the forest stands. Maintaining more of the mature forest characteristics in production forests would require lower harvest intensities in some areas than is currently typical. Determining exact levels that are required to secure long-term viable populations of different species, as well as the most cost-efficient implementation of these conservation measures, remains a major challenge for future research (Gustafsson *et al.*, 2010).

There is a continued increase in the amount of wood removals globally through industrial logging practices **(Figure 3.56)**. In 2019, global wood removals were estimated at 3.97 billion m^3, of which 2.02 billion m^3 was industrial roundwood and 1.95 billion m^3 fuel wood. The year 2018 had the highest level of production and trade values for global wood removals and all major wood-based products since 1947 (data from the Food and Agriculture Organization of the United Nations, http://www.fao.org/faostat/en/#data). The demand for and the consumption of wood products is escalating in line with growing populations and incomes, a trend expected to continue in the coming decades (FAO, 2010b). North American and European countries have the highest global wood yields (Chaudhary, Carrasco, & Kastner, 2017), which is partly attributed to clear-felling regimes prevalent in temperate Europe/North American countries with high yields

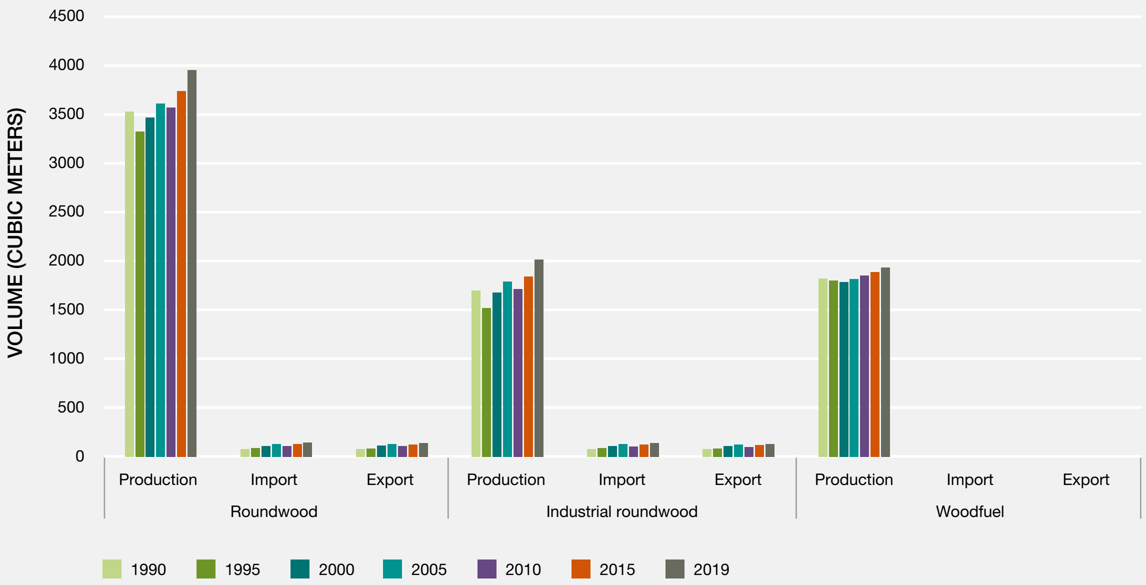


Figure 3 56 **Global wood removals 1990–2019.**

Data from FAO database (FAO, 2021b) under license CC BY-NC- SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453131.

compared with low-yield selective logging in the tropics (Chaudhary, Burivalova, Koh, & Hellweg, 2016). There are also large-scale imports of timber products by a limited number of countries especially China and the United States of America. The globalization of trade has enabled such countries to reduce local forest exploitation and achieve forest transitions from net deforestation to net reforestation (Kastner, Erb, & Nonhebel, 2011; Meyfroidt, Rudel, & Lambin, 2010; Mills Busa, 2013).

Some of the logging practices in species-rich tropical forests have been reported to resemble mining operations at the species level (Gómez Pompa, 1989; N. Johnson & Cabarle, 1993; Moad & Whitmore, 1994; M Schulze *et al.*, 2005), where a single, or group, or wider community of high value timber species are targeted for extraction. In the past, major target species included the big leaf Mahogany *(Swietenia macrophylla)*, Brazilwood or Pau-brasil *(Caesalpinia echinata)*, Brazil-nuts *(Bertholletia excelsa)*, rosewood (*Dalbergia nigra* and *Aniba rosaeodora*) and others (Martini *et al.*, 1994; Mark Schulze, Grogan, Landis, & Vidal, 2008; Veríssimo *et al.*, 1995). Due to these practices, some species were reported endangered and added to Appendix II of Convention on International Trade in Endangered Species of Wild Fauna and Flora. With scarcity and restrictions in extraction and trade of the Convention on International Trade in Endangered Species of Wild Fauna and Flora listed species, new species are targeted. This practice has led to severe and dense reductions of adult populations or old growth timber stocks, often at large spatial scales (Uhl, Veríssimo, Mattos, Brandino, & Vieira, 1991; Veríssimo, Barreto, Mattos, Tarifa, & Uhl, 1992; Veríssimo *et al.*, 1995).

Land occupation and timber extraction through conventional industrial logging has generated a culture of timber mining in many forest landscapes in the tropics, which has proved to be very persistent among some local stakeholders making an income from industrial timber extraction, which translates into low investments in operations or forest recovery. These cultural aspects of timber extraction in the tropics have been little studied, as well as shifts in social perceptions over time.

3.3.4.4 Uses

Like with the other practices reviewed in section 3.3, available knowledge on logging for a variety of uses was reviewed. In the case of logging, the relevant uses include decorative and aesthetic, energy, and shelter and construction. While it is certainly the case that many wood and tree products are used for ceremonial and cultural expression, food and feed, and medicine and hygiene, based on the definition of logging used in this assessment, these other uses (and the associated tree products) are discussed in the section on gathering (3.3.2).

3.3.4.4.1 Decorative and aesthetic

Harvesting timber for wood carvings is mainly a destructive process. The entire tree is felled at the trunk between 5 and 50 cm from the ground using a metal axe or chain saw and machetes, and the artists cut different lengths of timber from the fallen tree for their carvings (A. D. Griffiths, Philips, & Godjuwa, 2003; Koenig, Altman, & Griffiths, 2011; Purata, Brosi, & Chibnik, 2004). In other instances, only the prime section of the stem is removed, leaving the rest of wood in the forest. (B Belcher *et al.*, 2002). Tree sizes are selected based on the size and nature of the sculpture to be made. This can depend on the cultural subject matter (Koenig *et al.*, 2011). The average diameter of trees harvested for small sculptures such as birds would be smaller than those harvested to make canoes. However, the average diameter of trees harvested has significant implications on the sustainability of the tree species. Cutting down smaller sized trees before they produce and disperse seeds could affect the population of the tree species.

Wood for woodcarvings continues to be mainly harvested from the wild (Ellery, Cunningham, & Choge, 2005; Griffiths *et al.*, 2003; Purata *et al.*, 2004). These include forests on public land, communal and private forests (Ellery *et al.*, 2005; A. D. Griffiths *et al.*, 2003; Koenig *et al.*, 2011; Matose, 2006). However, there are no certain global statistics of volumes of wood extracted for wood carvings as this is primarily an informal activity (Ellery *et al.*, 2005), however that does not mean it is small in scale and scope. In 2002, woodcarving in Kenya were estimated to consume 50,000 trees per year (0.7% of the total round wood market share in Kenya). But although the amount of wood extracted for the purpose seems low, the wood carving practice relies on a selected number of species with desired qualities such as close grain, tensile strength and resistance to cracking or insect attack. In addition, a small range of different timbers are often favored as a result of social, cultural and historical factors (Cunningham *et al.*, 2005), which end up being over exploited. This has led to over exploitation of the particular wild species, especially those with other purposes, of which some are listed among the endangered species (Cunningham *et al.*, 2005; Ellery *et al.*, 2005).

From carving small household items, to carving the interior and exterior of houses and temples, ritual objects and decorative pieces, fashioning idols for various articles of furniture and for ceremonial objects (Saville, 1925), carving traditions have mainly been associated with culture, technology and change (Cunningham *et al.*, 2005). The practice was mainly associated with particular communities stretching back many generations, carving particular types of pieces that were mainly associated with long standing cultural significance. For example, in the tropics, subtropics, pre-industrial societies of Europe and some northern temperate regions, woodcarvings were and for some, are still the major sources of social and cultural materials

(Cunningham *et al.*, 2005). Whereas the practices have been socially and culturally sustainable among some woodcarving communities such as the Aboriginal wood carvers of Australia (Koenig, Altman, Griffiths, & Kohen, 2007), some communities such as those in the Mexican state of Oaxaca are engaged in carving novel creations without longstanding cultural significance (Purata *et al.*, 2004).

The wood carving industry has grown tremendously over the years, extending beyond the local and national to the international markets (Altman, 2005; Ellery *et al.*, 2005) which has increased demand of the wood carvings. The carvings are sold in a number of arenas including family workshops, markets and craft shops, either within the villages or other cities and countries (Purata *et al.*, 2004). An activity that was once predominantly a men's activity (Cunningham *et al.*, 2005) has progressively increased number of women and youths involved, becoming a family activity (Koenig *et al.*, 2007; Purata *et al.*, 2004). The women involved are mainly spouses and children of prominent wood carvers (Koenig *et al.*, 2007). However, these are mainly involved in the less labor-intensive activities such as sanding, polishing and painting (Matose, 2006; Purata *et al.*, 2004).

Other than the aesthetic values, these products have earned households, communities and national economies income. Wood carving is a major source of income through facilitating purchase of livelihood needs (Purata *et al.*, 2004) especially among communities in dry environments that suffer from lack of agricultural opportunities (Matose, 2006). However, it is not possible to obtain exact numbers of people involved (Ellery *et al.*, 2005) and the value of the industry as a whole is hard to determine (Griffiths *et al.*, 2003) due to its dynamic nature. The wood carving industry in Kenya generates about 20 million United States dollars per year in export revenue (Choge, 2002; Obunga, 1995), employing about 40% of thef national formal timber industry (Ellery *et al.*, 2005). Around the Victoria falls in Zimbabwe, the industry provides a source of livelihood to nearly a thousand households in a dry part of the country with households getting around 14 to 60 United States dollars a month.

The timber trade and woodcarving are closely linked, particularly in Asia, where timber is intricately carved to make buildings, doors or furniture. Trade in carvings is not new. It is bigger than ever before; however, it has spread internationally, rather than regionally, and has focused on a far smaller resource base (Cunningham *et al.*, 2005). Since many of the species used for wood carvings are endangered/threatened, their use and trade are restricted by both national regulations (for example sandalwood is restricted by the Kingdom of Tonga sandalwood regulations 2016, Tamil Nadu sandalwood possession rules, 1970, and the sandalwood (limitation of removal of sandalwood) order 1996 in Western Australia) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Groves & Rutherford, 2015). Nevertheless, there are some initiatives to ensure sustainability of these species by both community and corporations. For example, some species have been in cultivation through plantation establishment and agroforestry practices; In Bali woodcarving has been put on a sound basis through shifts to a fast-growing species like *Paraserianthus falcataria*. In India there is the roadside, village-level and plantation production of *Dalbergia sissoo*. In coastal Kenya there are plantations of the neem trees. There is recommendation and adoption of community/corporate tree plantations for sandalwood (A. N. A. Kumar, Joshi, & Ram, 2012) in different parts of India with appropriate incentives and adequate protective measures. Australia has been raising large sandalwood plantations, and may be able to meet the global demands, with the world's largest plantation of *S. album* established in the Kimberly, Western Australia.

3.3.4.4.2 Energy

Energy security is one of the requirements for a good quality of life, and this includes availability and access to clean, reliable, affordable and sustainable energy without compromising health (UN, 2015). Yet globally, 1.1 billion (14%) people do not have access to electricity and 2.4 billion (approximately one-third of the global population) people rely on unclean 'traditional biomass' for energy (including charcoal, coal, crop waste, dung, kerosene and wood), with the associated health implications from household air pollution (IEA, 2017) **(Figure 3.57A)**. Wood energy contributes 75-90% of sub-Saharan Africa's household energy mix (Hoffmann, Brüntrup, & Dewes, 2016; World Bank, 2011). An estimated 880 million people globally log firewood or produce charcoal (FAO & UNEP, 2020). Reliance on wood biomass for cooking is highest in developing Asian countries and sub-Saharan Africa (IEA, 2017). One third of the world's population (2.4 billion people) use fuel wood for cooking – which provides more nutrients than raw food - and other food preservation processes (e.g., smoking, drying), and one in ten people use fuel wood for boiling and sterilizing water (FAO & UNEP, 2020).

Most wild biomass energy is derived from wood, with implications for social and natural systems (Arnold *et al.*, 2006; Bailis *et al.*, 2005; Holdren *et al.*, 2000; Miah *et al.*, 2009; Munalula & Meincken, 2009; Smith & others, 2006). Logging for energy accounts for 50% of all wood consumed globally, and accounts for 90% of logged timber in Africa (FAO & UNEP, 2020). According to the Food and Agriculture Organization of the United Nations' statistics (http://www.fao.org/faostat/en/#data/FO), global fuel wood removals have increased over time with approximately 2 billion m^3 produced in 2019. There is great variation in fuel wood production and use in the different regions.

Production is highest in Asia and Africa at approximately 713 million m³ and 706 million m³ respectively **(Figure 3.57A)**. Whereas production levels are increasing in Africa (from 445 million m³ in 1990), the opposite is happening in Asia whose production has decreased from 897 million m³ in 1990. Latin America and the Caribbean have a fairly high level of production (268 million m³). Oceania has the lowest production of approximately 10 million m³ in 2019. Although absolute fuel wood consumption is increasing, especially in sub-Saharan Africa, per capita consumption is decreasing across all regions **(Figure 3.57B)**. All regions reported minimal trade in fuel wood, implying that fuel wood are mainly consumed locally and in domestic markets. However, wood-based energy industry has the potential to grow in a number of countries. This has motivated the investment in biomass-based energy generation, and research and development of new energy products such as biodiesel (Asikainen *et al.*, 2010). Although alternative energy sources reduce demand for fuel wood, in some areas fuel wood use persists due to habits, taste and custom (FAO, Schure, Ingram, & Yoo, 2017).

In several industrialized countries, wood energy provides nearly 25% of total energy supply, and the leading renewable energy source in Europe accounting for about 45% of primary energy from renewable sources (Francisco X. Aguilar, FAO, & UNECE, 2018). With the requirement of European Union states to have 27% of their energy generated from renewable energy by 2030 (European Commission, 2014), Europe's wood consumption for energy generation is expected to grow and reach 752 million m³ in 2030 (Mantau *et al.*, 2010). Logging for energy in North and Central America has been growing to meet increasing export demand for wood pellets.

In Europe and North America, wood energy utilization is commonly integrated in forest management practices and the wood products industry. Wood energy feedstocks can be considered a co-product of forest management as part of silvicultural treatments inclusive of thinning, final integrated harvests and salvage logging, as well as a by-product of the forest industry during the production of sawn goods (Asikainen *et al.*, 2010). Most of the wood used for energy comes indirectly through the forest industry as a co-product (58%) and a little over of a third of the wood mobilized for energy comes directly from forests (36%). Data from the Joint Wood Energy Enquiry for 2013 shows that the forest-based industry was the largest consumer of wood energy (44%), followed by the residential (36%) and combined heat and power (17%) sectors (F. X. Aguilar, Glavonjić,

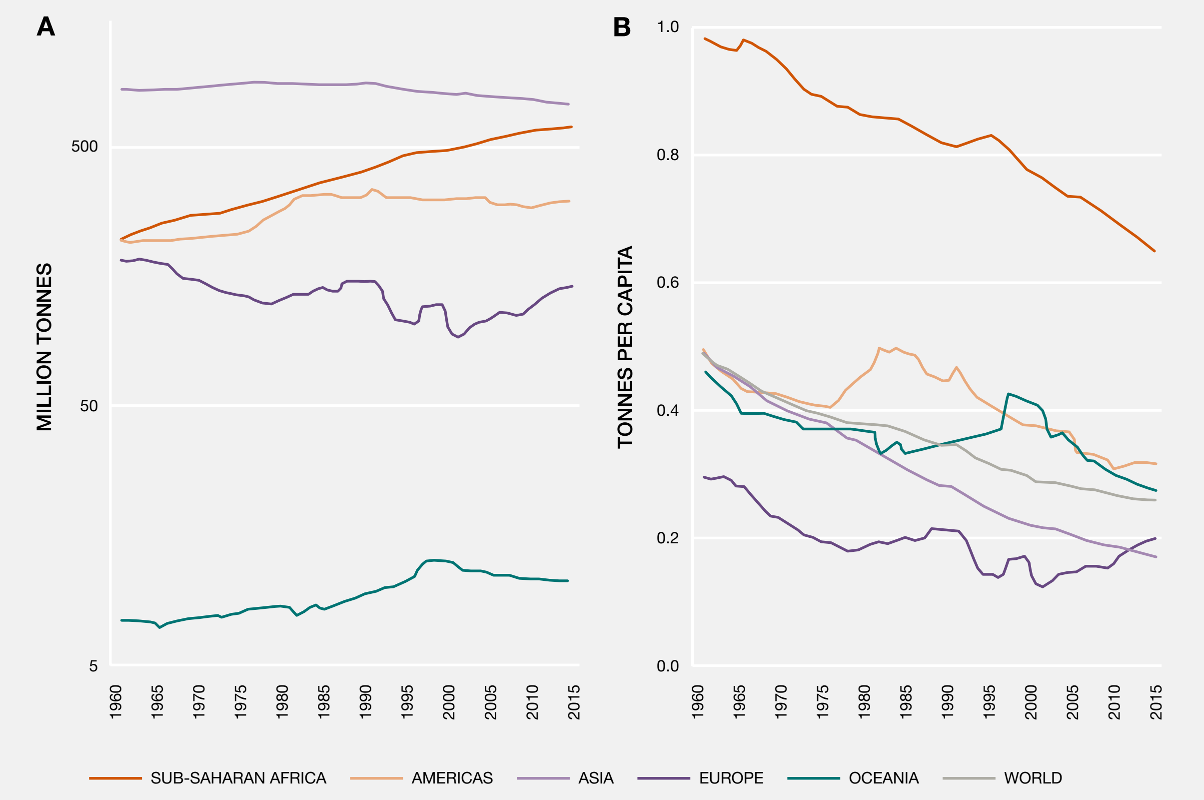


Figure 3 57 **Total (A) and per capita (B) fuel wood consumption trends by region.**

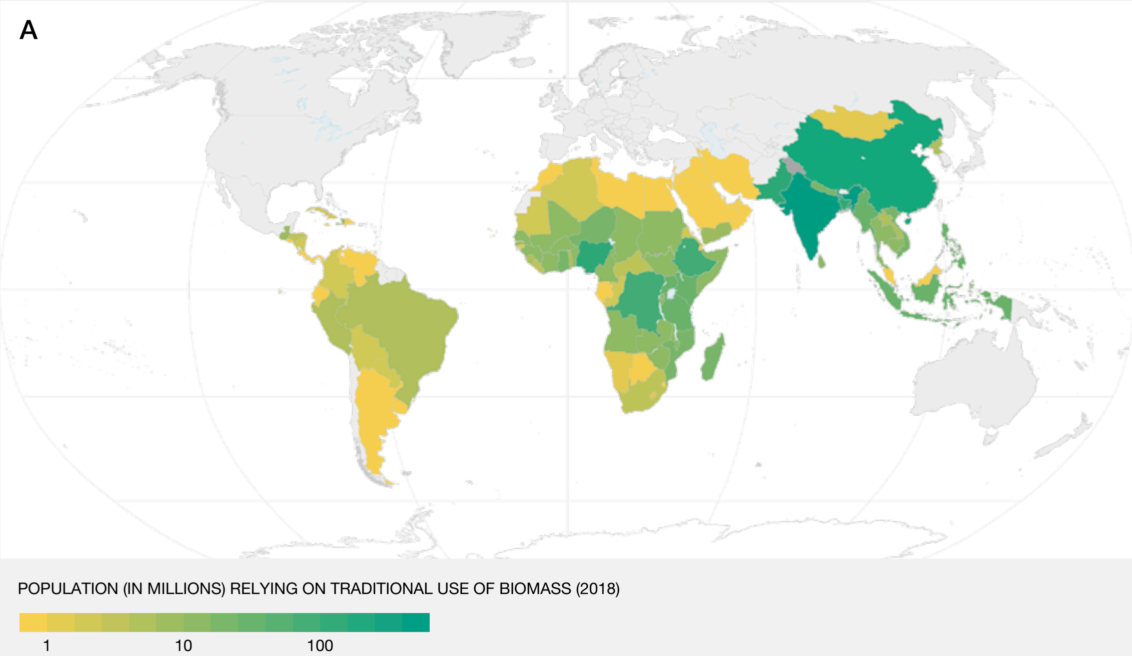
Source: (FAO, 2017b) © FAO, 2017.

Hartkamp, Mabee, & Skog, 2015). Use of wood for energy creates job opportunities not only along the supply-chain of woody biomass feedstocks, but also through investments in technology development and energy conversion and final consumption (Francisco X. Aguilar *et al.*, 2018). The FAO and the United Nations Environment Program (2020) estimated that over 40 million people are involved in commercial fuel wood activities to supply urban centers. Furthermore, fuel wood production generated an estimated 33 billion United States dollars in 2011 global revenue (FAO & UNEP, 2020). The number of jobs and net earnings is influenced by production method and organization of energy systems. For instance, the utilization of 390,000 dry tons of woody biomass estimated to feed a 100 megawatt power facility in the southern United States of America has been estimated to support 585 direct and 481 indirect jobs through the recovery of logging co-products, while direct and indirect employment associated with operation of the power plant were 281 and 115, respectively (Perez-Verdin, Grebner, Munn, Sun, & Grado, 2008).

Global fuel wood demand peaked in the mid-1990s (Arnold, Köhlin, Persson, & Shepherd, 2003), instigating a declaration of a 'fuelwood crisis'. However, the projected fuel wood supply-demand models predicting fuel wood stock collapse were an overestimation due to limited data and an incomplete understanding of social, economic and ecological interactions around wood energy (Dewees, 2020). Nevertheless, the available amounts of fuel wood may not be sufficient to meet local energy needs (Fabian, Volkmer, & Wiedemann, 2011; Swinkels, 2014). Household energy consumption is usually higher than fuel wood reported in official statistics, which mainly refer to wood from forests sources while leaving out other forms of wood biomass that contribute to household energy production. These include (for example in Europe) all by-products (sawmill by-products, other industrial wood residues and black liquor), solid wood fuels and post-consumer wood (Mantau *et al.*, 2010).

Although fuel wood demand can be met at a global, national or even regional scale, when comparing supply-demand balances, localized wood fuel scarcity persists (Arnold *et al.*, 2003; FAO *et al.*, 2017; Masera, Bailis, Drigo, Ghilardi, & Ruiz-Mercado, 2015). Fuel wood-scarcity 'hotspots' occur in areas where fuel wood is crucial for subsistence use and household-level well-being **(Figure 3.58A)** (Arnold *et al.*, 2006; Sampson *et al.*, 2005). In these areas, fuel wood users have few to no alternatives for cooking and heating, posing localized fuel wood driven challenges as most fuel wood (particularly firewood) is produced, harvested and consumed at a local level (Sampson *et al.*, 2005). In addition, regions where logging rates exceed growth rates are likely to cause degradation or deforestation (Robert Bailis, Drigo, Ghilardi, & Masera, 2015; Masera *et al.*, 2015). In 2009, 27-34% of fuel wood logging exceeded growth rates, predominantly in hotspots in South Asia and East Africa, affecting over 250 million rural people reliant on wood energy **(Figure 3.58B)** (Masera *et al.*, 2015). The FAO estimate that one third of fuel wood logging was unsustainable and a major cause of forest degradation (FAO *et al.*, 2017; FAO & UNEP, 2020). However, the link between fuel wood logging and deforestation or forest degradation is challenging to quantify and varies temporally and geographically (Rob Bailis, Wang, Drigo, Ghilardi, & Masera, 2017). Demand depends *inter alia* on household level preferences and economic context, vegetation species composition and physiognomy, the availability and cost of alternative energy sources (Rob Bailis *et al.*, 2017). Supply may vary with land use, productivity (and associated edaphic and climatic determinants), and accessibility of wood (Rob Bailis *et al.*, 2017). To further complicate quantification of fuel wood extraction, logging locations are not always from forests but are derived from many types of land cover (e.g., farms, roadside commons, home gardens), and may be a primary (logging specifically for fuel wood) or secondary activity (e.g., wood cleared from farms) (Rob Bailis *et al.*, 2017). Thus, fuel wood logging is often not the sole cause of forest degradation, but unsustainable fuel wood logging in Africa, particularly charcoal logging in open access systems with uncertain or unclear forest tenure, can be the primary driver of forest degradation (FAO *et al.*, 2017). The FAO found that fuel wood sustainability is strongly related to forest management rights and access, especially through permitting and/or taxation systems developed with local participation (FAO *et al.*, 2017). However, beyond these areas of localized shortages, sustainably logged fuel wood has the potential to be a viable, renewable, energy source that provides income (FAO *et al.*, 2017) and may be the preferred fuel source for cultural and economic reasons (P. Munro, van der Horst, & Healy, 2017), provided air quality (indoor and outdoor) and climate change emissions are mitigated (Rob Bailis *et al.*, 2017).

In low-income countries, fuel wood use occurs predominantly at the household scale for lighting, cooking and heating, but can support local and village-level industry. Commercial involvement with fuel wood, both firewood and charcoal, provides supplemental or an occasional income source (Arnold *et al.*, 2006), or an activity to fall back on as a 'safety net'. For example, firewood trading (and household subsistence use) increased in South Africa during economic shocks, such as loss of urban employment or breadwinner death as a result of HIV/AIDS (Human Immunodeficiency Virus) (Shackleton & Shackleton, 2004) or in response to the covid-19 pandemic, such as the switch from liquefied petroleum gas to fuel wood in Kenya and Malawi (Shupler *et al.*, 2020; Zalengera *et al.*, 2020). Eastern Afghanistan's forests have been an important energy resource during conflict-related crises in the region, although the forest wood stocks have been severely depleted (UNDP, 2014).



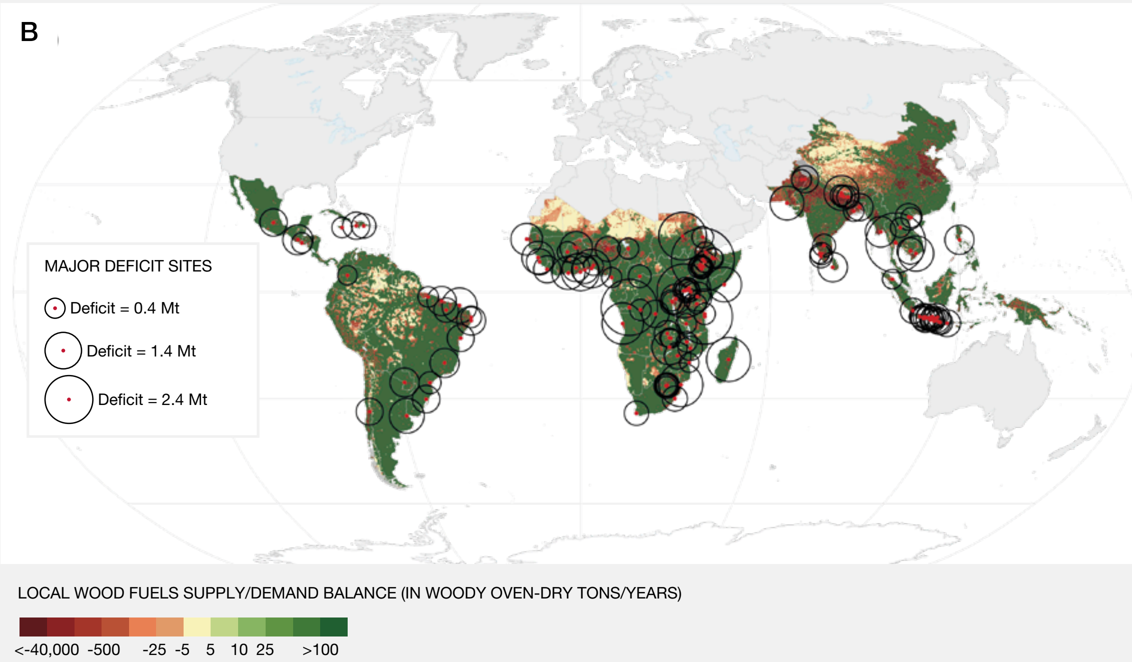


Figure 3 58 **(A) Global population reliant on traditional biomass, including fuel wood and animal waste, and (B) fuel wood supply/demand balance with circles on major deficit "hotspots".**

Sources: **(A)** based on data from (IEA, 2020) © OECD/IEA; **(B)** (Masera *et al.*, 2015). See data management report for the figure at https://doi.org/10.5281/zenodo.6453135.

Firewood trade can occur in conjunction with farmland clearing, with fuel wood being sold to wealthy urban clients through formal channels (Chidumayo & Gumbo, 2013; FAO *et al.*, 2017; Gandar, 1994). Firewood is normally logged on foot, limiting the logging radius to 1-3km, although this distance can be higher in arid regions with low tree cover (Cardoso, Ladio, & Lozada, 2013). Increasing firewood demand, locally and in urban areas has resulted in logged wood being collected and transported vehicle or horseback (Cardoso *et al.*, 2013; Matsika, Erasmus, & Twine, 2012), and may be by 'outsiders' (W. Twine, Saphugu, & Moshe, 2003). Localized shortages have also resulted in increased harvest time, changes in collected species or size classes, or harvest of live wood during deadwood shortages, often in violation of local traditional knowledge (Findlay & Twine, 2018).

Higher income is associated with a reduction in both firewood and charcoal use, although there is substantial variation between countries (Arnold *et al.*, 2003). The expectation that provisions of cleaner, more efficient energies and stoves would result in traditional energy users transitioning up the 'energy ladder' have largely not occurred, with households 'stacking' fuel, i.e., using multiple devices and fuels (Arnold *et al.*, 2006; Hiemstra-Van der Horst & Hovorka, 2008; Masera *et al.*, 2015; van der Kroon, Brouwer, & Van Beukering, 2013). Fuel wood use at household level is inelastic for a variety of reasons, including cultural and household taste preferences, high capital cost of appliances and energy, poor infrastructure and reflects dynamic, complex decision making at a household level (Arnold *et al.*, 2006; Hiemstra-Van der Horst & Hovorka, 2008; IEA, 2017; Masera *et al.*, 2015; van der Kroon *et al.*, 2013). There are indications that energy stacking, and the availability of a diversity of energy resources represents the adaptive capacity of communities, favors the conservation of local species and contributes to broader social-ecological resilience (Cardoso *et al.*, 2013). Energy stacking is a complex phenomenon, illustrated by a case in Patagonia, Argentina. A local village reliant on costly firewood, received subsidized liquefied petroleum gas (Betina Cardoso & González, 2019). This drastically reduced the amount of fuel wood collected in the region and reduced household air pollution, but not only did households continue to use wood burning stoves, their gas consumption to heat poorly insulated houses was extremely high (650 kilowatt-hour/m^2) incurring substantial operational and environmental costs (M. Betina Cardoso & González, 2019). The study's recommendations were two-fold: insulate the houses and receive a return on investment in liquefied petroleum gas savings in 2.2 years, and consider subsiding a household preference-determined mix of cheaper fire wood and gas to reduce subsidization costs (M. Betina Cardoso & González, 2019). This example clearly demonstrates the complexities in altering relative energy mixes and the potential trade-offs to social, economic and the environmental conditions.

Although firewood use is slowly decreasing, charcoal demand in urban areas is growing, doubling over 25 years to about 207 million m^3 wood for charcoal per annum in 2000 (Arnold *et al.*, 2003). In tropical South America charcoal use varies across the region with Brazilian use mainly for manufacturing and Central American for the food industry and limited domestic use (Chidumayo & Gumbo, 2013). In sub-Saharan Africa charcoal is mainly used for household cooking, particularly in urban areas (Chidumayo & Gumbo, 2013). Rural-urban charcoal trade is increasing as wealthy, urban firewood users 'transition' to charcoal (Arnold *et al.*, 2006). For example, 81% of energy use in Mozambique is fuel wood, with charcoal the predominant use in urban areas with the capital city, Maputo, garnering the highest prices for charcoal (Cuvilas, Jirjis, & Lucas, 2010). It is estimated that 91-99% of charcoal production is illegal (Cuvilas *et al.*, 2010). The high value and demand of charcoal in urban areas further incentivizes increased production (Cuvilas *et al.*, 2010). Charcoal production from plantations is increasing in the global tropics and charcoal is still predominantly derived from wild species in natural forests, and frequently related to deforestation or forest degradation (Chidumayo & Gumbo, 2013). Charcoal logging alone have resulted in the loss of 3 million hectares of forest cover in 2009 (Chidumayo & Gumbo, 2013). In Southern Africa charcoal production is valued at about 2-3% of gross domestic product (Malimbwi *et al.*, 2010) and forms a significant income source with households able to earn 1000 to 10,000 United States dollars per annum although studies suggest this income is not sustained over the long-term and does not provide improvements in human well-being (Baumert *et al.*, 2016; Smith *et al.*, 2019). Like firewood, the broad extent of charcoal logging and impacts remain unknown due to the informal and dynamic use of the resource.

Wood for firewood and charcoal are usually cut from main branches or the main stem, leaving the stump rooted in the ground. Many tree and shrub species logged for energy regenerate vegetatively, sprouting from the cut or damaged trunk, although the rate of coppice growth varies across species (Neke, Owen-Smith, & Witkowski, 2006), environmental context, post-logged land-use (Chidumayo & Gumbo, 2013), and the type of logging (Shackleton, 2000). Resprouting is a major source of regeneration in dry tropical forests and woodlands (Chidumayo, 2013; Tredennick & Hanan, 2015) and temperate forest regions, forming part of rotational logging management. A review of charcoal production reported 9-12 years logging rotations for Mali, Niger and Burkina Faso, 10-15 years for Mexico, 20-30 years in Zambia, and a wide 8–23-year range in Tanzania (Chidumayo & Gumbo, 2013). Underestimated coppice regeneration post-firewood and charcoal logging is one of the reasons that the 'fuelwood crisis' in which biomass stocks were predicted to collapse, has not occurred (Arnold *et al.*, 2003; Mograbi *et al.*, 2019; Twine & Holdo, 2016). Despite the significant productivity of woodlands and forests, fuel wood logging can alter floristic composition and vegetation structure (Mograbi *et al.*, 2015; Tredennick & Hanan, 2015). Depending on the fuel wood logging intensity, these ecosystem changes can alter the amount or type of nature's contributions to people derived from the forests (Chidumayo & Gumbo, 2013). For example, in Mozambique, charcoal production led to a reduction in firewood and construction material resources, with other natural resources such as wild food, medicinal plants and grazing mostly unaffected, although these trade-offs were mediated by village position and woodland resource characteristics (Woollen *et al.*, 2016). Variable ecosystem regeneration potential and context-specificity of environmental impacts and trade-offs in fuel wood logging are challenging to incorporate into large scale policy and management plans because of the social-ecological complexity and non-linear responses occurring across spatial and temporal scales.

Gender is one of the predominant features of traditional energy harvest, use and management of wood energy, including their (lack of) involvement in trade of fuel wood. While much of the research and interventions on inequality in forest resource use and management, many of the same challenges and barriers are faced by other vulnerable groups, such as minority ethnic groups, migrants, indigenous peoples, youths, landless people and other socially-differentiated groups such as lower castes (Chaudhary, McGregor, Houston, & Chettri, 2018; Kristjanson *et al.*, 2019). Gender gaps exist in almost aspects of natural resource use and management, including: disparities in participation; leadership; resource, land access, and tenure; forest use; division of labor and workloads; skills; access to technologies and inputs; access to information; access to forest services; access to benefits; access to credit; access to markets; policy engagement; and forest laws and regulations (Kristjanson *et al.*, 2019). With respect to the use of wood fuel for energy, women bear the majority of the responsibility for logging and using wood fuel (Clancy, Ummar, Shakya, & Kelkar, 2007; IEA, 2017; Murphy, Berazneva, & Lee, 2018). Households spend 1.4 hours a day harvesting fuel – a significant amount of time for women and children that could be used on other livelihood activities and education (IEA, 2017). The physical burden of headloads is not insignificant with a bundle weighing between 25-50 kg (IEA, 2017). Lack of access to clean cooking methods also has implications for household health (IEA, 2017), with women and children the most vulnerable to household air pollution which is a major cause of death and illness in low-income countries (Masera *et al.*, 2015).

An innovative approach to track how women are benefitting from interventions in forest resource use, trade and management is the W+ certification standard (WOCAN, 2020). The standard was created to measure women's empowerment and to accelerate investment to address gender inequality in access to resources and capital, specifically targeting improvements in: time, income and assets, health, leadership, education and knowledge, and food security (WOCAN, 2020). The standard provides certification for economic development and environment projects that improve socio-economic conditions for women. Benefits accrue to women through involvement in certified projects as well as from direct payments to women from the sale of W+ certification credits (WOCAN, 2020). Successful application of the W+ programme has demonstrated that interventions that save time and improve wood fuel efficiency are especially beneficial to women (Kristjanson *et al.*, 2019). W+ certification involving biogas digester projects in Nepal and Indonesia have resulted in tangible time and energy savings for women with improvements in income, assets and leadership capacity (Kristjanson *et al.*, 2019). Uptake of more fuel-efficient stoves has the potential for environmental benefits too. A case study in China documents a successful social media campaign to improve fuel-efficient stove uptake (DeWan, Green, Li, & Hayden, 2013). After two years, 43% of households had incorporated the stoves into their use, saving 40.1% on gathering time, and in the process saw a 23.7% reduction in newly felled trees in areas crucial to the conservation of the Sichuan Golden Snub-nosed Monkey (DeWan *et al.*, 2013).

Whilst gender inequalities are certainly a rights-based issue (S. Chaudhary *et al.*, 2018; Clancy *et al.*, 2007; Rights and Resources Initiative, 2014), investment in targeted programmes for women are opportunities for the sustainable management of forests and poverty relief (Kristjanson *et al.*, 2019). Ingram *et al.* (2016) document cases where male and female headed households harvest the same amount of wood, yet male households earned over three times more. In a Kenya study, women earn less than men in trading wood, and woodlots were mainly managed by men (Murphy *et al.*, 2018). Yet women's expenditures and increased roles in household expenditure decisions are associated with improvements in household nutrition, health and education (Ingram *et al.*, 2016). Women's income is a major determinant of household fuel choice and use (van der Kroon *et al.*, 2013). Thus, gender responsive interventions in training and enabling women to access markets and boost income can serve as leverage points for improving community well-being (de Groot, Mohlakoana, Knox, & Bressers, 2017; Ingram *et al.*, 2016). Similarly, opportunities for improved ecosystem health as empowering women's leadership and technical capacity building have been found to improve sustainable management of forests (Mwangi & Mai, 2011; Mwangi, Meinzen-Dick, & Sun, 2011). However, if fuel wood demand declines significantly, there are many women reliant on fuel wood sale income that will have reduced earnings in the event of a lack of alternate opportunities (IEA, 2017).

3.3.4.4.3 Material and construction

To have an idea of the amount of timber converted into wood for different purposes (sawn wood, energy, industrial round wood and paper and paper board), the assessment utilizes statistics on the production and trade of forest products over 245 countries and territories (FAO Stat, 2018). However, this does not include products from illegal timber trade.

Industrial round wood

Industrial round wood is all roundwood used for any purpose other than energy. It comprises pulpwood, sawlogs and veneer logs. Global industrial roundwood removals have increased from 1.7 billion m^3 in 1990 to 2.0 billion m^3 in 2019 **(Figure 3.59)**.

The increase in production is across all the regions except North America. Europe and North America had significant decreases in production in 1995 and 2010 respectively, while Asia had its greatest increase in production in 2010. There is a slight increase in trade of industrial roundwood. In 2019, approximately 144 million m^3 and 138 million m^3 were imported and exported respectively, while 83 million m^3 and 83 million m^3 were imported and exported respectively in 1990. Asia is a net importer, importing about 30 million cubic meters higher in 2019 than in 1990. Other regions are net exporters. Europe is the main exporter followed by Oceania. Africa and the Latin America and the Caribbean import and export very minimal quantities of industrial round wood (data from the Food and Agriculture Organization of the United Nations; http://www.fao.org/faostat/en/#data).

Sawnwood

Sawnwood encompasses planks, sleepers (cross-ties), beams, joists, boards, rafters, scantlings, laths, boxboards and "lumber". There was an increase in sawnwood production from 463 million m^3 in 1990 to 488 million m^3 in 2019, with the largest increase in Asia **(Figure 3.60)**. There are significant decreases in production between the two points in time happening in 2000 in Asia, 1995 in Europe and 2010 in North America. There is an increase in trade of sawnwood with 149 million m^3 and 156 million m^3 imported and exported respectively in 2019 as compared to 84 million m^3 and 78 million m^3 imported and exported respectively in 1990. Asia and Africa are net importer of sawnwood while the rest of the regions are net exporters. Asia is the major importer, importing about 47 million m^3 more in 2019 than in 1990, while Europe is the major exporter, exporting 71 million m^3 more in 2019 than it exported in 1990 (data from the FAO; http://www.fao.org/faostat/en/#data).

Wood based panels

The wood-based panels' product category consists of plywood (including blockboard and laminated veneer lumber), particle board, oriented strand board and fibreboard. In 2019, approximately 358 million m^3 of wood-based panels were produced globally **(Figure 3.61)**. This is an increase of 234 million m^3 from a volume of 124 million m^3 reported in 1990. The major producers of wood-based panels are Asia, Europe and North America, with Asia reporting the most tremendous increase of production from 25 million m^3 in 1990 to 196 million m^3 in 2019. Trade in wood-based products has also increased between 1990 to 2019 from approximately 28 million m^3 of imports and exports in 1990 to 88 million m^3 of imports and exports in 2019. Europe is the major trader of the product, followed by Asia and North America (data from the FAO; http://www.fao.org/faostat/en/#data).

Paper and paper board

The paper and paperboard product group comprises graphic papers (newsprint, printing and writing paper) and other paper and paperboard. There is an increase in global production of paper and paper boards **(Figure 3.62)**. In 2019, approximately 404 million tons were produced, an increase of 165 million m^3 from production volumes of 1990. The major producers and traders of paper and paper boards are Asia, followed by Europe and North America. Production levels of North America have fallen by approximately 11 million tons between 1990 and 2019, while those of Asia and Europe have increased by 138 million tons and 25 million tons respectively within the same time intervals. Trade in paper and paper boards has also increased with 110 million tons and 113 million tons imported and exported respectively. Asia is a net importer while Europe and North America are net exporters (data from the FAO; http://www.fao.org/faostat/en/#data).

3.3.4.5 Emerging issues in logging and timber management

3.3.4.5.1 Covid-19 pandemic

The COVID-19 pandemic has led to disruptions in international trade and supply chains of timber and its products globally. Many developing countries are heavily dependent on international trade of these products and the pandemic is having a significant effect on production and consumption patterns. For example, recent developments in the timber markets have increased the dependency on Chinese demand. With the pandemic triggered decline of exported round timber to China, stockpiles of export products are being built up in some places. This is further exacerbated by limited demand in typically strong markets such as Austria and Germany, while export markets in France, Italy and Spain are essentially at a standstill. Together these factors have resulted in a decrease in export incomes in developing countries (FAO, 2020c). As a result, the least developed timber-producing countries, in particular, may suffer directly from plummeting export volumes of roundwood and other wood products (FAO, 2020c). Nevertheless, in the post-COVID-19 environment, the trade and consumption of legal and sustainable wood products may be promoted through sustainable forest management for wood production, and can play a crucial role in economic recovery, especially considering efforts to promote a circular bioeconomy and climate change mitigation (FAO, 2020b).

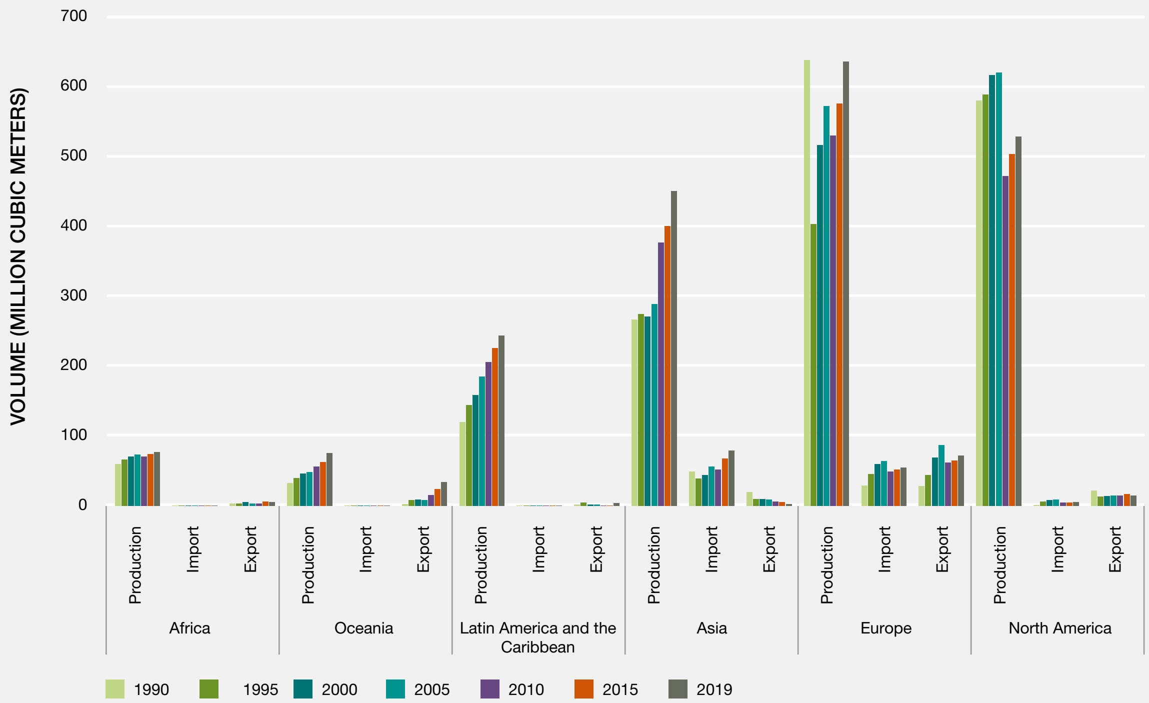


Figure 3 59 **Global trends in industrial roundwood use.**

Data from FAO database (FAO, 2021b) under license CC BY-NC- SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453131.

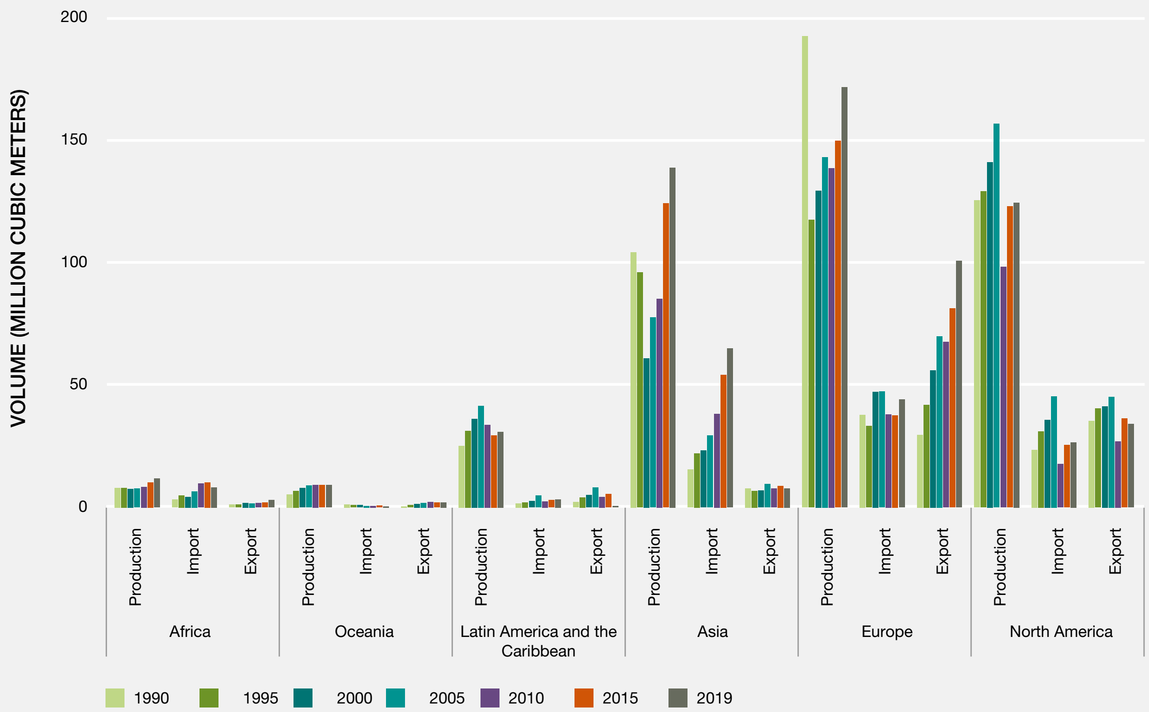


Figure 3 60 **Global trends in sawnwood.**

Data from FAO database (FAO, 2021b) under license CC BY-NC- SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453131.

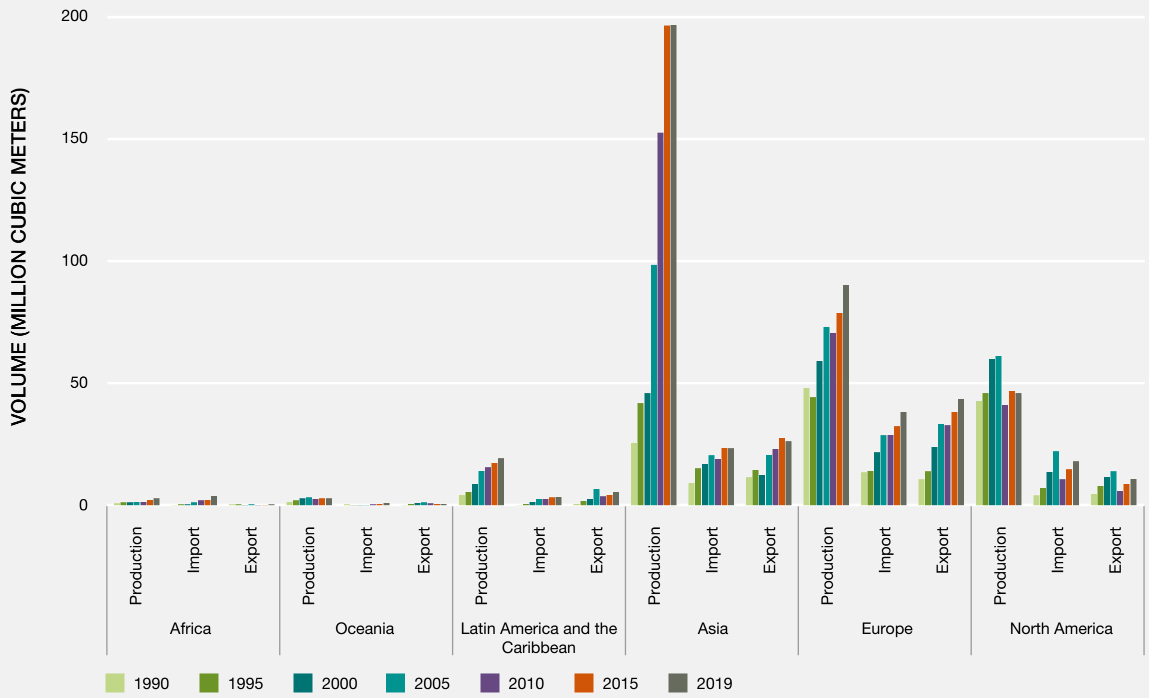


Figure 3 61 **Global trends in wood based panel production.**

Data from FAO database (FAO, 2021b) under license CC BY-NC- SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453131.

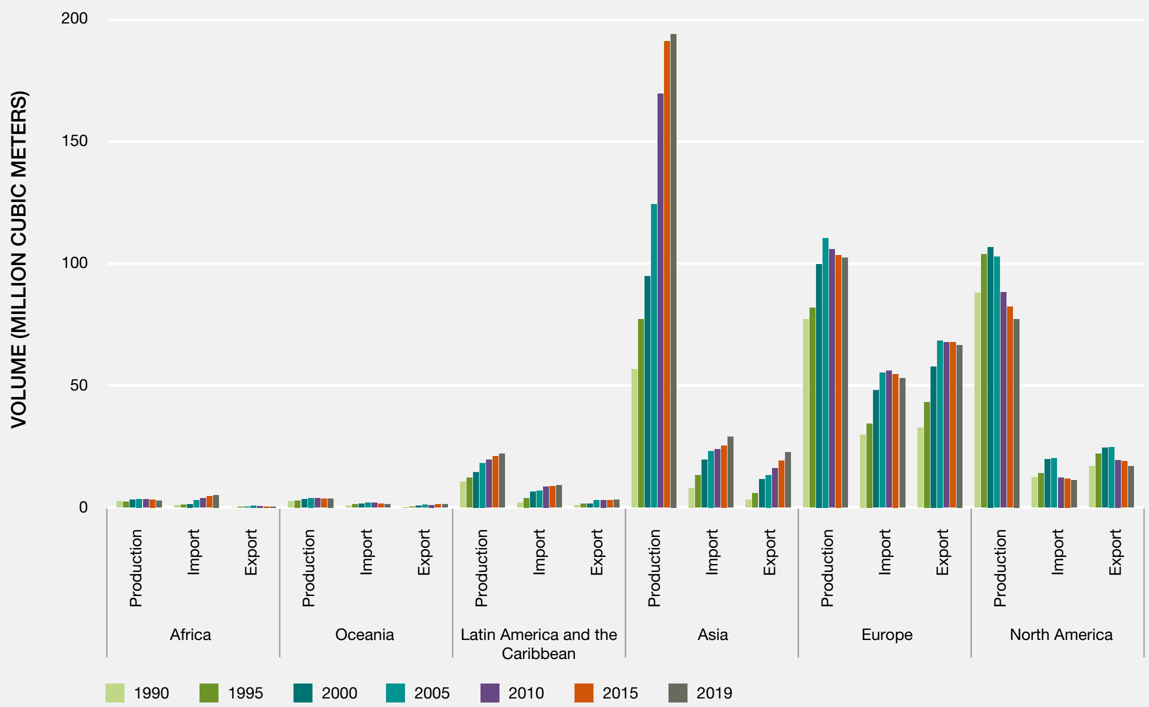


Figure 3 62 **Global trends in paper and paperboard production.**

Data from FAO database (FAO, 2021b) under license CC BY-NC- SA 3.0 IGO. See data management report for the figure at https://doi.org/10.5281/zenodo.6453131.

For indigenous people and local communities, negative effects of the COVID-19 pandemic on vulnerable communities, including women have been observed. Although, there has been steady progress made to date to empower women by supporting their participation in legal and sustainable fuelwood and charcoal production, the COVID-19 crisis is expected to put increasing pressure on forest resources through illegal charcoal production. Situations where livelihoods are put under significant pressure often tend to result in a shift towards activities with quick economic gains at the sacrifice of legal activities. In some countries, restrictions on travel and movements may affect the transportation and trade of fuelwood (particularly charcoal) from production sites to market centers (mostly urban areas). This may affect reliable access to energy for cooking in urban areas (FAO, 2020b). The COVID-19 pandemic also set the progress of universal access to electricity and clean cooking back, with the number of people without electricity access forecast to rise by 2% in 2021 (IEA, 2021). The economic shock of the pandemic also resulted in a return to fuel wood, with many people unable to pay for modern, clean fuels (IEA, 2021).

3.3.5 Non-extractive practices

3.3.5.1 Introduction: Significance of non-extractive practices

Non-extractive practices are widespread across the globe, occur in all ecoregions, and are essential to maintaining *inter alia* human relaxation, spiritual and cultural identity, connection to nature, belonging, sense of place, physical and psychological health, and inspiration.

The contributions of wild species to people from non-extractive practices are often intangible and resist commodity-based valuation (with the exception of recreational tourism). Yet many of the non-extractive contributions from nature are core to the human experience and contribute to the well-being of people (Millennium Ecosystem Assessment, 2005; Russell *et al.*, 2013). Knowing and experiencing nature is the foundation of cultural expression and identity; is inherent in the concept of biocultural diversity; forms the backdrop for social connections, religious experience and beauty; as well as contributing substantially to gross domestic product and local livelihoods (Russell *et al.*, 2013).

Although extractive practices are often the focus in the debate on what constitutes sustainable use of wild species (e.g., Abensperg-Traun, 2009; Di Minin *et al.*, 2019; Link & Watson, 2019; Nijman, 2010; Zeller & Pauly, 2019), non-extractive practices may also have sustainability implications, both for wild species and for human well-being. Although, non-extractive practices, by its very definition, are viewed as having less of a direct impact on wild species and ecosystems than extractive practices, there are many documented detrimental impacts and sustainability concerns in this practice. This is particularly well-documented for the use of wild species for tourism and recreation (see Section 3.3.5.2.3.). However, many of the adverse impacts may be avoided or mitigated through context-based understanding and collaborative engagement with all stakeholders.

Non-extractive benefits from wild species and nature are similar conceptually to the definitions of cultural nature's contributions to people (Costanza *et al.*, 1997) and non-material benefits (Millennium Ecosystem Assessment, 2005). In this assessment, non-extractive practices are defined based on the observation of wild species in a way that does not involve the harvest or removal of any part of the organism. The observation can imply some interaction with the wild species, such as the activities of wild species tourism and whale watching or no interaction with the wild species, such as photography (see Chapter 1).

Just as in extractive practices, the social contextual heterogeneity in the contributions from wild species to human well-being through their non-extractive use has implications for equitable environmental decision making (Martín-López *et al.*, 2012). The contributions from wild species to human well-being are perceived and valued differently, which influences the type and extent of use (Pascual *et al.*, 2017; Satz *et al.*, 2013). This also means that there may be conflict between different users of wild species (Pascual *et al.*, 2017). For example, one study documented interpersonal conflicts both within and between two recreational user groups in Hawaii, scuba divers and snorkelers, that held different nature-oriented values, those who valued nature intrinsically and held protectionist beliefs *versus* an anthropocentric-utilitarian value (Philips, Szuster, & Needham, 2019). Similarly, local residents near North American ski resorts placed high emphasis on recreational access and came into conflict with city residents who preferred that the area remain pristine wilderness, unaffected by tourism activities (Saremba & Gill, 1991). One proposed solution to avoid these types of conflicts is to spatially or temporally partition regions that can cater for different stakeholder's values (e.g., demarcated fishing and diving zones).

There can also be a disconnect between the importance placed on non-extractive practices of nature at a local level, where they are used on a daily basis, and the level to which they are incorporated into regional, national and global decisions on ecosystem management, which are made from a more distanced level (Brondizio, Ostrom, & Young, 2009; S. Chaudhary, McGregor, Houston, & Chettri, 2019). Thus, governance systems play a large role in which non-extractive contributions from nature are delivered to people, by identifying which stakeholder group's expectations and values are recognized (Gladkikh, Gould, & Coleman, 2019; Martín-López *et al.*, 2012; Pert *et al.*, 2015).

3.3.5.2 Uses

Regarding non-extractive practices, the following uses are well-documented in the literature and available data sources: ceremony and cultural expression (section 3.3.5.2.1), medicine and hygiene (section 3.3.5.2.2.), recreation (section 3.3.5.2.3.), education and learning (section 3.3.5.2.4).

The documentation of the non-extractive practices of nature, especially the use by indigenous peoples and local communities, often does not include species described at a species level, but frequently as part of a functional group (e.g., trees in urban green spaces; worship of sacred groves). For many indigenous and local communities their worldview and experiences are intimately connected with nature (Klain, Satterfield, & Chan, 2014; Pert *et al.*, 2015). Indigenous and local knowledge is premised on the interdependence of what scientific knowledge may identify as distinct components of nature and culture, such that worship of sacred groves is a holistic practice that includes the species in the grove (e.g., forest plant and animal species community), the ecosystem processes (e.g., primary production, pollination), the landscape features (e.g., rocks, rivers), and the particular cultural practices and language of the human community. However, in order to keep the scope of this section pragmatic and practical, literature that deals with quantifiable and measurable use of wild species up to the taxa level (e.g., trees) has been included in this review on non-extractive practices and literature on landscapes and landscape components (e.g., sacred pools, sacred mountains) was excluded.

The following uses are not relevant to this practice and/or were not documented: decorative and aesthetic, energy, food and feed, materials and shelter. Although aesthetic beauty and inspiration of nature are a form of non-extractive practice, this was excluded to maintain the scope of the assessment to quantifiable and measurable impacts of sustainable use. Keyword searches and methods for each review are detailed in each subsection.

3.3.5.2.1 Ceremony and cultural expression

Ceremony and cultural expression refer to the use of wild species in spiritual observances and practices, valued for their role in maintaining cultural identity (Chapter 1). In the context of non-extractive practices, the use of wild species can be through worship of religious or culturally important species. In urban areas, similarly urban green spaces have become important analogues for worship and ceremonial rituals (Ngulani & Shackleton, 2019). Thus, wild species can underpin cultural and religious identity by supporting spiritual, intellectual and emotional features and contribute to literature, lifestyles, value systems, traditions and beliefs, and ways of living together. The use of wild species for ceremony and cultural expression supports social cohesion, belonging and identity (Satz *et al.*, 2013). Wild species form part of history and cultural narratives (Pascual *et al.*, 2017; Satz *et al.*, 2013). Thus, unsustainable use of wild species central to cultural and ceremonial engagement can harm social relations (Millennium Ecosystem Assessment, 2005). Inversely, restoration of degraded forests and landscapes provides an opportunity for cultural and indigenous value revival (Constant & Taylor, 2020).

The text below is based on a literature review (Web of Science) using the following strings of terms (“non-extractive use*” OR “cultural ecosystem service*” OR “non-material contribution*” OR “non-consumptive use”) AND (spiritual* OR ceremon* OR religion* OR ritual*), generating 51 hits (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Articles that were recommended by citation databases were also considered, as well as harvested from personal libraries and recommendations from experts. The scope of this section is limited to the non-extractive practices of wild species for ceremonial and cultural expression where the impact of the use can be measured or assessed. After reviewing the title and abstract, 36 papers were selected for a full-text read. Relevance was determined by mention of either the status (current), trend (historical), or impacts of use of wild species (or taxa) in at least one dimension of sustainability (social, economic, or ecological). After a full text read of these papers, eight were deemed relevant and assessed for the literature review. These data form the basis of the text below.

Of the reviewed articles, half (4 out of 8) covered the importance of trees for ceremonial use, particularly sacred groves in Africa. Research on sacred groves was mostly anthropological and social data of long-term (>10 years) trends on a regional (<100 km) scale.

Sacred natural sites, such as sacred groves and burial sites, are an important feature across the world that can play a central role in biodiversity and resource conservation. These sites exhibit large diversity in their form and function, showing strong local context of both ecology and culture (Fournier, 2011; Juhé-Beaulaton & Salpeteur, 2017). Sacred groves are places of spiritual and cultural importance, protected by the authority of tribal taboos and spiritual “caretakers”. In general, restrictions forbid cutting down or harvesting any part of the trees, including dead wood, to burn or harm the fauna and flora, or to remove soil or stones (Fournier, 2011). Depending on the tribal custom, picking herbaceous plants and grazing livestock near the sacred trees may be permitted (Fournier, 2011). Taboos also vary depending on the type of sacred grove. For example, the Tandroy clan in Madagascar allows the use of fire in honey groves – kept for medicinal, food, and spiritual purposes – but has more stringent taboos in burial forests (von Heland & Folke, 2014).

The current status of sacred groves, or indeed of any wild species used for ceremonial and cultural purposes, is not well documented in the literature. But the limited data that do exist are mixed, with some evidence that taboos and traditional beliefs have protected sacred groves. Sacred groves can an important role in community-based conservation of biodiversity, acting as refugia for species. For example, India possesses relict populations of certain threatened tree species (*Actinodaphne lawsonii, Hopea ponga, Madhuca neriifol*i, and *Syzygium zeylanicum, Myristica fatua* and *Gymnacranthera canarica*) in numerous riparian groves. Sacred groves in the Karnataka state also shelter a high diversity of macrofungi, 49 out of 163 species are unique to sacred groves (Bhagwat & Rutte, 2006). Similarly, in central Tanzania, greater woody plant species richness was found in sacred groves than in a state-managed forest reserve (Mgumia & Oba, 2003). Despite droughts and pressure to use resources inside sacred forests, the ancestral forests in Ambonaivo have been preserved whereas elsewhere in Madagascar, sacred groves have been cut down for charcoal production (von Heland & Folke, 2014). Similarly, sacred groves in Morocco have been effectively conserved as a result of their sacred status (Frosch & Deil, 2011).

Despite their significance, the protection offered to wooded shrines may be limited in extent and may only be for a certain period of time (Fournier, 2011). In Burkino Faso, the clearing of wooded shrines has also been blamed on “foreigners” fleeing worsening climatic conditions in the Sahel, who are (either intentionally or not) ignorant of local traditions (A. Fournier, 2011). In Benin most sacred groves have been neglected or cut down, but a few have been restored and are being managed for nature’s contributions to people (Juhé-Beaulaton & Salpeteur, 2017). A vegetation assessment of wooded shrines in West Africa found more groves were cut down than restored and although they were less used for extractive purposes than similar secular forests, they were still being used for extractive purposes (Fournier, 2011). Sacred groves are also not necessarily ecologically ‘pristine’ by conservation standards. Whilst the preference by locals is for sacred groves to “have trees”, preferably dense vegetation, the species of tree is considered unimportant and wooded shrines range from almost natural to highly modified (Fournier, 2011).

The literature suggests the future of sacred groves is strongly dependent on how spiritual and religious practices adapt to changing socio-political conditions. The degrading social contract with nature and the erosion of ancestral and natural connections threatens the sustainability of sacred groves. Cultural trends show taboos around sacred groves are eroding as the elder “spiritual caretakers” who play an active role in supervising use of the groves, are not replaced (Fournier, 2011; von Heland & Folke, 2014). There are also changes to “social-ancestor contracts” which are being modernized, and more of the local people have converted to global religions (Juhé-Beaulaton & Salpeteur, 2017; von Heland & Folke, 2014). The increasing assimilation of local peoples’ moral order into one more closely aligned with modern, Western, democratic ideals governed by the nation-state has eroded the traditional and ancestral social-ecological system central to their identity, as well as the associated protection afforded to their land and the species it contains (Findlay & Twine, 2018; von Heland & Folke, 2014). As local protection erodes for sacred sites, there is an opportunity for more formal protection, such as the promising case developing in Estonia where Estonian indigenous peoples and local communities (Maausk) and the government are planning to confer legal protection to approximately 550 sacred groves (Kaasik, 2012). There are also opportunities to conserve sacred groves for purposes other than cultural worship provided the other uses are compatible and respectful of the sacred status. This has occurred in West Africa where sacred groves are also used for heritage and cultural tourism (Juhé-Beaulaton & Salpeteur, 2017).

The literature review on the use of wild species for ceremonial and cultural expression also described the use of urban green spaces for religious worship. However, increasing urbanization threatens the loss of green spaces used for worship, especially as these sacred sites are not associated with formal religious structures or buildings (Jackson & Ormsby, 2017). Use of urban green space for ceremonial purposes has been documented in Zimbabwe (Ngulani & Shackleton, 2019), Accra (Okyerefo & Fiaveh, 2017) and India (Gopal, von der Lippe, & Kowarik, 2019), but it is an underreported form of use of either formal or informal urban green spaces and has not received adequate research or policy attention (Jackson & Ormsby, 2017; Ngulani & Shackleton, 2019). No information on the use of urban green spaces for worship described whether this was an increasing phenomenon, or the sustainability of this use.

Overall, the use of wild species for ceremonial and cultural purposes is likely widespread but poorly documented. There are little to no data on the status and trends, or sustainability of this use. However, the literature on sacred groves do suggest that cultural erosion is driving a decreasing trend of ceremonial use, and thus also an erosion of traditional protection that the use afforded these species.

3.3.5.2.2 Medicine and hygiene

This section relates to the non-extractive practices of wild species for human health, both psychological and physical. The scope of this section is limited to the non-extractive practice of wild species for restorative and/or preventative effects and the impact this use has in terms of a measurable effect on the species. The text below is based on a literature review (Google Scholar) including the following search terms: ("non-extractive use*" OR "cultural ecosystem service*" OR "non-material contribution*" OR "non-consumptive use") AND (sustainab* OR "forest therapy" OR "human well-being" OR "human health" OR stress OR happiness OR dose-response) generating over 1 million hits (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). Articles that were recommended by citation databases were also considered, as well as collected from personal libraries and recommendations by experts After a title and abstract read, 24 papers were selected for a full-text read. After a full text read of these papers, 13 were deemed relevant and assessed for the literature review. Relevance was determined by mention of either the status (current), trend (historical) or impacts of use of wild species (or taxa) in at least one dimension of sustainability (social, economic, or ecological). These data form the basis of the text below.

Relevant material from the review covered mostly the use of trees (10 papers) for health purposes, with a few mentions of terrestrial mammals and birds (4 papers). 46% of the studies on this topic were global overviews, with regional studies mostly representing Asia-Pacific and Europe Central. Relevant research was overwhelmingly short-term studies (<1 year), but spanned a variety of spatial scales: global, national, regional and local.

There was an absence of information in the literature on trends in the non-extractive practices of wild species for health and hygiene. From the review, only one paper tracked trends in use for health over time. This was a paper that documented current and past trends in the use of forests for forest therapy in Korea (Shin *et al.*, 2017). Similarly, no information was found reporting on the sustainability of health-based use of wild species on species or ecosystems. Although undocumented, negative impacts on wild species used for medicine and health likely include the effects of trampling during nature visits (see section 3.3.5.2.3. Recreational). It is possible that the health benefits obtained from wild species motivate people to support and protect their natural spaces. Research on environmental education supports that the more people learn from (and in) nature, the more likely they are to develop pro-nature behavior (M. Richardson, Cormack, McRobert, & Underhill, 2016). But this has not yet been documented for the non-extractive practices of wild species for medicine and hygiene use. It is not a given that the benefits provided by wild species always confer protection. For instance, street tree vandalism is a significant driver of urban tree mortality (e.g., Richardson & Shackleton, 2014) despite the numerous benefits provided by urban greening.

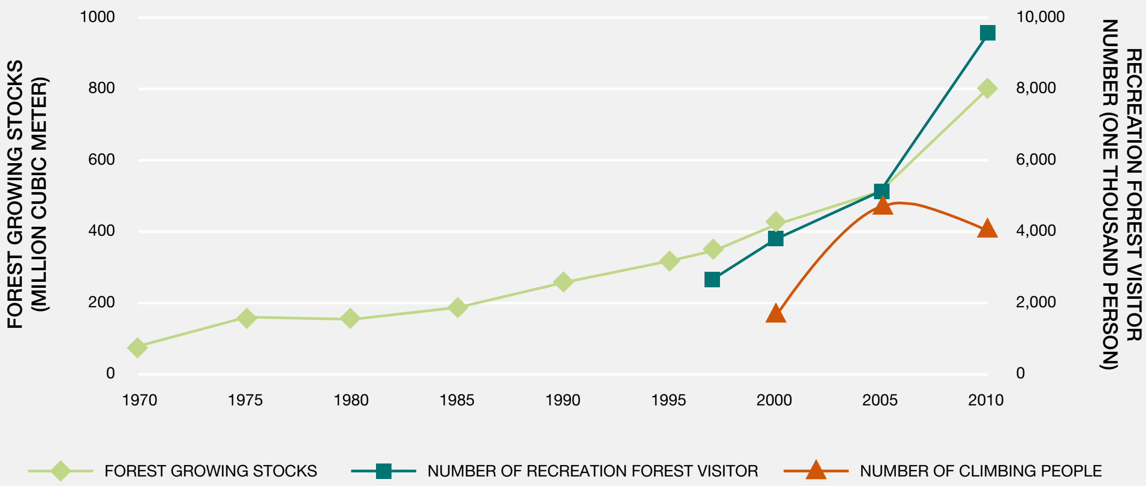
The literature on this topic extensively deals with the beneficial impacts of nature, especially forests, on *individual* human well-being. A significant research gap exists on the impacts of health-based use of wild species on human community health (Nesbitt, Hotte, Barron, Cowan, & Sheppard, 2017). The rest of this section will describe the evidence and examples of the impacts of health use of wild species on human individual's well-being.

Rapid urbanization and industrialization have been related to the rise in chronic mental and physical health problems, mostly associated with stress (Ashworth, 2017), costing millions in healthcare-related expenses and lost work days (Moore, Gould, & Keary, 2003). Thus, preventive measures, including nature-based remedies, to deal with the modern-day health crisis are economically prudent, and are supported formally by some governments, such as the legislation passed by the Korean government for the use of forests for health (Kotte, Li, & Shin, 2019; Shin *et al.*, 2017), or *shinrin-yoku* ("forest bathing") by the Japanese Forestry Agency (Rajoo, Karam, & Abdullah, 2020). There are also documented case studies of forest therapy, and the increasing demand for cost-effective preventive medicine and stress management using forest therapy, in Southeast Asia and Northern Europe (Kotte *et al.*, 2019; Lee *et al.*, 2019).

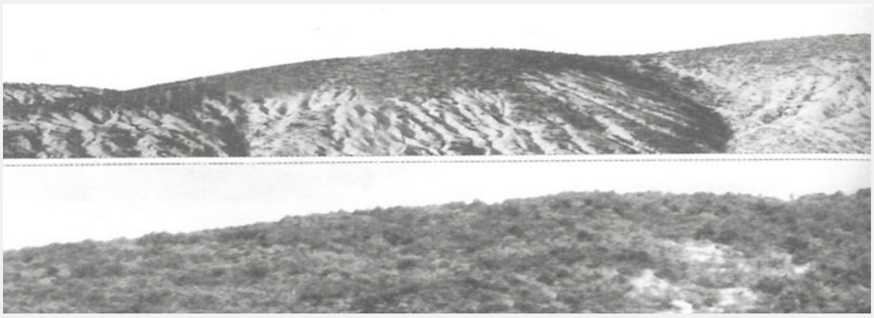
Shin *et al.*, (2017) documented a significant increase in the use of Korean forests for recreational visitors, primarily for forest therapy and the health benefits of spending time in "healing forests". This rise in health-based forest use has been facilitated by Korean government forests restoration programs, legislating certain forests specifically as "healing forests", and substantial investment in forest therapy research (Shin *et al.*, 2017). Although other studies mention that the demand for and use of nature for restoration and health has increased (Kotte *et al.*, 2019; Lee *et al.*, 2019; Rajoo *et al.*, 2020), the quantitative change in this use has not been documented **(Figure 3.63)**.

Reviews on the effects of forest therapy on human health found that most research reported positive effects (Frumkin *et al.*, 2017; Kotte *et al.*, 2019; Rajoo *et al.*, 2020; Wolf *et al.*, 2020). The benefits of natural settings for restorative effects, such as stress relief, decreased cognitive fatigue, and happiness (see Chapter 1), have been documented in both urban and non-urban settings. Natural settings have been associated with, amongst others, better cognitive functioning, fewer symptoms of depression and lower antidepressant use, reduced stress and psychiatric disorders, reduced diabetes, and improved immune function (see review in Frumkin *et al.*, 2017). Exposure to nature has also been shown to have a positive effect on infant birth weights, reductions in childhood obesity, and improved blood pressure (Aerts, Honnay, & Van Nieuwenhuyse, 2018; Frumkin *et al.*, 2017). Exceptions include the negative

A



B **Changes of growing stocks in Korea between 1970–2010; growing stock in Korea during 40 years. Comparison of scenery between 1970 and 2000 in Young-il Gyeongsangnam-do, Korea.**



1970s

2000s

C **Visitors of recreation forests and healing forests (2010–2013); Visitors of healing forest increased 11 times than visitors of recreation forests among 4 years.**

Visitors (number)	**2010**	**2011**	**2012**	**2013**	**Mean increase rate (%)**
Recreation Forests	9,437,000	10,684,000	11,614,000	12,780,000	10.6
Healing Forest	76,063	157,571	314,767	787,029	117.0

Figure 3 63 **The graph (A) and photos (B) show the recovery of forest stocks in Young-il Gyeongsangnam-do, Korea from 1970–2013.**

Concomitantly, the number of "recreational visitors" to "Healing Forests" have increased over time as the number of recreational climbers have declined (A) with a mean increase of 117% in healing forest visits over 3 years (C).
Source: (Shin *et al.*, 2017) under license CC BY-SA 4.0.

effects of plant pollen and volatile organic compounds from trees (Wolf *et al.*, 2020). Findings on the benefits wild species and ecosystems provide for mental and physical health have motivated for technology to provide this form of health benefit through virtual reality, and although exposure to nature through photographs or video does improve stress levels and reduce cognitive fatigue, the real experiences in nature significantly outperform virtual experiences for restorative benefits (Calogiuri *et al.*, 2018).

The studies mentioned above used a variety of self-reported measures to assess human well-being, with little research being done on clinical outcomes (Aerts *et al.*, 2018). The research was also mostly based on a limited set of variables to describe nature. The majority of studies were based on proximity to nature (e.g., Xiao *et al.*, 2019), or the number or cover of trees (Wolf *et al.*, 2020). There were fewer studies on the diversity of wild species for human well-being (Methorst *et al.*, 2021) and none was identified on specific wild species, rather focusing on functional groups such as trees or birds. The limited research on the effects of ecological quality (e.g., species richness) of trees suggests lower correlation with life satisfaction than overall abundance and denser tree cover, suggesting people were less affected by species diversity and more by the mere presence of trees (Marselle *et al.*, 2020; Methorst *et al.*, 2021), although the state of knowledge in this field is still mixed (Aerts *et al.*, 2018). Certainly, people have expressed preference for particular species, especially those that were aesthetically pleasing or reminded them of their childhood home (C.M. Shackleton & Mograbi, 2020).

Dose-response effects of wild species on human health have been demonstrated with trees and with birds. People living within 100 m of higher street tree density had lower antidepressant prescriptions (Marselle *et al.*, 2020). This effect was even more pronounced for individuals with low socio-economic status (Marselle *et al.*, 2020). A study exploring self-reported life satisfaction across Europe in relation to several taxonomic groups and socio-economic indicators found that bird species richness was highly correlated with life satisfaction, comparable with that of net household income **(Figure 3.64)** (Methorst *et al.*, 2021). Methorst *et al.*, (2021) hypothesize that the direct multisensory experience of birds and/or the supporting landscape properties that support bird diversity benefit human life satisfaction. Another study found that vegetation cover and afternoon bird abundance was positively associated with lower depression, anxiety and stress (Cox *et al.*, 2017). Cox *et al.*, (2017) modelled neighborhood vegetation cover thresholds at which population prevalence of mental health issues were significantly lower: more than 20% for depression and stress, and more than 30% for anxiety. A dose-response model suggested that visits to nature of 30 minutes or more a week could reduce population prevalence of depression by 7% and high blood pressure by 9% (Shanahan *et al.*, 2016). A significant reduction, especially considering that depression alone in Australia, where this study was conducted, was estimated at 12.6 billion Asutralian dollars per year (Shanahan *et al.*, 2016). A study from the United Kingdom of Great Britain and Northern Ireland found that individuals spending at least 120 minutes a week in nature reported better health and well-being relative to people spending no time outdoors; positive associations peaked at 200-300 minutes a week (White *et al.*, 2019). These "Green Prescriptions" highlight the importance of species presence and diversity to human well-being, a cost-effective means of supporting a healthy population.

There are significant socio-economic disparities in urban green space access, both as a result of restricted access (e.g., private space) and as a consequence of socio-economic class differentiation in urban planning (Venter, Shackleton, Van Staden, Selomane, & Masterson, 2020;

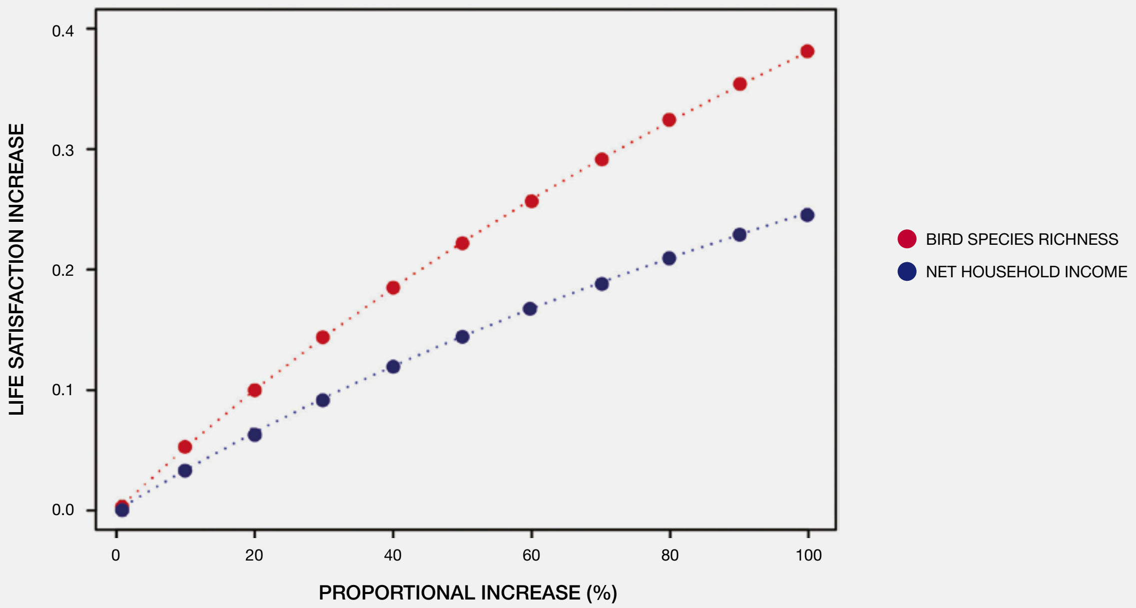


Figure 3 64 **Estimated life-satisfaction increase correlates to bird species richness and income across Europe.**

Estimates are based on the coefficients for log-transformed mean bird species richness and log-transformed net household income, both corrected for socio- and macro-economic factors. Source: (Methorst *et al.*, 2021) under license CC BY-NC-ND 4.0.

J. Wu, He, Chen, Lin, & Wang, 2020). Gentrification, while making cities more attractive to wealthy residents and attracting investment, has environmental justice implications, especially on urban green space access by lower class or income communities (Kronenberg *et al.*, 2020). Public space is also increasingly being 'corporatized', where public space maintenance is sponsored by private interests, and the urban green space is redesigned and highly controlled to meet the needs of the 'owner' rather than the general public (S. Schmidt, 2004). Research in North American cities on parks, urban forests and tree canopy cover found race, ethnicity and income disparities in tree distribution with non-white communities living in areas of lower tree density and lower quantity and quality of parks (Heynen, Perkins, & Roy, 2006; Rigolon, Browning, & Jennings, 2018). The disproportionate access to and distribution of urban green spaces creates inequitable health benefits derived from exposure to nature, with lower income and minority communities in cities more likely to live in "riskscapes" – environments that increase the vulnerability of these communities to pollutants and hazards (Jennings, Johnson Gaither, & Gragg, 2012).

"Green prescriptions" such as "forest bathing" are increasing as they improve human health, but there are also win-win opportunities for people and ecosystems through "reciprocal restoration". Pilot initiatives with urban youth working in habitat restoration programs have shown greater anti-inflammatory capacity, cardiovascular fitness, resistance to endoparasites, resistance to infectious diseases, reduced sensitivity to allergens, reduced frequency of nervous and musculoskeletal disorders and a wide range of positive effects on mental health (Nabhan, Orlando, Smith Monti, & Aronson, 2020). Concurrently, habitats are restored including vegetation cover and soil microbial content (Nabhan *et al.*, 2020).

The hypothesized mechanisms for the documented improvements in mental and physical health include the Microbiome Rewilding Hypothesis where restoring soil microbial diversity enhances human gut microbiome health and boosts immune functioning, and the Psycho-Evolutionary Restoration Hypothesis where humans exposed to forested systems exposes them to phytoncides that may reduce depression and lower cortisol levels (Nabhan *et al.*, 2020). In a critical review of the effects of environmental diversity on human health, Sandifer *et al.*, (2015) found the only unambiguous causal relationship was the maintenance of a healthy immune system and reduction of inflammatory diseases through exposure to environmental microbial diversity. There is also a limit in research on the sustained, long-term effects of nature-based therapies (Rajoo *et al.*, 2020). However, despite the limited information about the causal nature underlying the benefits of nature and biodiversity to human health, protecting and restoring a diversity of natural habitats seems crucial for maintaining human health in a developing world (Sandifer *et al.*, 2015). Indeed, the improvement of human health is a powerful tool to leverage support from multiple stakeholders to enhance social-ecological health in a variety of ways.

3.3.5.2.3 Recreation

Wildlife watching is an activity that involves the watching of wild species (animals and plants). Watching wild species is essentially an observational activity, although in some cases it can involve interactions with the animals being watched, such as touching or feeding them (UNEP/CMS, 2006). These recreational activities include nature-based tourism, hiking and nature walks, photography and cinematography, game watching and safaris, and snorkeling and scuba diving. The use of wild species for recreation is primarily for enjoyment but may also provide relaxation, restoration, physical exercise (see section 3.3.5.2.2. Medicine and hygiene), and educational experiences (see section 3.3.5.2.4. Education and learning).

The scope of this section is limited to the non-extractive practices of wild species for recreation where the impact of the use can be measured or assessed. The text below is based on a literature review (Web of Science) using the following strings of terms ("non-extractive use*" OR "non-consumptive" OR "cultural ecosystem service*" OR "non-material contribution*" OR "touris*" OR "community based tourism*" OR "ecotourism" OR "eco-tourism" OR "sustainable tourism" OR "recreational" OR "nature-based tourism" OR "wildlife watching" OR "wildlife viewing") AND (sustainab* OR trend*), generating 16117 hits. Articles that were recommended by citation databases were also considered, as well as collected from personal libraries and recommendations from experts. After a title and abstract read, 82 papers were selected for a full text read. After a full text read of these papers, 27 were deemed relevant and assessed for the literature review. Relevance was determined by mention of the status (current), trend (historical) or impacts of use of a wild species (or taxa) in at least one dimension of sustainability (social, economic, or ecological). These data form the basis of the text below.

The literature covered fairly equally (4-6 papers each): vegetation (trees and shrubs); terrestrial mammals; birds (terrestrial and marine); marine mammals; fish, rays and sharks; and arthropods (marine and terrestrial). The temporal scale of the research articles was 10 short term (<1 year), 1 medium term (1-10 years), and 9 long term (>10 years) studies. The review included articles from every IPBES region.

Most of the information in the text below relates to wildlife watching tourism, as 74% of relevant articles focused on tourism specifically. Wildlife watching does occur around people's homes (Wilkinson, Waitt, & Gibbs, 2014; Zarazúa-Carbajal *et al.*, 2020), but this is less well documented than wildlife watching tourism. Wildlife watching tourism overlaps with various types of tourism, such as tours focused on seeing a specific kind of wild taxa **(Table 3.19)** and tourism where wildlife watching is an added advantage but not the main focus of the activity (e.g., adventure and sports tourism) (UNEP/CMS, 2006). Similarly, a specific type of nature-based tourism is eco-tourism, where the tourism activity aims to contribute to the conservation of natural and cultural heritage through the involvement of indigenous peoples and local communities (UNEP/CMS, 2006). Eco-tourism has relatively low numbers of tourism and is suited to small groups and independent tourists (UNEP/CMS, 2006).

Social aspects

Enjoyment of nature for tourism and recreation is recognized as the most prominent cultural nature's contributions to people (Balmford *et al.*, 2015). Over the last half a century the demand for nature-based tourism experiences has been on the rise, with the ever-increasing breadth and depth of its global penetration, integrating more and more natural areas into commercial processes (Balmford *et al.*, 2009, 2015; Elmahdy, Haukeland, & Fredman, 2017; Hall, Harrison, Weaver, & Wall, 2013; Mowforth & Munt, 2015; D. Scott & Gössling, 2015). For example, according to rough estimations, world terrestrial protected nature areas currently receive approximately 8 billion visits per year, of

Table 3 19 **Examples of species- and taxa-based wildlife watching across the globe.**
Source: (UNEP/CMS, 2006) under license CC-BY.

Species being watched	Tourism Activity	Location example
Butterflies	Butterfly watching	Monarch butterflies in Mexico, United States of America and Canada
Glow worms	Glow worm watching	Springbrook National Park, Australia
Crabs	Red crab migration	Christmas Island, Indian Ocean
Corals and fish	Snorkel/scuba diving	Bunaken, Indonesia; Sian Ka'an, Mexico; Soufriere Marine Management Area, St. Lucia; Bonaire, Caribbean; Red Sea, Egypt
Sharks	Snorkel with whale sharks	Seychelles; Ningaloo Reef, Australia
Sharks	Underwater watching/feeding of sharks	Dyer Island, South Africa
Stingrays	Feeding and close interaction with stingrays	Cayman Islands; Maldives; Australia
Komodo dragons	Watching Komodo dragons	Komodo Island, Indonesia
Snakes	Watching pythons	Bharatpur, India
Crocodiles	Watching crocodiles	Black River, Jamaica; Kakadu Park, Australia
Turtles	Watching turtles	Projeto TAMAR-IBAMA, Brazil; Akumal, Yucatán Pennisula, Mexico; Cape Verde; Maputaland, South Africa; Sri Lanka; Indonesia
Birds	Independent or organized visits to reserves for bird-watching	Bempton Cliffs, United Kingdom; Keoladeo, India; Pantanal, Brazil
Albatrosses	Independent or coach tours to see breeding colonies	Taiaroa Head, New Zealand
Cranes	Watching cranes	Müritz National Park, Germany; Platte River, United States of America
Penguins	Watching penguins and penguin colonies	Antarctica; Peninsula Valdés, Argentina; Phillip Island, Australia
Large African mammals	Vehicle safaris to see large concentrations of mammals	Serengeti National Park, Tanzania; Masai Mara, Kenya
Tigers	Tiger watching from hides or elephant back	Chitwan National Park & Bardia National Park, Nepal
Gorillas	Mountain trek and camping to observe habituated gorillas	Bwindi National Park, Uganda; Virunga National Park, Democratic Republic of Congo; Volcanoes National Park, Rwanda
Orangutans	Watching orangutans	Sepilok Orangutan Centre & Danum Valley, Sabah Semenggok Wildlife Centre, Sarawak, Borneo
Polar bears	Watching polar bears	Churchill, Canada
Bats	Watching bats	Texas, United States of America
Dolphins	Watching dolphins	Red Sea, Egypt; Mon Repos, Australia
Whales	Watching whales	Peninsula Valdés, Argentina; Kaikoura, New Zealand; El Vizcaino, Baja California, Mexico; New England, United States of America; Plettenberg Bay, South Africa; Canary Islands

which 80% are in Europe and North America (Balmford *et al.*, 2015). In general, nature-based tourism and recreation are affected by the following global drivers of change, i.e., megatrends: *social trends* (population growth, urbanization, changes in household composition, aging population, health and well-being, changing work patterns, gender equality, values and lifestyle); *technological* (transportation, high-tech equipment, information and communication technologies); *economic* trends (economic growth; sharing economy; fuel costs); *environmental* (climate change; land use and landscape change); *political* (political turbulence; changes in border regulations; health risks; geopolitics) (Elmahdy *et al.*, 2017). The complexities of these drivers are discussed in Chapter 4 of this assessment. For the purposes of Chapter 3, it is important to point out that a combination of these interconnected global trends is and will be significantly affecting demand for nature-based tourist experiences and the way people engage with nature.

There is concern that the aforementioned global trends contribute to increasing disconnectedness of large masses of populations from natural phenomena and processes in their daily life, which generates interest to experience nature as a leisure activity in an organized, often commercialized setting (Buckley, 2000; Buckley, Gretzel, Scott, Weaver, & Becken, 2015; Curtin, 2005; Dwyer, 2003; Elmahdy *et al.*, 2017). It has been observed that nature-based tourism and recreation are increasingly characterized by the importance of experiences, achievement, adventure and well-planned activities rather than simple leisure and social interaction. Many studies indicate that tourism and recreation in nature are becoming more specialized, diversified, motorized, sportified and adventurized (Öhman, Öhman, & Sandell, 2016; Sandell, Arnegård, & Backman, 2011). In this context nature is transformed into a setting, a scenic backdrop for tourist experiences (Fossgard & Fredman, 2019; Margaryan, 2017). This also affects tourists' expectations regarding the availability of tourism-related services in nature. There is a growing demand for 'wild', 'unspoiled', 'pristine' nature in combination with high levels of comfort, accessibility and high-quality experiences (Elmahdy *et al.*, 2017; Fredman, Wall-Reinius, & Grundén, 2012). These pristine landscapes are advertised for tourism in brochures with backgrounds of teeming game, but absent of the human communities that live alongside wild species (Montgomery, Borona, Kasozi, Mudumba, & Ogada, 2020).

This marketing perpetuates that indigenous peoples and local communities are separate from the social-ecological system, constitute a threat to wild species conservation, and drives the alienation and displacement of indigenous peoples and local communities, often with indigenous peoples and local communities on the boundaries of conservation areas receiving few benefits from tourism activities taking place (Montgomery *et al.*, 2020; Saarinen, Moswete, Atlhopheng, & Hambira, 2020). Indigenous peoples and local communities also suffer from the negative aspects of tourism, for example disease and predation adjacent to protected areas (Swemmer, Mmethi, & Twine, 2017), or tourist-related disturbance of their activities (e.g., snow mobile recreation in the vicinity of Saami reindeer herders in Lapland (Kluwe & Krumpe, 2003), or rock climbers disturbing Native American rituals on Devils Tower/Mato Tipila in Wyoming (Taylor and Geffen 2004). There may also be a conflict in values between recreational and non-recreational users, especially around expected behavior in sacred areas or around traditional hunting practices (Zeppel, 2010). Tourists can also cause degradation of culturally important sites through or illegal removal of cultural heritage items (INTOSAI WGEA, 2013). Tourism may change local identities and values, through commercialization of local culture and standardization to meet tourists' expectations (INTOSAI WGEA, 2013).

As the demand for wild species-related experiences is on the rise, wild species-related content on social media and wild species documentaries have become more popular than ever. For example, the British Broadcasting Corporation (BBC) Planet Earth I and II have been among the most watched documentaries worldwide (Jackson, 2016). The growth of media attention and circulation of wild species-related content in the social media further stimulates demand to experience wild species in real life, as well as photograph and share 'selfies' with wild species. Between 2014 and 2017 there has been a documented increase of nearly 300% in the quantity of wild species selfies shared on the Instagram platform (World Animal Protection, 2017). Of these, over 40% could be classified as inappropriate wild species selfies – featuring handling, hugging, touching, feeding or other potentially detrimental interactions between humans and wild species (World Animal Protection, 2017).

Tourism marketing and social media sharing influences the demand for extremely close interactions with wild species (Dou & Day, 2020). However, research has shown the dichotomy of tourists' desires for intimate encounters with wild species and recognition of the detrimental effects on animal welfare as a result of these interactions (Dou & Day, 2020). Environmental education and increased awareness of wildlife watching sustainability can and does play a role in changing tourist behavior, such as that demonstrated in dolphin-watching tours where tourists were willing to trade-off close interactions for the purposes of dolphin welfare (Dou & Day, 2020). Research on Mozambiquan tourists showed low awareness of cetacean-based regulations, but the tourists were supportive of well-regulated activities, therefore educated tourists could increase operator compliance with regulations (Rocha *et al.*, 2020). In their review on wildlife watching sustainability, Dou and Day (2020) caution that environmental awareness does not occur automatically from increased exposure to wild species, but rather from focused environmental education with targeted, actionable messages on biodiversity conservation.

Wildlife watching has emerged as a widespread and lucrative tourist activity and its popularity is growing rapidly (de Lima & Green, 2017; Dybsand, 2020; Hassan & Sharma, 2017; Karanth *et al.*, 2017; Mowforth & Munt, 2015; World Animal Protection, 2017). International tourism has grown year after year for the last decade, driven in part by nature-based tourism (including extractive tourism activities) (UNWTO, 2019). Between 1990 and 2000, average annual international tourism growth was 4.4%, but wild species-rich countries like Madagascar, Brazil, Cuba and South Africa all experienced averages between 10-20% annually and Vietnam and Laos between 24-36% (UNEP/CMS, 2006). Regional share of wildlife watching tourism relative to overall tourism varies globally, from 36.3% in Africa to 1.6% in Europe (WTTC, 2019a). Domestic tourism is estimated to be ten times the scale, but the numbers are uncertain. Similarly, the proportion of non-extractive nature-based tourism in recreation and leisure tourism is difficult to unpack as increasingly tourism trends have seen a blend in various types of tourism, such as family holidays that involve urban, adventure tours and wildlife watching (UNEP/CMS, 2006), or visits that combine trophy hunting and wildlife watching. But comparisons of protected area visitation rates mirror overall tourism rates in low-income countries (Balmford *et al.*, 2009).

A global study estimates that protected areas receive 8 billion visits per annum, generating 600 billion United States dollars (Balmford *et al.*, 2015). Revenue generated from tourism in protected areas far exceeds the cost of managing these areas (Balmford *et al.*, 2015; WTTC, 2019a). Surveyed governments and tour operators overwhelming rank nature, national parks and wild species as their largest assets for tourism, a practice that is labor intensive and employs local communities, especially in remote areas where developing regions do not have many other employment options (UNWTO, 2015). Nature-based tourism has been increasing over the last decade as a result of increased demand (increased knowledge of wild species from media and the internet) and shrinking supply (reduced habitats and wild species scarcity) (The World Bank, 2018). This is apparent in visitation data for the iconic nature-based tourism destination, the Galapagos Islands, which has recorded an increasing trend in visitors from 1989 (<50,000 visitors) to 2019 (about 271,000 visitors) (Díaz-Sánchez & Obaco, 2020).

Recreational use of wild species also generates significant revenue, particularly through nature-based tourism. Wildlife watching contributed 120.1 billion United States dollars in 2018 (343.6 billion United States dollars with multiplier effects) to global gross domestic product, five times the estimated value of the illegal wild species trade (WTTC, 2019a). Wildlife watching also sustained 21.8 million jobs (WTTC, 2019a). The global monetary potential value of whale watching was estimated at over 2.5 billion United States dollars in 2009 and supporting 19,000 jobs (Cisneros-Montemayor *et al.*, 2010). Shark and ray watching generated over 314 million United States dollars per annum, directly supporting 10,000 jobs and is expected to double by 2033, generating over 780 million United States dollars globally (Cisneros-Montemayor, Barnes-Mauthe, Al-Abdulrazzak, Navarro-Holm, & Sumaila, 2013). In contrast the value of shark fisheries was estimated at 630 million United States dollars and has been on the decline over the last decade (Cisneros-Montemayor *et al.*, 2013). The expected revenue from entrance tickets to the Galapagos Islands in 2020 was about 18 million United States dollars, although significant losses have been predicted as a result of the COVID-19 pandemic (Díaz-Sánchez & Obaco, 2020). This revenue is mainly allocated to Galapagos Island conservation programs (Díaz-Sánchez & Obaco, 2020). International tourism arrivals in Africa, in large part for wild species tourism (including extractive recreational tourism), in 2013 were 56 million people, generating 34.2 billion United States dollars, and 134 million tourists are expected in 2030 (World Tourism Organization, 2014). During 2000 in East Africa alone, 1 billion United States dollars was generated from foreign tourist arrivals (UNEP/CMS, 2006). In the United States of America, wildlife watching engaged 86 million people in the vicinity of their homes, and 81.1 million people travelled away from home to view wild species, generating 75.9 billion United States dollars (United States of America Department of the Interior, United States of America Fish and Wildlife Service, United States of America Department of Commerce, & United States of America Census Bureau, 2018). Recreation represents over 75% of the value of the United States of America national forests, higher than the value of timber extracted (Groom *et al.*, 2006).

Although tourism revenue is significant at the national level, for economic benefits to alleviate poverty, the World Tourism Organization (UNWTO) found local level employment, infrastructure benefits, supply of goods and services and support by the tourism enterprises, as well as other pro-poor approaches were important (UNEP/CMS, 2006). If local communities and suppliers are able to meet the standard needed to cater to international tourists, considerable benefits can accrue to the local economies (Twining-Ward, Li, Bhammar, & Wright, 2018; UNEP/CMS, 2006). However, if supplies and expertise are sourced on imports, then 50% or more of the tourism revenue "leaks" from the local and national economies (UNEP/CMS, 2006).

Wild species which have the biggest importance for the tourism and recreation practices are those which attract interest from the widest spectrum of tourists, i.e., the 'flagship' species – most often the megafauna, 'charismatic' mammals and birds, the 'cute and cuddly', dangerous predators, threatened species, and species that are believed to display intelligence (Aguilera-Alcalá, Morales-

Reyes, Martín-López, Moleón, & Sánchez-Zapata, 2020; Carr & Broom, 2018; Devillers & Beudels-Jamar, 2008; Higginbottom, 2004; Newsome, Moore, & Dowling, 2012). The growing awareness of biodiversity loss has created a demand to see places and wild species that might disappear, including "endangered experiences", highly exclusive tourism packages offering unique opportunities (WTTC, 2019b). For example, in Eurasia and Africa, national parks that hold large mammals have much higher visitation rates than those which do not (Devillers & Beudels-Jamar, 2008).

Difference in preferences for wild species has its roots in a range of evolutionary as well as cultural predispositions (Jacobs, 2009). While some countries have a long history of wildlife watching tourism (e.g., in the East and South Africa), recent rapid growth of this business has been observed in many new destinations, for example in Southeast Asia and the Amazon (Karanth *et al.*, 2017; World Animal Protection, 2017). Overall, natural areas of high value for wildlife watching tourism tend to be characterized by (i) abundance of large animals, (ii) presence of charismatic species, and (iii) high biodiversity (Higginbottom, 2004; Newsome *et al.*, 2012). It is expected that presence of tourism in such areas will only be increasing, so special attention needs to be paid to aspects of sustainability in these processes.

Wildlife watching activities and tourism accrue considerable funds for conservation projects, as well as raising public awareness of the need for conservation. A case in point is Projeto Tamar which, through working with local communities and fishers, successfully promoted turtle conservation along the Brazilian coastline, improving turtle hatching success through protecting hatchery sites and establishing alternative employment and income opportunities based on tourism and turtle protection (UNEP/CMS, 2006). Similarly, a public-private partnership in a heavily poached region resulted in increased revenue for local communities and provided alternative revenue, to such a degree that wild species are again abundant in Majete Wildlife Reserve, Malawi (Twining-Ward *et al.*, 2018). Conservation of one of the last remaining nesting sites of Little Penguins *(Eudyptula minor)* on Australia's Phillip Island Nature Park, on Bunurong Aboriginal Land, is funded by an inclusive, collaborative business plan for tourism (UNEP/CMS, 2006). The business plan is revised every five years with the community and stakeholders and the Bunurong community representatives are involved in education programs and project supervision of a high-quality, high-volume tourist enterprise (UNEP/CMS, 2006).

Ecological aspects

Wildlife watching can have unintended consequences for wild species in three ways: changes to species behavior, changes to physiology, or damage to habitats (UNEP/CMS, 2006).

Behavioral changes to wild species include changes to feeding or resting time, expending energy to try and move away from the disturbance, altering interactions between different species (UNEP/CMS, 2006), aggressive behavior, increased stress, or alternatively a reduction in fear towards humans, and dependency on non-natural and supplemental food sources especially at feeding sites (Dou & Day, 2020), or preventing optimal spatial distribution relative to resources (Blanc, Guillemain, Mouronval, Desmonts, & Fritz, 2006). Short-term changes in animal behavior as a result of human-wild species interactions in tourism contexts are easier to detect and well-studied, but long-term changes are under researched (Dou & Day, 2020). Similarly, tourism effects on wild species individuals are more detectable and better documented than the repercussions of these individual effects at the population level (Blanc *et al.*, 2006).

The evasive nature of wild species together with tourists' expectations for a close contact with wild species creates a strong incentive for tourist destination managers to minimize sighting uncertainty and decrease the watching distance through invasive practices ranging from baiting, attracting, and habituating, to capturing animals (Dybsand, 2020; Knight, 2009; Margaryan & Wall-Reinius, 2017), and driving off-road (Nortje, 2014). Commercial wildlife watching activities rely on wild species being made viewable, which is often achieved through highly unsustainable and unethical practices (Dybsand, 2020; Knight, 2009; World Animal Protection, 2017). For example, high tourist volumes in the Serengeti have created serious disturbance for wild species and the large area of the park makes it challenging to enforce responsible game watching behavior (UNEP/CMS, 2006). In one case, the cubs of a cheetah were scared away by 15 vehicles and assumed to be predated on by lions as they were never seen again (UNEP/CMS, 2006).

Snorkeling and diving may also disturb the aquatic habitat and influence species behavior (Teresa, Romero, Casatti, & Sabino, 2011). The practice of fish feeding during diving may affect fish communities (Ilarri, Souza, Medeiros, Grempel, & Rosa, 2008). A long-term, intensive study of the detrimental impacts on wild species from even well-managed, low level, commercial watching and controlled feeding of bottle-nosed dolphins at Monkey Mia, Western Australia documented long-term dolphin responses to human-wild species interaction. Over decades of monitoring, dolphin abundance (immigration and mortality) and fecundity declined at the tourism sites but not the control sites (Higham & Bejder, 2008). Highly responsive management interventions were implemented based on the research recommendations (Higham & Bejder, 2008) and impacts were reduced after regulations limiting the duration of feeding events (Foroughirad & Mann, 2013). However, findings of this nature are of great concern for the unknown long-term sustainability at other, especially high-intensity and/or low management tourism sites, for cetaceans and other wild species (Dou & Day, 2020; Higham & Bejder, 2008).

A similar activity has been conducted in the Negro River, in the Brazilian Amazon, directed to feeding the freshwater pink (or red) dolphin *(Inia geoffrensis)*, but the potential effects of this activity on dolphin's behavior are not well known, but potentially increase dolphin aggression and may be harmful to both the dolphins and tourists (Pinto de Sá Alves, Andriolo, Orams, & de Freitas Azevedo, 2013). White sharks *(Carcharodon carcharias)* watching activities elicited curiosity and aggressive behaviors associated with feeding, leading the authors to advise against intentional feeding to avoid human-shark-cage associated incidents and the conditioning of sharks to boats (Becerril-García, Hoyos-Padilla, Micarelli, Galván-Magaña, & Sperone, 2019).

Even relatively innocuous recreational activities can have an impact on animal behavior. Research using camera traps to assess the prevalence of human recreational activities in association with terrestrial mammal occurrence in a Canadian protected area showed avoidance of mountain biking by moose (*Alces* spp.) and grizzly bears *(Ursus arctos)*, although all recorded mammal species avoided humans on trails, especially mountain bikes and motorized vehicles (Naidoo & Burton, 2020). Even "silent activities" such as windsurfing may have impacts as they enable off-path access to otherwise "sanctuary" areas (Blanc *et al.*, 2006). But the presence of tourists and vehicles can be reduced through spatial or temporal zonation to provide sanctuary for wild species. The adverse impacts of high volumes of tourists and vehicles on wild species is managed in the Serengeti through strict park zonation, where certain areas are designated "No-Go" zones where no wildlife watching is allowed, "Intensive" and "Low Use" zones have designated tourism activities and "Wilderness" zones where no vehicles are allowed and low numbers of tourists do walking tours (UNEP/CMS, 2006).

Habituation (stress response decreases with repeated exposure to humans) or sensitization (stress response increases with repeated exposure to humans) varies across and within species, and with the type of stressor, the type of tourism, spatiotemporal aspects, life history traits and intraspecific characteristics (Geffroy, Samia, Bessa, & Blumstein, 2015). For example, African penguins *(Spheniscus demersus)* and Magellanic penguins *(Sphenicus magellanicus)* habituate to humans but yellow-eyed penguins *(Megadyptes antipodes)* sensitize to humans (Geffroy *et al.*, 2015). Thus, the impacts of repeated exposure to humans are extremely context-dependent and need to be assessed locally, as well as monitored over the long-term. This has important repercussions for wild species, as behavioral changes as a result of tourist-exposure may compromise their susceptibility to poaching or their risk of predation by other animals (Geffroy *et al.*, 2015).

Wild species' physiology may be affected by tourism activities even though their behavioral patterns have not altered (Dou & Day, 2020). Yellow-eyed penguins *(Megadyptes antipodes)* at unregulated tourism sites showed significantly higher stress-induced corticosterone concentrations, with lower breeding success and lower fledgling weights than penguins visited for monitoring purposes only (Ellenberg, Setiawan, Cree, Houston, & Seddon, 2007). The presence of roads and traffic can also increase animal stress levels (Lunde, Bech, Fyumagwa, Jackson, & Røskaft, 2016). A well-studied intensive tourism site at the Grand Cayman Islands where stingrays *(Hypanus americanus)* are visited and fed by recreational scuba divers since 1986 have shown haematological changes, increased parasite loads, high injury rates and open wounds from boat collisions, and major behavioral changes from being normally solitary to forming schools of 12-15 individuals, as well as switching to diurnal feeding at the dive sites (UNEP/CMS, 2006). Most of the stingrays' food now comes from divers and the reduced dietary diversity has compromised their disease resistance and immune response (UNEP/CMS, 2006). However, these kinds of examples of poor tolerance of tourist activities by species are species, habitat, tour operator and regulator specific. For example, a comparison between the effects of provisioning and viewing on the Cayman stingrays, which has been shown as detrimental, against the highly self-regulated and limited number of shark-feeding tour operators in Fiji suggests no effects on bull shark (Carcharhinus leucas) fitness and health (Healy, Hill, Barnett, & Chin, 2020).

The trend in using wild species as photo props for "selfies" as photographic souvenirs has driven an increase in captive and handling of wild species, like slow lorises (*Nycticebus* spp.) in Asia, which have their teeth clipped to reduce the risk of injury to tourists, and results in early death (Osterberg & Nekaris, 2015). A study of three-toed sloths *(Bradypus variegatus)* in Brazil and Peru found each sloth was held by on average five tourists, often by the claws and had their limbs stretched and manipulated (Carder *et al.*, 2018). Wild species handled for long durations have been shown to display increased behavioral and physiological stress responses, leading to injury, stress and death (Baird *et al.*, 2016).

Tourists and other recreational users of nature, especially in high volumes, can damage the environment and species habitats. Trampling vegetation and the creation of informal trails both damages the environment and reduces the appeal and restorative impact on human health and well-being of these areas to other recreational users (Taff, Benfield, Miller, D'Antonio, & Schwartz, 2019). There is evidence that scuba diving, even without fish feeding, may cause unintentional damage to aquatic organisms, such as corals and algae, which may be hit by divers (Di Franco, Milazzo, Baiata, Tomasello, & Chemello, 2009). The sunscreen from divers and swimmers has been associated with bleaching of coral reefs (Danovaro *et al.*, 2008; Downs *et al.*, 2014) and Hawaii has banned the use of sunscreens containing oxybenzone or octinoxate from the 1st of January 2021 with similar bans predicted to follow in other coral-reef containing countries (Raffa, Pergolizzi Jr, Taylor Jr, Kitzen, & Group, 2019). Even a single vehicle driving on sandy beaches has been estimated to crush up to 0.75% of the intertidal population (Schlacher, Thompson, & Price, 2007) and beach camping zones show a 20.2% reduction in dune vegetation (Thompson & Schlacher, 2008).

A review of winter recreational activities in Alpine areas found ski resorts and associated infrastructure have negative impacts across all studied taxa, independent of geographic region or ski modification (Sato, Wood, & Lindenmayer, 2013). This is concerning as the area affected in Europe by ski-runs is large and increasing, currently spanning about 4000 km across Italy, Switzerland and Austria, although there is a suggestion that environmentally-friendly ski-run design could mitigate many of these impacts (Rolando, Caprio, Rinaldi, & Ellena, 2006). Tourism facilities (e.g., lodges, ablutions) and impacts from waste, as well as high water usage are concerns in the nature-based tourism industry (UNEP/CMS, 2006). Despite initiatives to foster sustainable travel behaviors (e.g., carbon offsetting for unavoidable travel emissions) and attempts to improve the eco-efficiencies of tourism industries, tourism carbon emissions have increased at 3.3% annually (Sun, Lin, & Higham, 2020), driven by increased travel frequency, long-haul flights and shorter stays per trip (Sun *et al.*, 2020).

Altering resource availability to wild species to increase watching potential can have unintended consequences on the surrounding ecosystem. The provision of artificial water points in Kruger National Park, South Africa, although intended to maintain herbivore numbers during droughts expanded the range of water-dependent species (e.g., zebra and wildebeest), and in association their predators (e.g., lions) to the detriment of less common species (e.g., roan antelope) (Harrington *et al.*, 1999). The widespread availability of surface water has also been implicated in the reduction of vegetation structure by homogenizing elephant impacts across the landscape (Gaylard, Owen-Smith, & Redfern, 2003).

These unintended effects to facilitate watching wild species demonstrate the complexity of tourism impacts on populations and ecosystems. As these impacts are species and context specific, there is much to be discovered about the potential of tourism impacts. Even under the best code of conduct, there might still be detrimental, often cryptic, effects on animal reproduction and long-term survival (Carr & Broom, 2018; Szott, Pretorius, Ganswindt, & Koyama, 2020; Tyagi *et al.*, 2019). A review of tourist impacts on wild species cautions that although the literature overwhelmingly reports on negative impacts, the findings are strongly dependent on the methods used and many findings (especially behavioral responses) could be interpreted as short-term coping strategies that do not necessarily have long-term repercussions (Bateman & Fleming, 2017). Considerable variation exists between and within species and locations, in tourism operator methods and regulations. Therefore, more serious and coordinated global multi-stakeholder efforts to regulate this practice, involving tourism businesses, local communities, science, governmental and non-governmental organizations, are needed.

Considerations for sustainable recreational use

Based on the current trends one can expect further growth in demand for wildlife watching experiences and, consequently, an increasing number of wild species integrated into tourism operations. Particularly vulnerable in this perspective are the megafauna and 'charismatic' wild species, which, however, also receive the most media attention and conservation support (Carr & Broom, 2018). Megafauna are the best studied taxa of animals, whereas there is a lack of research on the impacts of tourism on the lesser fauna, e.g., ground-dwelling mammals, small reptiles, insects, etc. (Wolf, Croft, & Green, 2019). The interlinkages between tourism, representations of wild species on social media, conservation and sustainability have acquired great importance and need further research and policy attention. Likewise, the role of environmental education in changing tourist attitudes and behavior requires further research attention (Dou & Day, 2020).

Specific attention needs to be paid to the emergence of the so-called tourist-driven destinations, which appear spontaneously based on a spike in media popularity and uncontrolled tourist demand, rather than coordinated marketing efforts of the local tourism actors. In addition, the expansion of tourism into remote, 'pristine' areas needs to be managed and monitored to avoid detrimental impacts to sensitive and vulnerable species (UNEP/CMS, 2006). As tourists prefer areas that are deemed 'pristine' (i.e., more ecologically and aesthetically sound), there are opportunities to increase recreational tourism by restoring ecosystems. For example, work in RAMSAR (the Convention of wetlands of international importance) listed wetlands in India suggest that annual recreational visits could increase by 13% if the water quality could be improved to maintain wild species and fisheries diversity and abundance (Sinclair, Ghermandi, Moses, & Joseph, 2019). Researchers have also highlighted the need for studies that integrate the ecological and social aspects of human-wild species interactions to inform the sustainable development of the tourism industry, local communities and wild species conservation (Dou & Day, 2020). Financial resources and operational experience are sorely needed at the human-wild species interaction interface, with many wild species populations attractive to tourists in countries least able to afford the research, management and monitoring needed in these sites (Dou & Day, 2020). Finding ways to mobilize the power of new communication technologies and channel them towards sustainable tourism practices will be crucial in achieving more sustainable wildlife watching operations.

Sustainable nature-based tourism needs to make a positive impact to the natural and social setting that tourism takes place in, and should generate benefit for the host communities and indigenous peoples and local communities in a manner that does not compromise the future human well-being needs of indigenous peoples and local communities or the ecosystems (UNEP/CMS, 2006). Well-managed wildlife watching is a significant boon to community development and revenue, as well as an important source of funding for wild species conservation (UNEP/CMS, 2006). However, tourism is only sustainable where the habitats and species being used recreationally are sufficiently resilient to the impacts related to the use, where tourism and the associated development is kept within manageable limits, where the tourism experience attracts a long-term and viable tourism economy, and where local communities and the local economy benefit from the activity (UNEP/CMS, 2006). The direct benefits range from increased income and employment through education and access to many new facilities, up to perception of pride and recognition. Although the direct economic benefits are most important to local residents (Akis, Peristianis, & Warner, 1996), the indirect benefits such as improved public infrastructure, education, public safety and healthcare facilities may reach even wider groups of people (e.g., Afenyo & Amuquandoh, 2014) and gain the support for tourism among those who do not benefit directly from the activity. Addressing the above points to plan and manage sustainable nature-based tourism requires stakeholder engagement in a process that helps identify diverse interests, provides expertise, and facilitates local commitment to managing tourism ventures and impacts (UNEP/CMS, 2006).

An exemplary case study of stakeholder engagement in wild species tourism is that of Bunaken national marine park, Indonesia. Bunaken national marine park pioneered a co-management approach that is being modelled by other protected areas (UNEP/CMS, 2006). Bunaken national marine park is a popular dive site for international tourists, as well as the home of 30,000 people whose livelihoods depend on fishing. Park management is overseen by a multistakeholder advisory board, including governmental, non-governmental organizations, representations of the villages within the park, park authorities, Tourism and Fisheries Departments, the local universities and the private tourism sector (UNEP/CMS, 2006). Local community elders advised on the location of the marine sanctuaries and no-take zones, the local community is involved in reef restoration efforts, and advised where to place marine sanctuaries which replenish both diving and fishing sites. Proceeds from park fees are managed by the multistakeholder board and are used for conservation and development programs, village development schemes, plastic and waste disposal, environmental education of villagers, rehabilitation and restoration projects, and law enforcement and patrols for destructive fishing and tourism practices (UNEP/CMS, 2006). Stakeholder needs have evolved as the social and environmental landscape has changed, and management has recognized the need to be adaptive in this regard. In Bunaken, the growing popularity for tourism is placing additional stress on the reefs and the large numbers of dive operators are not all members of the stakeholder association. They are considering a mandatory license system rather than voluntary compliance to manage the number of divers, dive operators and boats (UNEP/CMS, 2006). In another example, an unexpected repercussion of a successful public-private partnership in a heavily poached reserve has resulted in a tourism and revenue boom in Malawi's Majete wildlife reserve, but the now abundant wild species are affecting local communities' resources, increasing human-wildlife conflict (Twining-Ward *et al.*, 2018).

Stakeholders differing needs and perspectives need to be negotiated, as power imbalances between stakeholders can undercut effective collective management actions (Meza-Arce *et al.*, 2020). Recreational use may also be at odds with the extractive natural resource use needs of the local communities. This highlights the need to manage both physical and cultural conflicts between recreational users and indigenous peoples and local communities, through temporal or spatial zoning as well as by addressing the disparate cultural and social values of the respective stakeholders sensitively (Zeppel, 2010).

Significant opportunities exist for tourism revenue to support indigenous peoples and local communities that are already involved in conservation practices through local and traditional practices. The *Entim e Naimina Enkiyio* (Forest of the Lost Child) is one of few ungazetted forests in Kenya supporting abundant wild species, including threatened and highly endemic species (Tebtebba Foundation, 2010). This site is estimated to have tourism potential of up to 40,000 United States dollars per annum, notwithstanding the other benefits supporting conservation would ensure, such as catchment protection, wild algae, fungi and plants, grazing, and spiritual and cultural value (Tebtebba Foundation, 2010). The communities conserving biodiversity, as well as managing the natural resources for their subsistence, should be supported and strengthened where appropriate.

However, the benefits of tourism should not be overstated and require careful consideration of what is realistic (UNEP/CMS, 2006). For example, in a survey of World Bank Global Environnement Facility projects, most projects had positioned tourism as key to sustainable resource management and wild species conservation, but only 8% of the projects analyzed the tourism-derived income potential (UNEP/CMS, 2006). A key finding of this World Bank survey was that although tourism did generate revenue, it could not be solely relied on and was not even the most important source of funding (UNEP/CMS, 2006).

An economic model of the impacts of increased tourism revenue in the Philippines demonstrated that although economic benefits are accrued to all local households in the short-term, over the long-term increased demand for natural resources driven by the tourism industry eroded local household incomes, particularly for households directly involved in the natural resources economy (Gilliland, Sanchirico, & Taylor, 2020). Similarly, tourism in Latin America was associated with increased agricultural expansion and deforestation to service tourist consumption (Gunter & Ceddia, 2020). Providing indigenous peoples and local communities with title deeds and land rights seemed to mitigate this effect, although the research authors caution this effect should not be overstated (Gunter & Ceddia, 2020).

The Monarch Butterfly Forest Project is often lauded as a win-win-win success for tourism-livelihoods-conservation. Established in Mexico at forest locations where monarch butterflies *(Danaus plexippus)* congregate in winter, the project promoted recreation centers, established butterfly visitor centers and implemented tourism management at butterfly sanctuaries (UNEP/CMS, 2006). The project focuses on livelihood solutions for a region characterized by high unemployment, and has provided tourism training for local people, is involved in reforestation of areas critical to the butterfly habitat, and spans to managing logging impacts in Canada and the United States of America which threaten monarch summer habitat (UNEP/CMS, 2006). Without detracting from the immense strides the Monarch Butterfly Project has made in livelihoods and conservation, in some areas there is evidence of local residents returning to extractive activities as the project failed to yield the expected employment opportunities (Barkin, 2003). Although the rate of logging within the core areas of the Monarch Butterfly Biosphere Reserve have declined, logging is still present (Flores-Martínez *et al.*, 2019; Vidal, López-García, & Rendón-Salinas, 2014), particularly small-scale logging (López-García & Navarro-Cerrillo, 2020). The Monarch Biosphere Reserve zonation policies restricting community use of natural resources and the subsequent compensation for lost legal logging permits through payment for ecosystem services has had unintended consequences through provoking social conflict, often armed, in some areas (Gonzalez-Duarte, 2021). Indeed, the local communities who were ancestral inhabitants of what is now core biosphere areas do not share the biosphere reserve paradigm of a binary use/non-use landscape, but instead view the relationship with the forest ecosystem as a continuum of co-inhabitation and Gonzalez-Duarte (2021) suggests the enforced split in ancestral ecological practices has supported a fractured social compact, fostered illicit extractive activities, undermined community forest management, encouraged organized crime and has created a disregard for core areas where monarch butterflies do not overwinter. For an overview of the challenges facing Mexico's biosphere reserves, see Sada (2019)). These challenges are by no means unique to the Monarch Butterfly Biosphere Reserve and occur in many of the global biospheres reserves where integration of core conservation areas is not adequately incorporated into the multi-use, social-ecological system that the core reserves and local communities exist within (Coetzer, Witkowski, & Erasmus, 2014).

Often local livelihoods are believed to be in conflicting relation with conservation and therefore they are highly restricted by the rules and regulation that impede local economic development (Stone, 2015; West, Igoe, & Brockington, 2006). Cases of prohibition of traditional activities that involve unsustainable use of natural resources in favor of conservation were reported in Tanzania (Charnley, 2005), Bangladesh (Islam, Rahman, Iftekhar, & Rakkibu, 2013), Botswana (Sebele, 2010), and Nicaragua (de los Angeles Somarriba-Chang & Gunnarsdotter, 2012). The high dependence on natural resource for self-subsistence (Belsky, 2009; Moswete, Thapa, & Lacey, 2009; Prachvuthy, 2006; Rozemeijer, 2000; Wunder, 1999) often give communities no choice but to engage in illegal activities. For example, in a case study in Central Amazonian Rainforest, Brazil, some of the families were reported to risk starving because fishing became very difficult and the large-scale agriculture was prohibited in the conservation area (Lima & d'Hauteserre, 2011).

It should be highlighted that nature-based tourism as a complementary activity that substitutes completely, or partially, unsustainable use of natural resources requires a fundamental re-organization of a community's economic and social structure, which might trigger ideological opposition of those communities that have been relying on those activities for generations (Schweinsberg, Darcy, & Wearing, 2018). Local communities who participate in nature-based tourism and receive tangible benefits tend to become cautious in their use of natural resources and, therefore, more likely to support tourism and conservation (Lindberg, 2001). However, the employment in tourism must be high enough in terms of demand to maintain the workforce, and the financial benefits must be higher than gains from unsustainable activities (Kiss, 2004; Mbaiwa & Stronza, 2010).

In destinations where community-based tourism is already in place, but it does not provide enough employment, the unsustainable use of resources is a common practice. The limited economic opportunities reduce or disable any incentives for conservation (Simmons, 1994). Immediately after the incentives for tourism development or benefits from it decrease, local residents go back to previous livelihood-supporting extractive activities (Wilkinson & Pratiwi, 1995). Direct employment is one of the most common limitations of many community-based tourism initiatives as often a small-scale project is not able to employ many people and still remain profitable. A study by Zapata *et al.* (2011) on 34 community-based tourism projects in Nicaragua reported that they were able to generate an average of 6.8 permanent jobs and 12.2 part-time positions. However, it should be stressed that what is considered low or high employment is highly situational as it depends on the size of the community and their direct needs. When resource consumption is prohibited within the protected area, the high dependence on resource extractive activities may also have adverse effect on resources surrounding the area, as demands intensify due to a shrinking resource base (Durbin & Ralambo, 1994; Parry & Campbell, 1992). This might also have a negative effect on tourism itself that is based on supply of pristine landscape, biodiversity of animal and plant species. For example, in Wolong Nature Reserve, China, activities such as logging and clearing for fuelwood, agriculture, gathering of herbal medicinal plants, and ranching have significantly degraded and fragmented giant panda habitat that is the main tourism attraction offered by the local community-based tourism initiative (He *et al.*, 2008).

Nature-based tourism, and the associated reliance on tourism-derived funds for conservation, is also sensitive to economic shocks. For example, as a result of the COVID-19 pandemic, the predicted loss in park entrance fees to the Galapagos Islands is expected to cost between 35-55% of total revenue, monies mainly allocated for conservation (Díaz-Sánchez & Obaco, 2020). Continued conservation in the Galapagos will require alternate sources of funding or loans (Díaz-Sánchez & Obaco, 2020).

The potential for detrimental effects of human-wild species interactions needs to be closely managed, requiring local community empowerment, supportive and cooperation from tour operators and enterprises, and buy-in from tourists (Dou & Day, 2020). The management of the recreational use of wild species needs complementary enforcement and voluntary compliance measures, especially in the tourism context, managing human-wild species interactions is in effect managing people (Dou & Day, 2020). Instilling and supporting a sense of pride and custodianship of wild species amongst tour operators can facilitate responsible tourism.

In summary, for sustainable recreational use of wild species there needs to be:

1. low impact on the wild species being used
2. long-term monitoring of wild species populations and habitats
3. long-term improvement in the livelihoods of local communities
4. awareness and support for conservation from all stakeholders
5. adaptive management and limits on “acceptable change” for wild species tourism, conservation and local communities, including the ability to limit further development
6. supportive regulatory frameworks from local and national government (UNEP/CMS, 2006)

As every tourism initiative is different, there is no single set of suitable conditions that enable both conservation and local livelihoods to flourish (Beeton, 2008; Faulkner & Tideswell, 1997; Okazaki, 2008; Reimer & Walter, 2013). However, a number of factors emerged from a global analysis of over 100 community-based tourism case studies in natural areas (Yanes, Zielinski, Diaz Cano, & Kim, 2019; Zielinski, Kim, Botero, & Yanes, 2020).

Aspects that are critical for a success are:

1. the availability of financial resources
2. skills and technical expertise
3. political influence
4. local control over land and resources
5. community cohesion
6. involvement in local planning and management

The external support provided by non-governmental organizations and governmental organization is crucial for ensuring the abovementioned conditions (Beeton, 2008; Okazaki, 2008)(Beeton, 2006; Okazaki, 2008). The external factors enabling community-based tourism are the political will and decentralization of power and control to the community.

The main barriers for successful community-based tourism development are:

1. the lack of skills and expertise in areas required for tourism
2. lack of noticeable improvement of quality of life in the community (health, education, economy)
3. lack of independence in the decision-making process
4. lack of participative decision making

5. lack of community control over land and resources
6. low level of control over tourism activities in the area
7. internal conflict within community
8. high dependence on resource consumptive activities
9. lack of significant employment in tourism, among others.

3.3.5.2.4 Education and learning

This section deals with the non-extractive practices of wild species for the production of knowledge (Chapter 1). The scope of this section is limited to the non-extractive practices of wild species for learning and education where the impact of this use has a measurable effect on the species. The text below is based on a literature review (Google Scholar) using the following keywords: wildlife, nature, environmental, education, and learning generating 119 000 hits. Articles that were recommended by citation databases were also considered, as well as collected from personal libraries and recommendations from experts. After a title and abstract read, 18 papers were selected for a full text read. After a full text read of these papers, 12 were deemed relevant and assessed for the literature review. Relevance was determined by mention of either the status (current), trend (historical) or impacts of use of a wild species (or taxa) in at least one dimension of sustainability (social, economic, or ecological) (see the data management report for Chapter 3 systematic literature review at https://doi.org/10.5281/zenodo.6452651). These data form the basis of the text below.

Although the use of wild species and ecosystems for scientific research and environmental education, amongst other purposes, is certainly widespread, there is no indication whether this has increased over time or on the current status of use. Relevant articles represented all IPBES regions and most ecosystem types. The literature mostly addressed the use of 'nature' for education and learning, rather than a species/taxa specific approach, but where taxa were mentioned, they were either mammals (terrestrial and marine) or birds. There was little to no information in the literature about the sustainability or the effects of use on wild species or ecosystems. The exception was one article which mentioned concern over the routine use of outdoor teaching sites and their management plan to rotate use of environmentally sensitive areas as needed (Ernst & Stanek, 2006). Although undocumented, the non-extractive practices of wild species are likely to experience similar impacts to recreational watching of wild species such as stress-related responses from wild species and habitat damage through trampling (see section 3.3.5.2.3. Ecological aspects of recreational use).

There are two main methods of using wild species for learning and education. The first is via scientific research and the second through environmental education, mostly to school children and tourists, although a significant amount of informal, experiential learning and knowledge transfer occurs through other practices and uses of wild species, such as birdwatching (recreational use of wild species) (Zvonar & Weidensaul, 2015) and urban foraging (gathering) (Poe, LeCompte, McLain, & Hurley, 2014). Scientific use of wild species is generated through measuring faunal and floral diversity, and population structure and ecological processes. A review of "intellectual ecosystem services" generated by South African National Parks showed a bias towards research on animals, particularly mammals (Smit, Roux, Swemmer, Boshoff, & Novellie, 2017). Similarly, the journals that published research from protected areas were mostly mammal dominated, with little to no focus on social science, environmental governance or social-ecological studies (Smit *et al.*, 2017). Wild species use in education in Europe was dominated by threatened and charismatic species, such as wolves *(Canis lupus)*, brown bears *(Ursus arctos)* and Imperial Eagles *(Aquila adalberti)* (Aguilera-Alcalá *et al.*, 2020). These cases highlight the paucity of research conducted on less "popular" taxa, such as fungi and invertebrates, forbs and shrubs. Notwithstanding, the public's interest in charismatic species has been harnessed effectively for scientific research, such as in the analysis of data such as camera traps (e.g., https://www.zooniverse.org/) or in data collection such as atlas projects (e.g., http://sabap2.birdmap.africa/). These citizen science projects both solve significant big-data processing and collecting challenges facing scientists, as well as providing enjoyment and ecological education to interested citizens.

The second major use of wild species for education and learning is environmental education. Here environmental education is defined as a process that allows individuals to explore environmental issues, engage in problem solving, and take action to improve the environment. As a result, individuals develop a deeper understanding of environmental issues and have the skills to make informed and responsible decisions (EPA 2018: https://www.epa.gov/education/what-environmental-education Accessed on 9 January 2021). Most of this literature focuses on education and on nature rather than wild species *per se*.

Most children today have more access to environmental knowledge through nature documentaries and films than all previous generations (Hudson, 2001). Ironically, such media-educated children in developed countries may fervently campaign for saving polar bears, cheetahs and whales, while they have almost no contact with wild animals or plants common in their own country (Hudson, 2001). There was consensus in the research on environmental education, especially for school children, that educational programs that use the environment for learning supported improved attitudes toward the environment and a desire to look after the environment. An education program specifically on wild Bornean orangutans *(Pongo pygmaeus wurmbii)* led to 13.6-40.4% increase in student knowledge and more positive attitudes towards conservation (Freund *et al.*, 2020). In a study on primary and secondary school children in an environmental education program, 41% of students indicated their feelings about the environment had changed as a result of the nature-based excursion through a combination of observation and instruction (R. Ballantyne & Packer, 2002). Responses include: "I had a better understanding of the impact of people on the forests." (15-year-old) and "Don't feed the native wildlife." (15-year-old).

The benefits of using wild species for learning and education are considerable. In terms of ecological benefits, scientific research on wild species is applied by wild species managers to improve sustainable conservation (Smit *et al.*, 2017). Learning in (and from) nature engenders pro-nature behaviors (Richardson *et al.*, 2016) such as fostering a sense of responsibility and stewardship, and changing attitudes and behavior via increased ecological knowledge (Kwan, Cheung, Law, Cheung, & Shin, 2017). This knowledge can ripple outwards from the primary recipients and be transmitted to parents and neighbors (Vaughan, Gack, Solorazano, & Ray, 2003). Educational courses and formal training on wild species and nature can build constituencies with neighboring communities, indigenous peoples and local communities and other stakeholders, as well as capacity building for future wild species research and management (Smit *et al.*, 2017). Imparting environmental knowledge to tourists and students also provides employment, especially important when this is in local communities involved in these practices (Ternes, Gerhardinger, & Schiavetti, 2016; UNEP/CMS, 2006).

The aspects of engaging with wild species that contribute significantly to conservation education in the public include: watching wild species in their natural habitat, opportunities for close encounters with wild species, opportunities to observe natural wild species behavior, engaging the public emotionally, connection with the public's prior knowledge and experiences, convincing communication, and establishing a link between everyday actions and changes to these actions people can make to foster conservation outcomes, and providing incentives and activities to support behavior change (Ballantyne, Packer, Hughes, & Dierking, 2007).

Beyond generating knowledge and awareness, there is concern on whether knowledge translates into action, and the longevity of pro-environmental awareness and behavior changes. In terms of longevity of pro-environmental awareness and attitudes, there is limited longitudinal research on this aspect. One study on the influence of a six-week bird feeding and monitoring program on school grounds showed that a year later, several schools had continued the program themselves, suggesting that such interventions have the potential to be maintained in the longer term (White, Eberstein, & Scott, 2018). Another example illustrates the benefits of a close engagement with a wild species over the longer term. Here secondary school students reared captive-born juvenile threatened Asian horseshoe crabs *(Tachypleus tridentatus)* for 14 months, which were then released into the wild (Kwan *et al.*, 2017). Rearing involved training students to collect data, test water conditions, and provided opportunities to improve on the protocols through experimentation (Kwan *et al.*, 2017). The students were also tasked with presentations on the importance of horseshoe crabs and after the horseshoe crabs were released, tagged individuals could be tracked by students to monitor their movements and growth (Kwan *et al.*, 2017). The extended period of rearing and engagement with the horseshoe crabs engendered a strong emotional attachment and fostered a sense of responsibility, resulting in more pro-environmental attitudes and behavior (Kwan *et al.*, 2017).

Both Ernst and Stank (2006) and Freund *et al.*, (2020) highlight self-efficacy as crucial to pro-environmental behavior. Self-efficacy engenders the belief that one can personally make a difference and empowerment is key to translating environmental education into pro-environmental action. This is related to Hudson (2001) cautioning that environmental educators should avoid the "psychology of despair." The overwhelming documenting of declines in the health of the natural world and species populations can create a sense of hopelessness for the future and negate the belief that an individual can make a difference.

A drawback of environmental education is the limited reach of the programs. Although some ripple effect in increased awareness in the community (Vaughan *et al.*, 2003), in communities reliant on natural resources and living in vulnerable ecosystems, it is the children who do not attend school who are more likely to be involved in illegal and unsustainable wild species activities in the future (Breuer & Mavinga, 2010). Furthermore, education alone cannot be solely responsible for changes in behavior. Environmental education programs need to be complemented by projects that alleviate poverty and develop alternative livelihood opportunities (Breuer & Mavinga, 2010). Conservationists and local governments should also provide information on the importance of ecological functions of wild species that cause problems in human-wildlife conflict, whilst mitigating the drawbacks of close contact with 'problematic' species (Hosaka, Sugimoto, & Numata, 2017).

3.3.5.3 Emerging issues

Tourism is one of the practices most affected by the COVID-19 pandemic (Spenceley *et al.*, 2021; UNCTAD, 2021). As a result, the COVID-19 pandemic has exposed the vulnerability of nature-based revenue streams to global economic shocks, and the reliance of communities and conservation funds on international tourism (Peter Lindsey *et al.*, 2020; Rondeau, Perry, & Grimard, 2020; Spenceley *et al.*, 2021). Loss of conservation funds has been severe as a result of decreased tourism revenue. For example, the predicted loss in park entrance fees to the Galapagos Islands is expected to cost between 35-55% of total revenue, monies mainly allocated for conservation (Díaz-Sánchez & Obaco, 2020). Continued conservation may require alternate sources of funding or loans (Díaz-Sánchez & Obaco, 2020; McCleery, Fletcher, Kruger, Govender, & Ferreira, 2020). Early evidence from the COVID-19 pandemic impacts suggests that communities reliant on nature-based tourism turned to extractive activities to meet their local livelihood needs (Spenceley *et al.*, 2021), compounded by the return of migrant workers to rural areas and the associated increase in demand of local resources (Rondeau *et al.*, 2020). There are preliminary indications of increase poaching and a surge in illegal logging during the pandemic, possibly as a result of decreased conservation authority presence and no wildlife watching tourists (Rondeau *et al.*, 2020; Spenceley *et al.*, 2021). In addition to the lack of tourism revenue, it is unknown what the impacts of COVID-19 transmission from tourists on wild species will be (A. Gibbons, 2020) or from tourists to local communities (Hakim, 2020). But these early findings still need to be corroborated with more data as the effects of the pandemic on wild species, conservation funds, and local livelihoods becomes more understood.

Another emerging issue is the non-extractive use of wild species through novel finance mechanisms, such as Rhino Impact Bonds (www.rhinoimpact.com), Lion Carbon (www.lionlandscapes.org/lioncarbon), The Lion's Share Fund (www.thelionssharefund.com), or the Luc Hoffmann Institute's Innovation Challenge "Beyond Tourism in Africa" (https://luchoffmanninstitute.org/beyond-tourism-in-africa-innovation-challenge) which seek to support wild species conservation and sustainable livelihoods in the absence of recreational hunting or wildlife tourism. However, there is currently insufficient information on the use, trends or impacts of these finance mechanisms on wild species or wildlife economies.

3.4 TRADE-OFFS AND SYNERGIES

3.4.1 Introduction

Chapter 3 focuses on the status and trends of the use of wild species through its three interacting systems: the wild species themselves, the human practices by which they are obtained from nature, and the uses for which they are intended. Because it is impossible to include all wild species in the assessment, we have focused on those species which are more intensively utilized, those whose sustainable use is of particular concern, and those whose use exemplifies sustainable use in meaningful ways which are informative for overall consideration of the sustainable use of wild species discourse. Throughout the chapter we have followed the practices and uses typology outlined in chapter 1, with adaptations in each section in accordance to the standards in the various literatures and sectors reviewed. However, these use categories (and sometimes practice categories) are not exclusive. In this section we make an effort to consider the interactions among the uses and practices.

While the specific practices and uses of particular wild species have been studied in greater detail, the interactions and influences among species and the related consequences for sustainable use of wild species has been much less examined. These interactions between, within and among wild species-related practices and uses, and their cross-influences relate to the notion of trade-offs and synergies. To avoid developing a compartmentalized and regimented understanding of sustainable use of wild species, the attempt in this section is to use the notions of trade-offs and synergies as analytical perspectives to understand how the practices and uses of wild species are connected in multiple ways, how they interact with each other and, in the process, how they engage with and cross-influence each other both negatively and positively.

According to the IPBES Glossary (IPBES core glossary, 2021), a trade-off is a situation where an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of a different aspect. Trade-offs characterize most complex systems and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes. Synergies arise when the enhancement of one desirable outcome leads to enhancement of another. Trade-offs are distinct from synergies as the latter are also referred to as "win-win" scenarios.

While it is important to aim for a "win-win" synergy, this cannot be done without appropriate responses to the "win-lose" situations presented by existing and potential trade-offs between and among the practices and uses of wild species. Biophysical, economic and social factors all make it unlikely that multiple needs will be met simultaneously without deliberate efforts; so while there is still much interest in developing win-win outcomes there is little understanding of what is required for them to be achieved (Howe, Suich, Vira, & Mace, 2014; Tallis, Kareiva, Marvier, & Chang, 2008).

While win-wins may be attractive, they are not inevitable and may be unlikely in practice in the absence of carefully designed interventions (Bennett, Peterson, & Gordon, 2009). Howe *et al.*, (2014, p. 263) suggest that "taking account of why trade-offs occur is more likely to create win-win situations than planning for a win-win from the outset. Consequently, taking a trade-off as opposed to a win-win approach, by having an awareness of and accounting for factors that predict a trade-off and the reasons why trade-offs are often the outcome, it may be possible to create the synergies we seek to achieve.". Without attention to trade-offs, one is left with the notion that sustainability of wild species hinges separately on the individual practices and/or uses, which is both ecologically and socially unrealistic.

3.4.2 Conceptualizing trade-offs and synergies

Based on the ecosystem services literature, a two-fold understanding of trade-offs and synergy is proposed: First, trade-offs or synergies only occur if the considered practice and use interact with each other (Bennett *et al.*, 2009; García-Llorente *et al.*, 2015). Second, trade-offs and synergies require assessment of supply, demand and use together and not separately (Geijzendorffer, Martín-López, & Roche, 2015). Following Turkelboom *et al.* (2016) a trade-off is a situation where one use or practice directly decreases the benefits supplied by another. A synergy is a situation where one use or practice directly increases the benefits supplied by another use or practice. Both synergies and trade-offs have spatial and temporal dimensions (see section 3.2).

Trade-offs may depict an array of phenomena including conflicts, contestations, negative correlations, incompatibilities, rivalry and excludability in relation to sustainable use. The inverse of these phenomena signifies synergy. Both trade-offs and synergy are closely associated with benefits and well-being components, value dimensions, and management strategies (Iniesta-Arandia, García-Llorente, Aguilera, Montes, & Martín-López, 2014; Martín-López, Gómez-Baggethun, García-Llorente, & Montes, 2014; McShane *et al.*, 2011). Trade-offs and synergies reflect a host of interactions, connections, relationships and linkages within, between and among practices and uses. If so, achieving the goal of sustainable use of wild species depends on the level of understanding of the key trade-offs and possible areas of synergy within and across practice areas.

3.4.3 A framework to analyze trade-offs and synergies in the sustainable use of wild species

The main purpose behind exploring trade-offs and synergies is to understand their implication for sustainable use of wild species, key trends and status. It is evident from section 3.3 that the assessment considered a large number of wild species, five broad categories of practices and sub-practices, and more than nine different types of uses. A simple three-pronged approach is used to consider the various trade-offs and synergies across these practices and uses of wild species by focusing on (i) trade-offs and synergies at intra-practice and intra-use level; (ii) trade-offs and synergies between practices and uses; and (iii) trade-offs and synergies involving the social, economic and environmental aspects of sustainable use.

3.4.3.1 Trade-offs and synergies at intra-practice and intra-use level

The lack or presence of a range of scientific and indigenous and local knowledge-based methods and their effective combinations for assessing the sustainability of wild species are linked to possible trade-offs and synergies. A diverse range of methods to analyze the status and trends of sustainable use of wild species under each practice category has been discussed in section 3.3. They include both scientific methods (e.g., stock assessment, biomass estimation) and the use of a variety of indigenous and local knowledge. However, there is a predominance of scientific methods for assessment of wild species even though use of indigenous and local knowledge is quite widespread. In fishing practices scientific assessments are publicly available for roughly half of the global fish catch while there is considerable effort to better understand the status of the remaining half of the stocks. This shows how science and technology are focused on only portions of wild species and not all that are important for human use. This may trigger undesirable trade-offs between assessed and non-assessed species. Addressing this may be tricky but not impossible. For example, the state of world fisheries and aquaculture by the FAO makes scientific assessment of status of 500 fish stocks worldwide, while the remaining almost half of the world's stocks are covered through the expertise provided by expert knowledge to fill in the gap (Melnychuk *et al.*, 2017). In some cases, this might mean that small stocks, especially the unassessed ones, are in a disadvantageous position of below target levels compared to large stocks which are often covered under scientific assessment (Costello *et al.*, 2012). In order to ensure that partial nature of scientific information does not lead to ineffective decisions it may be combined with other types of knowledge, including indigenous knowledge, and use pluralistic and interdisciplinary forms of assessment of trade-offs. Further discussion on this appears in Chapter 5 and other sections of this assessment focusing on indigenous and local knowledge.

Trade-offs between multiple uses under a specific practice may reallocate science, technology, investment and innovations in favor of new or emerging uses over the already established and traditional uses of wild species. This may dramatically alter any existing synergies between use categories and significantly impact the sustainability trajectories associated with individual use types of wild species. Section 3.3. offers adequate understanding that while some uses under a practice type are well-established and traditionally recognized, others may be new or emerging in nature. Despite the potential for synergy between these multiple use categories there seem to be inherent competition and overlapping contestations amongst them, ultimately affecting the levels of their sustainable use. In the process of competing with one another, some of the uses have become more prominent than others and thereby known to drive science, technology, investment and innovations away from existing use areas to the new uses that have the potential to negatively affect sustainable use of wild species as a whole.

Several examples of these intense trade-offs ensue from the practices outlined in section 3.3. Fishing offers examples of two sets of mostly conflicting rather than complementary use categories that seem to pose significant challenges to the question of sustainability around this practice: (i) the overlapping interactions between capture fishery and aquaculture; (ii) the tussle between the invisibility of small-scale fisheries and the high visibility of large-scale / industrial fisheries.

(i) Capture fishery and aquaculture: the FAO estimates the total volume of capture fisheries as about 90 million metric tons which constitutes the largest wild food consumed by humans as well as one of the most established / traditional uses under fishing as a practice. Aquaculture as a new use category has gained momentum since the mid-1980's but already in significant competition with capture fisheries. **Figure 3.31** provides estimates of the global fish production as about 170 million metric tons with close to 50 percent coming from aquaculture. This is a consistently increasing trend in the last three decades whereby aquaculture is all set to takeover capture fisheries in the next decade or so. Not only that but aquaculture is reportedly encroaching into the dominant use of capture fisheries for the purpose of food for humans, i.e., out of the 90 million metric tons of fish obtained from capture sources over recent decades, about 60 million metric tons goes to direct human consumption and most of the rest is diverted as feed for aquaculture and livestock. Such trends might threaten to further marginalize the capture fisheries practice which is already experiencing a sharp decline in its biologically sustainable levels from 90 percent in 1974 to 65.8 percent in 2015 and stands at more than 34.2% stocks being overfished (FAO, 2020d). Even though it is not included in the scope of this assessment,

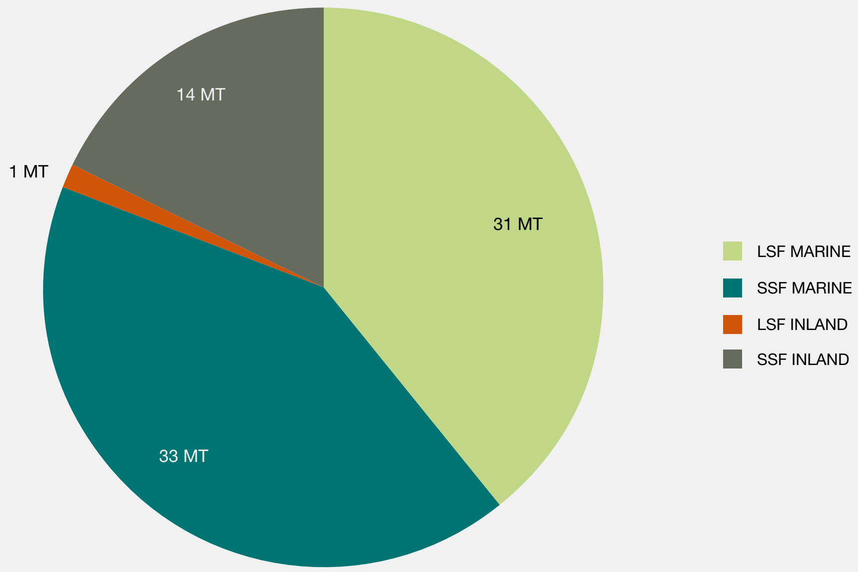


Figure 3 65 **Total annual catch in small-scale and large-scale fisheries around the world.**

Abbreviations: MT: MillionTons, LSF: Large-Scale Fisheries, SSF: Small-Scale Fisheries. Source: (Toobigtoignore.Net – Big Numbers Project Report by World Bank/FAO/World Fish, 2010) under license CC-BY.

reference to aquaculture is imperative because of the significant trade-offs it has with capture fisheries.

(ii) Small-scale and large-scale / industrial fisheries: Data in **Figure 3.65** below clearly shows that the annual catch in small-scale fisheries is higher than the large-scale fisheries both in the marine and inland fisheries practices. In the inland fisheries, small-scale fisheries have 14 times more catch than inland large-scale fisheries. Despite this lead in catch size and the significant contributions small-scale fisheries make to nutrition and food security, poverty alleviation and livelihoods, and local and national economies, especially in developing countries (Béné, Macfadyen, & Allison, 2007; Berkes, 2015; Lilian Ibengwe & Fatma Sobo, 2016), the policy attention this practice has received remains marginal. Small-scale fisheries communities have remained economically and politically marginalized, are highly vulnerable to change (including climate change), and until recently, remained largely invisible in policy debates in most countries and internationally (Berkes, 2015; FAO, 2015). These factors, together with increasing vulnerability due to climate, environmental, economic and policy drivers have created a global crisis in small-scale fisheries (Muzuka, *et al.*, 2011; Paukert *et al.*, 2017; Satumanatpan & Pollnac, 2017).

In contrast, the large-scale fisheries practice has received significant policy attention across the national and international boundaries. A major example of this attention pertains to the extent of global subsidies to the tune of 35 billion United States dollars to the large-scale fisheries practice (Sumaila *et al.*, 2019; Sumaila, Lam, Le Manach, Swartz, & Pauly, 2016). These discrepancies between the small- and large-scale fisheries signify intense levels of trade-offs between the two use types. Possible synergies can be built between these two practices within fishing practices if the small-scale fisheries can be recognized as a use type of wild species that is simply 'Too Big To Ignore' (Chuenpagdee, 2019; Chuenpagdee *et al.*, 2019). Afterall, small-scale fisheries support over 90 percent of the 120 million people engaged in capture fisheries globally, about half of them are women, and it contributes approximately 45% of the global fish catch destined for direct human consumption (World Bank, 2012). Better synergies between these two use types under the fishing practice have the potential to contribute to both goals of ecological conservation and global human development, all of which can potentially lead to sustainable outcomes.

Fisheries bycatch is a growing trend and an example of how increased use of technology and the mechanization of vessel and gear types result in trade-offs. A related area is unreported volumes of fish discarded at sea. According to **Figure 3.65**, the global catch of fish reported by individual countries include only estimates of landing and do not include non-retained catch that are discarded at sea. Globally, estimated discards accounts for about 10% of total annual catches and most discards are generated by industrial (i.e., large-scale) fisheries (Dirk Zeller *et al.*, 2018). Compared to this, landing estimates for small- scale fisheries are widely regarded as an underestimation.

3.4.3.2 Trade-offs and synergies between practices and uses

Trade-offs and synergies are inherently linked to fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices being treated exclusively or in isolation from each other. Several sections in 3.3 acknowledge the interconnections between practices. However, it was necessary to treat them in a somewhat stand-alone way for clarity in the systematic literature reviews and in reporting. This treatment exposes problems around synergies and trade-offs. Artificially created or not, the disconnections between major practice categories are not healthy for sustainable use of wild species. For example, fishing is not all about fish and fishers alone. Aquatic systems that host fish habitats are integrally connected to terrestrial ecosystems as they mutually benefit or impact each other. Or when people harvest fruits from wild trees (gathering), they may also harvest the entire tree for firewood (logging). People who are primary users, engaged in one of these practices, tend to move between multiple practices and uses either as a seasonal livelihood routine or under pressure from multilevel drivers when their primary engagement in a specific practice is disrupted.

First, several groups of wild species users are known to move between fishing, gathering and harvesting across a range of ecosystems which is influenced by their livelihood, cultural and occupational needs and complementary seasonality among the wild species, i.e., occurrence and availability. Second, even those who depend on one specific use or practice category as their primary source of food, subsistence or livelihoods are seen entering into other practices and uses of wild species due to unforeseen pressures. This includes increasing instances of how coastal inhabitants, primarily reliant on fishing, are forced to engage in the harvesting, gathering and use of wild species under non-fishing practice categories when they are faced with loss of fish and related income due to multilevel pressures. Natural disasters (i.e., cyclones, floods, tsunami, earthquakes, etc.) are known to push people from one practice and use category to others through temporary, semi-permanent and permanent displacement. It is understood that better synergies will facilitate this cross-practice mobility of users, especially in times of crisis and positively contribute to the sustainable use of wild species. It may also help resolve negative trade-offs between the practices or, at the minimum, bring them up for timely attention.

As discussed in the preceding paragraph, if trade-offs between practices are related to their separation from each other, the need to consider synergies between practices at global, regional, national and local policy and program levels cannot be underestimated.

Trade-offs between uses within a practice may be related to differential policy attention each of the uses has received. For example, the use that generates the most revenue may move up in the hierarchy and receive most policy and related attention, and this may take place at the cost of other uses. It is evident that in the tussle between capture fisheries and aquaculture the later receives significantly higher attention compared to the former (section 3.3.1). Similarly, tourism tends to grab significant policy and program attention as compared to medicinal, ceremonial and cultural uses (section 3.3.5).

The spaces and places where practices occur influence the nature of trade-offs and synergies. Section 3.3 offers numerous examples of this. Fishing practices are specific to marine, coastal, inland sectors as dominant fisheries within which multiple uses are operationalized by the users and the possibility of trade-offs and synergies are within and between these spaces. Similarly, gathering, harvesting, logging and non-extractive practices take place within multiple resource sectors that tend to interact and influence each other. Each of these resource sectors have their own social, economic, cultural, political and ecological characteristics which shape the nature of the practice and uses. Trade-offs and synergy result from how the practices and uses across these multiple sectors interact and influence each other.

It is important to recognize that trade-offs and synergies may not only be considered to be existing between or within practices and uses but also the scale at which they operate has significant role. The tussle between the small-scale and large-scale fisheries is more about scale than anything else (as discussed above). There can be multiple interpretations of how scale is linked with trade-offs and synergies in other practices and uses.

Related to scale, understanding trade-offs and synergies between and within geographical contexts within which practices occur is important. The literature review on small-scale fisheries in section 3.3 provides detailed account of geographical context specificities by characterizing small-scale fisheries within Europe, Arica, Asia, Latin America, North America, and the Pacific. It is important to note that the key characteristics and the major drivers influencing trade-offs and synergies in each of these geographical regions of the world may significantly vary.

Section 3.2 offers a systematic analysis of the role of indicators in understanding sustainable use of wild species. Examination of the sustainable indicators has a lot to offer in terms of clarifying trade-offs and synergies. In fact, many sustainable use indicators are indicators of trade-offs and synergies. Tools such as monitoring in many indigenous peoples and local communities focus on interlinked social and ecological elements and can inform the development of local and global indicators that recognize these linkages. The acknowledgement of the value of including the knowledge of indigenous peoples and local communities contribute importantly to monitoring and assessment of the species and ecosystems used by these communities.

Trade-offs and synergies between knowledge systems guiding the practices and uses is a whole new area to explore. While the politics and power dynamics between knowledge systems (Van Assche, Beunen, Duineveld, & Gruezmacher, 2017) may be inherently connected to trade-offs, systems of knowledge coproduction (Norström *et al.*, 2020) signify synergies between sustainable use practices. In this context, indigenous knowledge is increasingly challenging to pass on because the environments in which indigenous and local communities live are threatened (3.3.5). Indigenous peoples and local communities report a loss of nature that supports their local livelihoods and well-being, in part as a result of natural resource extraction by both outsiders and locals (Ichii, Molnár, Obura, Purvis, & Willis, 2019). Increasing efforts to synthesize indigenous and local knowledge have shown that the natural indicators indigenous peoples and local communities use are reasonably compatible with scientific knowledge and show their deep connection with nature, albeit it at a very local scale (Ichii *et al.*, 2019). Indigenous and local knowledge is increasingly being used to generate more accurate data on species trends, non-iconic species data and geospatially relevant data using technology (e.g., Cybertracker: (Ansell & Koenig, 2011; Liebenberg *et al.*, 2017), participatory mapping using Google Earth (Peters-Guarin & McCall, 2012) and Open Data Kit (ODK): (Jeffers, Humber, Nohasiarivelo, Botosoamananto, & Anderson, 2019)). However, it is important to note that the goal in working with indigenous peoples and local communities is to honor their knowledge in its own right, not only when it is compatible with scientific knowledge or supportive thereof (Barron, Sthultz, Hurley, & Pringle, 2015).

Changing gender roles and dynamics can lead to the disruption of existing synergies and the creation of new trade-offs. One case that shows the complexity of trying to develop sustainable use practices based on gender assignments of particular practices and uses is the gathering practices of orchids in Tanzania. The majority of gatherers of wild edible orchids are female, orphans also commonly engage in this practice, and there are slightly more boys than girls among orphans affected by HIV/AIDS (Human Immunodeficiency Virus) in villages in the southern highlands of Tanzania (Challe & Price, 2009; Challe, Struik, & Price, 2018). Children gather less species than adults and generally learn about the use and identification of wild species from their mothers and to a lesser extent also from their fathers (Cruz García, 2006; Łuczaj & Nieroda, 2011). When children's parents die before they share their knowledge, orphans teach each other and or learn from middlemen as a result of "trial and error". This can lead to the gathering of too many non-marketable orchid tubers, which may in turn negatively affect the sustainability of the practice (Challe *et al.*, 2018).

3.4.3.3 Trade-offs and synergies involving the social, economic, environmental and policy aspects of sustainable use

Sustainability is multidimensional but the essence of it can be captured by considering the social, economic and environmental aspects as inclusive categories. The questions about trade-offs and synergies are integrally linked to the three pillars of sustainability, i.e., economic viability, environmental protection and social equity (Purvis, Mao, & Robinson, 2019). Policy is also recognized as a supporting element of sustainability. In other words, economic, social, environmental and policy aspects of the sustainable uses of wild species help link practices and uses with key sustainability parameters. While negative trade-offs among and between these parameters threaten the viability of sustainable use, synergies among them provide pathways for sustainable use. In many contemporary societies, terrestrial animal harvesting has multiple functions and sustainability hinges on the synergies and trade-offs between social, ecological and economic dimensions of this specific practice. Human populations engage in animal harvesting (such as, hunting and trapping) to meet a range of nutritional, economic, medicinal, cultural and recreational needs and the level of synergy between these needs may have implications for the level of extraction of the resource, therefore its sustainability.

International and national policy instruments and guidelines, along with civil society actions have supported processes to resolve negative trade-offs and potentially build synergies between practices and uses. There is strong evidence presented in section 3.3 to support this conclusion. The impact of fishing on marine ecosystems other than the target species and their habitats is well established. Several international instruments (such as agreements, policies, protocols, treaties) have been developed to help respond to these challenges and provide guidance for action. Prominent among those are United Nations Convention on the Law of the Sea, created in 1982, which established the 200-mile exclusive economic zone and the concept of maximum sustainable yield as an international measure for sustainable fisheries management.

Given the inadequacies associated with the United Nations Convention on the Law of the Sea regarding fish stocks that range across multiple exclusive economic zones or in the high seas, the United Nations Fish Stocks Agreement, 2001 was brought into effect to offer international protocols for managing the overlapping stocks. Further, the Food and Agriculture Organization of the United Nations has put in place a range of international policy guidelines to promote sustainable use of aquatic ecosystems and facilitate the conservation of biodiversity of ecosystems by minimizing trade-offs in forms of competition, contestations and unsustainable practices. These include: the 1995 Code of Conduct for Responsible Fisheries (FAO, 1995b); Voluntary International Plan of Action on reducing the incidental capture of seabirds in longline fisheries (FAO, 1999a); International Plan of Action on the Conservation and Management of Sharks (FAO, 1999c); International Guidelines on Reducing Marine Turtle Fishing Mortality (Eric Gilman & Bianchi, 2010); International Guidelines on Managing Fisheries Bycatch (FAO, 2011); Small-Scale Fisheries Guidelines (FAO, 2015).

While these international policy measures have produced favorable results, there are gaps that still exist, such as the issue of the sustainability of non-target species relative to target fish stocks is still unclear. This indicates that species that are not covered by a treaty or international policy may be subject to overexploitation and, therefore, unsustainable or in the process of being so. In order to address this, further responses have come through the legally binding United Nations resolution 61.105 (2005) which provided for responsible fishing in vulnerable marine ecosystems and of non-target species. Additionally, the International Agreement on Port State Measures (FAO, 2016a) aims to prevent, deter and eliminate illegal, unreported and unregulated (IUU) fishing by preventing vessels engaged in illegal, unreported and unregulated fishing from using ports and landing their catches. These measures suggest that they are geared towards addressing factors (e.g., illegal, unreported and unregulated) that can trigger trade-offs and create barriers for possible synergies.

Apart from the international responses to critical trade-offs, major efforts have also come from national governments and non-governmental organizations. For example, the formation of the Marine Stewardship Council (1997) to improve fisheries sustainability along with the initiation of several environmental non-governmental organizations for marine conservation, expansion of the science and management efforts by national and regional governments including the Common Fisheries Policy in the European Union are important landmarks.

The above discussion suggests that the history of sustainable use of capture fisheries is closely tied with a number of critical international, national, regional policy guidelines, and non-governmental organizations and civil society action focusing on fisheries and their ecosystem conservation. These policy instruments and agreements provide a strong foundation for possible actions and responses to trade-offs and processes through which synergies for sustainable use can be achieved.

3.4.4 Selected case studies of trade-offs and synergies in sustainable use

The following cases studies help explore the question 'whether non-extractive uses can become an alternative to extractive uses?

3.4.4.1 Whaling and whale-watching

Whale watching is commonly seen as the global success story of a non-extractive use replacing an extractive use, and in the process encouraging sustainable use, generating economic revenue and contributing to conservation. The growth in whale watching is a result of bans on whale hunting, the decline in whale-derived products, and environmental campaigns by non-governmental organizations to support whale watching as a sustainable alternative to whale hunting (Neves, 2010). Many whale populations are recovering after the global commercial moratorium was enacted on whaling in 1985, although determining the status for some populations has remained challenging (IWC, 2020a). In addition, some countries continue to hunt whales under objection or reservation to the moritorium, or because they are not members of the International Whaling Commission (see section 3.3.1.4.5 above for additional discussion of this point).

Whale watching has undoubtedly become a lucrative industry, particularly for tour operators in developing regions who often enjoy direct income streams considerably greater than existing levels of regional gross domestic product per capita (Mustika, Birtles, Welters, & Marsh, 2012) and so, by extension, for local communities that benefit from the tourism activities. Whale watching tourism has brought additional revenue to the Maoris in Kaikoura, New Zealand (Curtin, 2003), and the inhabitants of both Lajes in the Azores (L. Silva, 2015) and Baja, Mexico (Schwoerer, Knowler, & Garcia-Martinez, 2016), through direct expenditure on tours but also through the accompanying expenditure on transport, accommodation and hospitality. It has also brought positive attitudinal effects amongst whale-watching tourists and local populations. Mintzer *et al.* (2015) note that the creation of a sustainable development reserve and the presence of dolphin researchers have had positive effects on the attitudes and behaviors of an indigenous fishing community on the Amazon towards botos, which have in the past been killed for both bait and superstition. Wilson and Tisdell (2003) report that 78% of whale- watching tourists visiting Hervey Bay, Australia, find the experience convinces them of the need for a worldwide ban on whaling, 80% of the need for greater protection of whales in Australia, and 73% to be more likely to report whales that are stranded, injured or mistreated: biocentric effects that are supported by the findings of Gowreesunkar and Rycha (2015). However, whale watching is not without negative impacts on whales and marine ecosystems. The International Whaling Commission has released a Whale Watching Handbook addressing these concerns and supporting sustainable whale watching (IWC, 2020b).

In some areas, whale watching and whaling co-exist. Whale watching is the more economically lucrative and globally accepted activity. Although whaling depends on government subsidies, some indications are that public support for whaling in whaling countries like Japan and Iceland is growing as a perceived cultural and nationalistic right (Andersson, Gothall, & Wende, 2014; Cunningham, Huijbens, & Wearing, 2012). Yet, in both Japan and Iceland, whale watching tourism is booming (Cunningham *et al.*, 2012), but there has been concern that continued whaling alongside tourism will negatively impact tourism industries (Bertulli, Leeney, Barreau, & Matassa, 2016; Cunningham *et al.*, 2012; Hoyt & Hvenegaard, 2002; Kuo, Chen, & McAleer, 2012; Orams, 2001; Parsons & Draheim, 2009; Parsons & Rawles, 2003), the extremes of which could result in tourism boycotts such as happened in St. Vincent and the Grenadines (Hoyt & Hvenegaard, 2002).

The whaling-whale watching nexus is complex and the discourse at the intersection of these activities needs further research (Cunningham *et al.*, 2012). There are contradictory tensions involved in whaling-whale watching that need unpacking. Tourists who eat whale meat are also pro-conservation and support the ban on whale hunting (Burns, Lilja Öqvist, Angerbjörn, & Granquist, 2018). Ironically, the market for whale meat is strongest for tourists (Bertulli *et al.*, 2016; Rasmussen, 2014). Iceland seems to have retained tourists who are tolerant of whaling (especially for subsistence) and who support local and cultural expression, but at the cost alienating tourists who cannot reconcile with whaling for commercial, scientific or indigenous reasons (Andersson *et al.*, 2014). Although the number of whale watching tourists has continued to grow in Iceland since 2002 when whaling resumed, the relative contribution of whale watching tourism to other tourist activities has declined (Andersson *et al.*, 2014). Overall, whaling seems likely to face increased global resistance and unlikely to generate substantial economic incentives, whilst whale watching has global support and generates substantial revenue. It would be prudent for whaling countries to assess the implications of the negative impacts of whaling on their national "image" – their biggest tourism asset (Hoyt & Hvenegaard, 2002) – and conduct a thorough compatibility analysis. Conversely, highly visible national policy for cetacean conservation can attract tourists (Parsons & Draheim, 2009).

3.4.4.2 Recreational trophy hunting and wildlife watching tourism

Trophy, sport or recreational hunting has attracted increasing negative attention, particularly since the widely publicized killing of “Cecil the Lion” in Zimbabwe in 2015. Trophy hunting has long been banned in some source countries (e.g., in Kenya since the 1970s) and efforts have been made to restrict it by banning imports of hunting trophies, at least from certain species, in consumer countries (e.g., France banned the imports of lion trophies in 2015, while the Netherlands and Australia banned imports from a wide range of species in 2016 (Ares, 2019). Trophy hunting can have negative impacts on wild species populations, particularly if offtake is too high or where infanticidal population dynamics exist (e.g. Loveridge, Searle, Murindagomo, & Macdonald, 2007; Milner, Nilsen, & Andreassen, 2007; Wielgus, Morrison, Cooley, & Maletzke, 2013) but can also positively impact conservation and local livelihoods, particularly by generating revenue from habitat and species conservation (Naidoo, Weaver, *et al.*, 2016; Snyman *et al.*, 2021). Debates have played out in the scientific literature and beyond as to the ecological, social and economic costs and benefits of hunting, but one key element of arguments against hunting has been that such extractive practices are repugnant because of ethical issues concerning certain types of harvesting of wild species. It has consequently been suggested that one solution would be to replace such practices with non-extractive uses, and in particular, with wildlife watching (e.g., photographic tourism).

This argument assumes, in the first place, that wildlife watching is indeed a non-extractive use of wild species. Some commentators would argue against this on the basis of its negative ecological impacts on some species and ecosystems. For example, Ballantyne and Pickering (2013) identify tourism as a problem for 46% of threatened vascular plant species in Europe alone, while it has also been documented as limiting cheetah reproduction (Broekhuis, 2018). In addition, wildlife watching can have wide ecological impacts, including water use and carbon emissions (Gössling *et al.*, 2012; Spenceley, 2005).

A key argument for the conservation benefits of recreational hunting is similar to that made for photographic tourism, i.e., income is generated and this plays a role in in i) directly financing conservation agencies including national parks authorities (e.g., Brink, Smith, Skinner, & Leader-Williams, 2016; Lindsey *et al.*, 2020), and ii) providing an incentive for habitat and biodiversity conservation beyond state-managed protected areas by communities and private landowners. Opponents of hunting suggest that wild species are worth far more for wildlife watching tourism than for hunting. For example, a report by the David Sheldrick Wildlife Trust (2014) estimated that a single elephant may be worth 1.6 million United States dollars over its lifetime through income from photographic tourism. A wider review by Lindsey *et al.*, (2007) highlighted that photographic tourism undoubtedly generates greater gross revenues than trophy hunting at a continental scale across Africa. Importantly though, they note that even if smaller, “hunting revenues are significant because they enable wild species production to be a viable land use across a wider range of land uses than would be possible relying on revenues from photographic nature-based tourism alone.” Unlike wildlife watching tourists (generally, obviously exceptions may apply) hunters are often prepared to hunt in areas lacking attractive scenery, and require less infrastructure, therefore minimizing habitat degradation (Di Minin *et al.*, 2016). Because wildlife watching tourism is not viable in all the places where hunting happens, the suggestion that one type of use can simply be replaced with another is thus naïve. For example, Lindsey *et al.* (2006) argue that not all land suitable for trophy hunting would be suitable for wildlife watching tourism, and that low visitor numbers would be unlikely to make it economically viable. Similarly, in Botswana, a ban on trophy hunting implemented in 2014 meant that communities were forced to shift their income earning opportunities from hunting to wildlife watching tourism (Mbaiwa, 2018). Photographic tour operators apparently had little interest in developing lodges in the concessions that lacked high tourism potential (Winterbach, Whitesell, & Somers, 2015). Consequently, there was a reduction of local benefits such as cash income, employment opportunities, scholarships and funeral insurance. This lack of local economic benefits had negative effects on conservation including negative attitudes by rural residents towards wild species conservation and an increase in poaching (Mbaiwa, 2018).

Very few studies have directly compared the benefits of trophy hunting and wildlife watching tourism to the same people, in the same location. One that has is an analysis of communal conservancies in Namibia (Naidoo, Weaver, *et al.*, 2016). The study looked at financial and in-kind benefit streams from wildlife watching tourism and hunting on 77 Namibian communal conservancies from 1998 to 2013. It found that although total benefits from hunting and tourism increased at roughly the same rate, conservancies typically started generating benefits from hunting within three years of formation compared to after six years for photographic tourism. Regarding the types of benefits, the majority (64%) of benefits from trophy hunting were in the form of cash for income for conservancy management, while 32% of benefits were meat for the community at large. In contrast, 58% of the benefits from wildlife watching tourism were in the form of jobs, with 30% used for conservancy management. A simulated ban on trophy hunting significantly reduced the number of conservancies that could cover their operating costs, whereas eliminating income from wildlife watching tourism was still negative but a less marked effect. The study concluded that maintaining both trophy hunting and wildlife watching tourism was likely to produce the greatest incentives for conservation while only focusing on one would reduce the competitiveness of wild species as a land-use option and harm the viability of community-based conservation efforts in Namibia, and possibly elsewhere.

Other comparisons that have been made between hunting and wildlife watching relate to the broader environmental impacts of the two activities. Di Minin *et al.*, (2016) argue because there are fewer trophy hunters compared to wildlife watchers and because it can generate more revenue from a smaller number of visitors, trophy hunting can have a smaller footprint than wildlife watching tourism in terms of carbon emissions and infrastructure development. One case study where an analysis has been conducted between numbers of hunting tourists compared to photographic tourists is Timbavati Private Nature Reserve in South Africa (Timbavati Private Nature Reserve News, 2020). The annual operating budget of the reserve is currently 1.26 million United States dollars which is generated primarily through wildlife watching tourism and hunting. In 2016 an analysis by the reserve's management team found that the conservation levies paid by the approximately 24,000 wildlife watching tourists who visited the reserve that year amounted to less than a third of the income earned from the 46 hunters who visited over the same period (Conservation Frontlines, 2020). The reserve has subsequently increased the fees charged to wildlife watching tourists to increase revenue without having to increase the number of bed-nights, and hence the human footprint. Similarly in Tanzania, Estes (2015) suggests that trophy hunting and wildlife watching bring in similar amounts to the Tanzanian economy but the ratio of tourists who come to see the wild species and hunters who come to shoot it is many hundreds to one with one hunting tourist paying at least 10 times as much as every wildlife watcher.

3.4.4.3 Elasmobranch tourism opportunity and shark fishing

Just as whale watching has contributed to the decline of whaling, there is opportunity for shark and ray watching tourism to mitigate shark fishing effects by providing additional income sources. In a review on elasmobranch tourism, Healy *et al.* (2020) demonstrate that the tourism value of individual sharks exceeds the fisheries value, contributing revenue to developing countries. In Palau, shark tourism contributed over 18 million United States dollars, 8% of the 2012 gross domestic product and the tourism value of sicklefin lemon sharks *(Negaprion acutidens)* in French Polynesia exceeds the payment received by fishers (Healy *et al.*, 2020). Diving, snorkeling, feeding and cage diving currently occur in 42 countries focusing on 49 target species, predominantly in tropical and subtropical Africa, Oceania, Asia and the Caribbean, but also in temperate seas such as Canada, England, Scotland, Japan and New Zealand (Healy *et al.*, 2020).

There may be unintended social-ecological feedbacks between different uses (e.g., tourism, fishing) and wild species. An interesting example is the decline in white sharks *(Carcharodon carcharias)* in South Africa as part of the greater social ecological system. The decline has been of ecological concern, but also impacts on the white shark tourism industry. Killer whale *(Orcinus orca)* presence was initially attributed to the decline, as killer whales have been shown to displace white sharks (Jorgensen *et al.*, 2019). However, continued white shark decline outside of the season niche overlap with killer whales has prompted speculation that demersal long line fishery of smaller shark species, a white shark resource, mostly exported to Australia for human consumption (Braccini, Blay, Harry, & Newman, 2020). This speculation, in turn, resulted in boycott calls against the Australian 'fish and chip' sales to protect South African white sharks, which has negatively affected an overall legitimate and sustainable Australian industry (Braccini *et al.*, 2020).

Sea horse tours and extractive sea horse harvesting

An interesting local example of non-extractive use replacing extractive use is the case of sea horse *(Hippocampus reidii)* tours by self-organized and self-governed *'jangadeiros'* in a Brazilian village (Ternes *et al.*, 2016). Here the local communities impart their comprehensive local ecological knowledge of sea horses to tourists. They take tourists out by raft boat and dive sea horse specimens out to hold in glass jars for viewing by the tourists before releasing them back into their habitat (Ternes *et al.*, 2016). The community involved in these tours no longer harvest sea horses for medicinal or ornamental purposes as they derive economic benefits from them *in situ*, unlike other villages in the region (Ternes *et al.*, 2016). The authors of this case study suggest that by careful guiding this non-extractive approach could be expanded to other villages to benefit sea horse conservation and local livelihoods (Ternes *et al.*, 2016).

These case studies show that while non-extractive uses can improve the conservation status of wild species and improve livelihoods in a sustainable fashion, it is unlikely that complete extractive use will be halted. As always, careful consideration of the context and the implications of such a shift need to guide interventions. Furthermore, the eradication of extractive activities is not necessarily desirable, especially where the extractive use fosters cultural practices that result in conservation. Yet, where extractive indigenous peoples and local communities' use occurs in conjunction with non-extractive use there is potential for conflict as a result of the opposing value systems between the user groups (see section 3.3.5.2.3). And there are nuances between different forms of extractive or non-extractive use. For example, illegal poaching has been shown to negatively impact wildlife tourism (Naidoo, Fisher, Manica, & Balmford, 2016) whereas hunting concession impacts on wildlife tourism can be avoided with careful management.

Choices around sustainable use of wild species will not always be between extractive and non-extractive use. Novel financial mechanisms such as Lion Carbon (2020) or 'rhino bonds' (Aglionby, 2019) may provide important alternatives for some areas, but these currently are only nascent initiatives. It is important to recognize that this is not just about the degree of benefits but their distribution, as benefits from one type of use may be distributed very differently compared to another. So, it may be tempting to conclude that because a non-extractive form of wild species use (e.g., shark watching) has the potential to generate more revenue and jobs than an extractive form (e.g., shark fishing) the former is more sustainable. The same applies in cases where extractive appears to be "better" than non-extractive use. However, sustainability is about more than just economics: the benefits and costs of different activities may accrue to very different stakeholder groups, which is likely to affect the degree to which each option is viewed as socially sustainable. Ultimately, wider non-economic aspects of sustainability of different uses (e.g., likely long-term impacts on the wild species population, interactions of that use with other conservation threats, resource demands of the users, perceived social acceptability etc.) should also be considered when examining trade-offs between different options. Furthermore, the likelihood of unsustainable activity should also be factored in to provide a reliable comparison, particularly the likelihood of land conversion to non-wildlife-based land uses under different scenarios. In all cases, understanding who benefits, and how, from the use of wild species is critical to designing effective policies and programmes that encourage the sustainability of that use and incentivize conservation over other land and resource use options.

3.4.5 Key attributes necessary to respond to trade-offs and strengthen synergies in sustainable use

In the use of wild species, there are synergies and trade-offs among the policies, practices and technologies used to address individually the issues of loss of biodiversity (wild species), land degradation, water pollution and climate change. Economic, ecological and social dimensions play pivotal roles in setting the context for use of wild species; the ways wild species are used differ under different economic conditions, law enforcement regimes, culture and traditional meanings and perception of users. Evidence supports that there are risks associated with the harvesting of wild populations under challenging conditions, and these are often highlighted in low-income countries (Leao, Lobo, & Scotson, 2017) although they can occur in developed countries as well. Therefore, the issues are strongly interconnected and cannot be addressed in isolation (Watson, 2005).

Better understanding of the underlying mechanisms and motivations for trade-offs and synergies can be beneficial for planning and managing sustainable use through (i) predicting and anticipating where and when trade-offs might take place; (ii) reducing undesirable trade-offs and related conflicts; (iii) enhancing desirable synergies; (iv) promoting honest dialogue, creativity, and learning between concerned user / stakeholder groups; (v) creating more effective, efficient and credible management and governance decisions; and (vi) obtaining more equitable and fair outcomes by taking into account distributive impacts of trade-offs (Turkelboom *et al.*, 2016). Key lessons on trade-offs and synergies pertaining to sustainable use of wild species include, but are not limited to:

- Trade-offs and synergies reflect a host of interactions, connections, relationships and linkages within, between and among practices and uses. Without consideration of these interactions and their effects, sustainable use cannot be adequately assessed.

- While trade-offs and synergies between uses within a practice is somewhat well understood, the exact nature of trade-offs and synergies between practices, for example the interactions among gathering and fishing, are not very well studied. This knowledge gap involving the lack of inter-practice trade-offs and synergies has the potential to adversely impact sustainable use of wild species.

- Bifurcation of existing uses and the emergence of new uses within a practice area (e.g., capture vs. aquaculture within fishing practices; ceremony and cultural expression vs. recreation (tourism) within non-extractive practices) have led to a reconfiguration of intra-practice trade-offs and synergies. These changes drive technology, science, investment, policy focus, innovation away from existing use areas to the new uses that have the potential to negatively impact sustainable use of wild species as a whole.

- Trade-offs and synergies between and among fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices are inherently linked but often treated exclusively or in isolation from each other. This exclusivity is reflected in the dominant culture of practice-specific policies leading to significant compartmentalization. Consideration of trade-offs and synergies between these practices and their use categories across global, regional, national and local policy and program levels could enhance sustainable use of wild species.

- A combination of indigenous and local knowledge and scientific knowledge is effective to better understand and respond to the trade-offs and synergies relating to status and trends in sustainable use. Knowledge co-production processes based in ongoing collaborations are useful in this respect.

Due to uncertainty and the plurality of values and information on wild species, addressing trade-offs requires inclusive adaptive co-governance that is sensitive to power dynamics, principles of justice and equity.

3.4.5.1 Levels and scales at which trade-offs and synergies occur

Trade-offs and synergies are scale-bound. IPBES Glossary defines scale as the spatial, temporal, quantitative and analytical dimensions used to measure and study any phenomenon, i.e., trade-off and synergy in this case (IPBES core glossary, 2021). The need for considering multiple scales (and levels) at which trade-offs and synergies around sustainable uses take place bears significance (Carpenter & Brock, 2006; Mayer, Pawlowski, & Cabezas, 2006). Empirical insights have been recorded from observations of modifications and reorganizations of system dynamics at the level of the ecosystem (Stephen R Carpenter & Kinne, 2003; Scheffer & van Nes, 2004). However, choices about scale of observation are not easily matched with strategies for intervention. For example, specific components of a wild species use regime can cross thresholds (understood as synergy) and lead to varying outcomes at substantially different temporal and spatial scales associated with the influences resulting from trade-offs. There is also an issue that boundaries that delineate units of scale (e.g., ecozones, *de jure*/formal administrative boundaries) do not always correspond to the reality of the ecosystems or human use which are instead (at best) 'soft' (as opposed to 'hard') boundaries (Norris, 2014; Veldhuis *et al.*, 2019). Systematic treatment of trade-offs and synergies relevant to sustainable use of wild species will require scale-sensitive perspectives, and reflection on appropriate scales of understanding and intervention (Scheffer, Westley, & Brock, 2003).

A related aspect of scale is to focus on the units of analysis for measuring trade-offs and synergies. Studies on ecosystem changes and shifts in use and management regimes tend to have mostly emphasized a single resource (or practice) type (Biggs, Carpenter, & Brock, 2009; S. R. Carpenter & Brock, 2006; Scheffer *et al.*, 2003), including marine systems (Beaugrand, 2004; Mantua, 2004; Steele, 2004), lakes and lagoons (Gal & Anderson, 2010; Scheffer & van Nes, 2004), freshwater systems (Carpenter and Kinne, 2003), forests (Ludwig, Jones, & Holling, 1978), woodlands (Dublin, Sinclair, & McGlade, 1990), dry lands (Foley *et al.* 2003), rangelands (Skaggs *et al.*, 2011), and agroecosystems (Gordon, Peterson, & Bennett, 2008), all of which act as sources of wild species. However, using individual resource systems (or practices) to define boundaries of sustainable use inevitably neglects the full range of human expectations from, and interactions with, the larger social, ecological and environmental system necessary to achieve sustainability (Nayak & Armitage, 2018). Incidentally, critical trade-offs and opportunities for building synergies may be missed if a narrow focus on the scale of sustainable use is adopted. Therefore, it is important to conceive what is an appropriate social-ecological unit within which to best capture trade-offs and synergies and why this is critical for observing trends and reporting status of wild species. Units of analysis of trade-offs and synergies in sustainable use may have both a physical (e.g., coastal line, bottom, rivers, and vegetation, landscape) and a normative (e.g., culture, rituals, law, institutions, social interactions) dimension to their boundaries. Recognizing and understanding both these dimensions are useful from scale-sensitive perspectives.

3.4.5.2 Equity and justice considerations in responding to trade-offs and negotiating synergies

How can it be ensured that the outcomes of trade-offs and synergies associated with sustainable use of wild species are distributed equitably? The procedural and distributive aspects of trade-offs and synergies offer multiple pathways to sustainability, depending on the culture and the ecosystem. If inequity and injustice reign, there are few and often no sustainable pathways.

Greater attention to equity and social justice considerations (i.e., winners and losers in the context of sustainable use) is needed to better understand the process and outcomes of trade-offs and synergies. Recognizing issues around sustainable use, trade-offs and synergies through the prism of social and environmental justice facilitates the identification of key motivations of users and main ingredients influencing these processes. Section 3.3 presents material that points towards equity and justice as both cause and effect of trade-offs and synergies. For example, an equity and social justice perspective helps clarify if outcomes from critical trade-offs disproportionately impact a multitude of users, e.g., poor, disempowered and other marginalized communities including women through a process of uneven distribution of benefits and impacts (see Walker & Bulkeley, 2006). Literature from multiple disciplines suggests that changes and shifts in ecosystem processes, structures, functions and services associated with sustainable use may redistribute benefits among stakeholders (Selkoe *et al.*, 2015), and such redistribution may lack sensitivity to equity and justice issues. It is important to recognize that these shifts and redistribution processes are inherently linked to unresolved trade-offs and the absence of synergies among practices and uses of wild species.

In economically and socially stratified social-ecological systems that host wild species, the outcomes of trade-offs and synergies pertaining to the diverse use regimes are often beneficial to some while adversely affecting others (Nayak, Armitage, & Andrachuk, 2016). For example, case studies by Nayak and Berkes (2010), Armitage and Marschke (2013), and others provide evidence that changes in the management practices in coastal and inland fisheries of Bay of Bengal and South China Sea (e.g., outcomes of the trade-offs from the introduction of aquaculture within a predominantly capture fishery system) have benefitted higher caste or wealthier aquaculture owners respectively but have proven negative for customary users. This trend is also evident in section 3.3. These experiences clarify that trade-offs around sustainable use can create new opportunities and upward social and economic mobility for some users (and in this case those that were already upwardly mobile) but simultaneously exclude others (often those already marginalized). Such discrepancies in the nature and level of impacts are related to power and authority, structural advantage and institutional and political favor. Consequently, equity and social justice conditions influence how sustainable use related trade-offs, synergies and the outcomes thereof are 'framed' by certain groups as significant or not, and to what extent that framing can be used to design strategies to respond.

An additional consideration pertains to a multi/inter species justice dimension within the trade-offs and synergy discussions. This underscores the question whether sustainable development can really be accomplished without taking animals' own interests into account (Visseren-Hamakers, 2020). It is important to consider trade-offs and synergies between human and non-human justice leading to further explorations about the types of relationships humans can cultivate with animals so as to produce just outcomes. In doing so, neglecting the spiritual and cultural can also result in the lack of attention to the ways in which dominant Western cultural and spiritual forms sustain narrow conceptions of justice (Celermajer *et al.*, 2021; Santiago-Ávila & Lynn, 2020).

3.4.5.3 Power dynamics and politics of use

The appearance and disappearance of trade-offs and synergies, and the ways in which they are responded to and negotiated upon are not politically neutral. Social relations of power expressed through institutions, the position of different users in the society, and the language adopted to characterize trends in the use of wild species are crucial to understanding trade-offs and synergies. There is tremendous scope to comprehensively articulate the implications of power for sustainable use when it is under pressure from negative trade-offs, especially within a rapidly changing social-ecological context of the wild species (see similar arguments in Boonstra, 2016; Crépin, Biggs, Polasky, Troell, & de Zeeuw, 2012; Kull *et al.*, 2018, 2018; Nayak *et al.*, 2016). Important questions to further examine trade-off and synergy issues in sustainable use include: (i) What can be gained by assessing who wins and who loses in the context of changes in sustainable use of wild species and its emerging trends under the influence of multiple trade-offs? (ii) Is it possible to better assess the chances that a wild species use regime may be deliberately steered by some towards or away from other users? Such questions help to understand that sustainable use can benefit some and adversely impact others (see Armitage, Marschke, & van Tuyen, 2011; Ho, Ross, & Coutts, 2015).

Divergent views on how a wild species use regime should be managed, who should benefit and who gets to decide on the essential features of the use system, and what needs to be done, are crucial questions with important consequences for how to respond to trade-offs and manage possible synergies. This is a highly context-specific issue, and no silver bullet exists. "What Works" in one context may be completely different in another. Further, this will require careful assessment of the dynamics associated with what Lebel *et al.* (2005) have termed as the "politics of scale" with attention to "politics of position" and "politics of place", and this construct can be well placed in the analysis of trade-offs and synergies around sustainable use of wild species. Reid *et al.* (2006) adds to this view by highlighting the importance of user perspectives in problem formulation and analysis, and user knowledge to deal with governance and management issues. Users' own views of their situation reflect a rather different narrative and reality and failure to account for these diverse perspectives that emerge at different scales and from different users and actors can potentially restrict ability to deal with trade-offs and achieve sustainable use of wild species (Andrachuk & Armitage, 2015; Barron, Hartman, & Hagemann, 2020; Narayan, D., *et al.*, 2001; Narayan, D., R. Patel, K. Schafft, A. Rademacher and S. Koch-Schulte., 2001; Nayak & Berkes, 2010). Berkes (2002) highlights numerous examples where higher scale perspectives and practices exert an influence over or dominate lower scale realities, including through centralized decision-making, limited acceptance of alternative systems of knowledge in formal decision-making, nationalization of resources, influence of national and international markets, and top-down development policies and projects. These issues have significant connection with questions about trade-offs and synergy between and across practices and uses of wild species.

3.4.5.4 Governing trade-offs and synergies for sustainable use

What can be done when the outcomes of multiple, cross-cutting trade-offs between uses and practices become untenable for achieving sustainability of wild species, and when possible, synergies between and among use regimes and practices are not readily available? What approach could be useful when unresolved trade-offs have the potential to become stubborn and act as wicked problems, and configuring innovative synergies becomes a challenge? The question of adopting a governance approach to address these situations becomes important. Kooiman *et al.* (2005, p. 7) define governance as "the whole of interactions taken to solve societal problems and to create societal opportunities; including the formulation and application of principles guiding those interactions and care for institutions that enable and control them." According to this view, governance is qualitatively different from the related task of management in directing societal and environmental processes. It adds dimensions that are absent in a hands-on management approach. 'Interactive governance' emphasizes solving societal problems and creating societal opportunities through interactions among actors (Kooiman, J., Bavinck, M., Chuenpagdee, R., Mahon, R., & Pullin, R., 2008). The emphasis on 'interactions' constitutes the main innovation that fits appropriately with the need for responding to the trade-off and synergy related questions outlined at the beginning of this sub-section. IPBES Glossary (2021) adds rules, norms and actions as crucial elements of governance that can help structure, sustain, and regulate trade-offs and synergies. These multiple elements of governance help ensure dynamic problem-solving abilities based on values, principles, institutions and practices.

Debates around sustainable use may trigger the need for biologically informed management and use targets that require an adaptive governance response (Selkoe *et al.*, 2015). Here, governance refers to the "interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies toward preventing, mitigating, and adapting to global and local environmental change" (Biermann *et al.*, 2009). Social and ecological processes, such as use regimes of wild species, influence and are influenced by governance arrangements in which social outcomes remain contingent upon ecological dynamics and vice-versa (Dale *et al.*, 2000; Waltner-Toews & Kay, 2005). These interacting influences are very visible, for example, in section 3.3.5 regarding the dynamics in non-extractive use and governance, social, and ecological dimension of recreational tourism. As explored in section 3.3.4 on logging, responses of social agents (users) in a given system to ecological change (wild species) have a direct bearing on outcomes (quality of life) (Following Lade, Tavoni, Levin, & Schlüter, 2013). In this respect, aggregated informal responses or coping strategies of local users to the shortage of wild species are important drivers of natural resource depletions, but often overlooked in the policy development of the natural resource management (Ehara *et al.*, 2018). These complex dynamics are visible across sections 3.3.3 and 3.3.5, for example, in relation to the interplay between the harvesting of wild meat for subsistence and protection of livestock, and the establishment of national parks in low-income countries throughout Africa to generate revenue.

Both ecological variables (e.g., biodiversity, biogeochemical cycling, hydrological processes) as well as social variables influencing sustainable use, including human agency, social relations of power, institutions and rules that influence human behavior need to be assessed. As well, humans (users and other agents) both produce unsustainable use regimes and simultaneously adapt to them. Here the focus of governance will be on navigating or adapting, but in other cases the focus will be on steering towards more fundamental social transformation to avoid unsustainable use regimes under the influence of undesirable trade-offs and ensure stronger synergies between uses and practices (see Chapter 5 and 6).

3.5 KNOWLEDGE GAPS

There is an increasing tendency today to shift the focus away from sustainable use of wild species; whereas the emphasis is to view biodiversity conservation and sustainable use through the lens of ecosystem functioning and its capacity to produce ecosystem goods and services (Heywood, 2017). Therefore, it is very challenging to compile knowledge gaps on sustainable use of wild species as there is lack of consistency among worldwide databases to quantify the harvesting and use of wild species by people in different countries across the world. This happens because different countries and organizations have different accounting methodologies, making the merging of different datasets a huge challenge. Major knowledge gaps in the sustainable use of wild species are summarized here.

(i) Across all practices, and especially in global fishing, existing data and reporting do not differentiate adequately between wild and non-wild species. Explained most explicitly in sections 3.2 (global overview), 3.3.1 (fishing), global indicators and data reported by the Food and Agriculture Organization of the United Nations and other agencies do not separate out wild and aquaculture, wild and farmed, wild and plantation, or wild and domesticated species when calculating global or regional off-takes. This makes it almost impossible to accurately assess and report on status and trends in sustainable use of wild species. There is vast legacy of available data on species taxonomy, conservation or economic value related to trade and markets rather than specifically on use as defined in the assessment. In addition, most of the datasets available lack detailed information on practices and uses of utilized and non-utilized species that challenges to make comparative account of population trends.

(ii) Knowledge gap in status of taxonomic groups and their uses at different levels and scales. Information is available on the conservation status of vertebrates, particularly with regard to mammals and birds, to a lesser extent with amphibians and fish including demersal fish; however knowledge on conservation status and use is severely lacking for invertebrates (insects), fungi and microbial species (Coleman *et al.*, 2019; Naranjo-Ortiz & Gabaldón, 2019; Willis, 2018), and in some taxa, especially invertebrates and fungi, there are still thousands of species yet to be described and being named. The knowledge gap also includes widely used and internationally traded species, for example porcini mushrooms (*Boletus* spp.).

Marine species are especially susceptible to exploitation. However, the status of half of the world's fisheries, largely from Southeast Asia, is not scientifically assessed (Costello *et al.*, 2012). We know less about inland fisheries than marine fisheries. Marine mammals are especially susceptible to exploitation due to low reproductive rates and the many other threats they face, including noise pollution and climate change (Perrin, 2009).

With regards to insects, fungi and microbes, insufficient taxonomic information makes it difficult to assess the sustainability of their use, and more generally knowledge on their roles in the supply of nature's contributions to people is limited (Kassas, 2002). For example, it is believed that more than 90% of species remain unknown to science out of 148,000 species of fungi that have been scientifically identified (Antonelli *et al.*, 2020). Sustainability of wild algae, fungi and plants harvesting is challenged by many factors and comprises interlinked dimensions such as socio-cultural, economic and political (Ghimire, 2008). Similarly, the sustainable management of medicinal trees requires knowledge on how different species respond to different harvesting techniques (Delvaux, Sinsin, Darchambeau, & Van Damme, 2009). As discussed in section 3.3.3.3.3 invertebrates provide an important source of nutrition in some areas, but data are missing on the sustainability or unsustainability of the gathering of edible insects. Overexploitation probably only concerns some species, but insects and fungi (sections 3.3.2.1; 3.3.3.2.3) on the whole are vulnerable due to the destruction of their habitats, to pesticides and other pollution, and to climate change (Arnold van Huis *et al.*, 2013).

Another limitation of indicators of sustainable use is related to spatial scales. Not all populations, taxa, systems and regions are equally or adequately represented in the scientific literature, meaning that while it is possible to assess the available knowledge, it is not actually possible to assess the sustainability of use. At the global level, there is a lack of pertinent data for many species of whales and seals, and the polar bear *(Ursus maritimus)* in the Arctic (Tierney *et al.*, 2014) and for many small-scale fisheries in tropical developing countries, such as in Africa, Asia and South America (see small-scale fisheries section). There is a lack of data on how many species in each vertebrate class are used and how much is harvested. For example, data on harvested Arctic species are biased towards marine mammal and marine fish populations, and this could mask declines in some seabird colonies that are over-harvested (Tierney *et al.*, 2014). Relatedly, many of the conservation models, protocols, procedures, monitoring and assessments are based on experience of animals, notably mammals and birds, and do not necessarily apply to plants, invertebrates or fungi (Heywood, 2017).

(iii) Life histories and stocks of marine fish species not well understood. In most fisheries, there exist large gaps in understanding of life histories for many marine fish species, information on total cumulative anthropogenic levels of fishery removals from an individual population, knowledge of the conservation status of individual populations, and deficits in monitoring, including in data collection protocols, observer coverage rates, and sufficient time-series to detect the response in absolute population abundance of long-lived species to this anthropogenic mortality source (Gilman *et al.*, 2014, 2020; Lewison, Crowder, Read, & Freeman, 2004b; Musick, 1999). Status of fish stocks of both large- and small-scale fishing is little understood for those countries and regions where fishing management intensity is low. Further, there is data of status and trends individual fish stocks for IPBES regions such as Europe (e.g., https://www.eumofa.eu/) and North America, whereas data for other IPBES regions are missing.

(iv) Knowledge gap in direct and collateral sources of fishing mortality on associated and dependent species. While there is increasing understanding of the status of stocks of principal market species of marine capture fisheries, albeit still incomplete especially in low-income countries, there remains a very large gap in knowledge of the effects of direct and collateral sources of fishing mortality on associated and dependent species including fecund species. For example, rare-event bycatch of species such as toothed whales and some pelagic sharks are unmonitored in most fisheries, there is a lack of knowledge of which populations are captured in individual fisheries, and as a result of these data quality constraints, extremely limited understanding of the sustainability of the 'use' of these wild species. For instance, 47 of 68 fisheries that catch marine resources managed by regional fisheries management organizations have no observer coverage (Gilman *et al.*, 2014) for the vast majority of the ca. 4.6 million fishing vessels globally, information on non-retained catch is non-existent, and information on retained catch only is available in some cases. While a target stock of a relatively productive species may be determined to be sustainable when assessed against various standards, the sustainability of the fishery and when assessed against impacts on incidentally captured species is very often unknown. Stock assessments which do not incorporate recreational fishing do not provide accurate assessments of global uptake and fish mortality.

(v) Data gaps on sustainable use of wild species and their monitoring regarding small-scale fisheries, inland fisheries, marine and freshwater fisheries, and reef fisheries. One of the major challenges or data gaps to properly assess sustainable use of wild species, especially regarding small-scale fisheries and inland fisheries in tropical developing countries consists in the lack of long temporal series of data on resource use. Most of the small-scale fisheries worldwide show a chronic lack of monitoring data on time series of landings, fishing effort, biology of exploited species, among other relevant fisheries indicators (Welcomme, 2011). Similarly, there is no reliable information on value or number and diversity of sustainability of marine and freshwater ornamental fishery, and many species of reef fishes lack biological and ecological information. This indicates that conservation status of almost half of the species is still unknown (SOTWP, 2016).

This lack of data precludes a proper assessment of the sustainability of most small-scale fisheries and inland fisheries. Furthermore, those indicators based on stock dynamics or population parameters, which have been widely applied in industrial fisheries, may not be suitable to complex, multispecies small-scale fisheries, or data needed to calculate these indicators cannot be gathered on a cost-effective and timely manner to inform policy intervention in many small-scale fisheries and inland fisheries. However, these limitations have been successfully addressed, in the context of small-scale fisheries, by studies adopting a scientific approach to record and analyze local or indigenous knowledge held by small-scale fishers on resource use over broad temporal scales (see section 3.3.1.3.2).

(vi) Research gap in gathering. Estimates on the number wild plant species that are used across different regions are unclear, despite documentation from (SOTWP, 2020) and (FOC, 2020). Also, there are limited information on wild species used as food, and these come mainly from ethnological or ecological inventories. As a global phenomenon, urban gathering that promotes positive cultural, ecological, economic and health outcomes research has received little scholarly attention and due emphasis has not been equally given in all regions of the globe. For example, 70% of the studies are from the Americas, Europe and Central Asia, 20% are from Africa, and the remaining are from Asia and the Pacific based on literature search retrieved for this assessment. Recently, an emerging gap has been in high demand of collection of recently described new species or rare species when their type localities were published in particular by specialized collectors. For this reason, an increasing number of scientists warn against publishing type localities (Lindenmayer & Scheele, 2017b); and the sustainability of this form of consumer-driven use is unclear.

(vii) No data for global sale of cut flowers from wild and cultivated conditions. Cut flower or foliage of bromeliads, or ornamental plants like aloe and orchids share global market and these plant species are either gathered from cultivated or wild sources. But no data was available at the time of this assessment on the share of global market sales from wild vs cultivated plants.

(viii) Gaps in *ex situ* conservation of wild plant species. Botanic gardens gather live plant species from wild for conservation purpose, however, those botanical collections have focused mainly in the temperate parts of the world. For example, the PlantSearch database hosted by Botanic Gardens Conservation International indicates that 107,340 accepted species grow in botanic garden collections, representing 31% of vascular plant species. However, 93% of these species are held in temperate parts of the world. As a result, a temperate species has a 60% chance of being cultivated within the botanic garden network, whereas a tropical species has only a 25% chance. Similarly, the diversity of crop wild relatives is poorly represented in gene banks. For example, there are over 78,000 accessions representing about 688 species of crop wild relatives in gene banks, and over 70% of taxa are recommended as high priority for gathering so as to improve their representation in gene banks. However, gaps in gathering occur in the Mediterranean and the near East, Western and Southern Europe, Southeast and East Asia, and South America **(Figure 3.45)**.

(viii) Identification gaps in taxonomic groups of terrestrial animal harvesting. Some groups of terrestrial animals harvested mainly for trade lack proper identification. For example, more than 50% of all traded individuals of reptiles had no species-specific identification, and this makes implementation of species-based regulations ineffective. Further, scientific studies suggest that consumption of *Didelphis marsupialis*, a species of undeniable cultural significance for local communities in Latin America, but carrying a reservoir of parasites that cause severe diseases, should be the subject of further study.

(ix) Insufficient information on recreation from green hunting. Green hunting that takes place with the help of tranquilizer dart guns is cheaper and less harmful compared to traditional hunting (section 3.3.3.4.2. However, green hunting is as of yet not a significant recreational activity. There exists insufficient information on the status, trends and/or impact of the activity with regards to its potential impact on sustainable use of terrestrial animal harvesting from wild.

(x) Gap of trade of exotic pet animal species under the Convention on International Trade in Endangered Species of Wild Fauna and Flora list. Many wild animal species have been unsustainably traded to supply the international pet markets for natural breeding purpose, including rare and endemic species that are most threatened. Even with existing international regulations, the majority of species in exotic pet trade are not protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora, therefore, leaving international trade mostly unregulated and unmonitored of threatened species (Janssen & Shepherd, 2018) (section 3.3.3).

(xii) Inadequate available information on wild species informal and formal trade, and consumption. Wild species are traded in informal and formal markets. Much of this trade goes unrecorded and is difficult to monitor. A complex and nuanced temporal association between the illegal and legal wild species trades exist (Tittensor *et al.*, 2020). The gap is so great that in many cases the phrase, "we do not know what we do not know" applies. Cases where it is known that data are lacking include tropical fish for the aquarium trade, freshwater turtles and tortoises for terraria, recreational fishing (including catch and release) and spearfishing, amphibians, and reptiles (Alves, Rosa, *et al.*, 2013; Castello, McGrath, & Beck, 2011; Costello *et al.*, 2012; Schlaepfer, Hoover, & Dodd, 2005). Similarly, insects, especially butterflies and beetles, are harvested and traded all over the world, but there are few data about this exploitation and trade (Alan L. Yen, 2009). Further, the consumer-driven harvest of live specimens may have benefits for local peoples' economically, however, sustainability of use is unclear.

Wild meat harvest and trade are often excluded from official statistics (Pangau-Adam *et al.*, 2012). Overall, there is much less information available on wild meat harvest in the Asian tropics, especially outside Borneo (Swamy & Pinedo-Vasquez, 2014). A conspicuous knowledge gap concerning the causes of lion mortality has been identified, and this requires knowledge of both the existing population size and its dynamics over time and space (fecundity and mortality) (Macdonald *et al.*, 2017). In addition, where markets in such species are monitored, often it is not clear whether sources are wild or domesticated.

Existing data are available mainly for timber species traded in the global market (FAO, 2018a), but timber from illegal logging activities used within producing countries as well as across the transboundary are not available (Chaudhary *et al.*, 2016).

(xii) Knowledge gap in logging. Timbers are supplied to the markets; however, it is unclear to estimate which come from legal or illegal sources as well as differentiate timber from wild vs plantation sources.

(xiii) Knowledge gap in non-extractive practice and uses. Assessment of knowledge gap in non-extractive practice and use is challenging as the non-extractive use of nature often does not include species described at a species level, but frequently they appear as part of a functional group (e.g., trees in urban green spaces) or in terms of multifunctional landscapes (e.g., worship of sacred groves). Further research is especially needed to clarify the benefits of living in nature and focus on ecosystem elements. For example, in commercial wildlife watching, an increasing number of wild species such as megafauna and 'charismatic' wild species are integrated into tourism operations. Megafauna are well studied taxa of animals, whereas there is a lack of research on the impacts of tourism on the lesser fauna, e.g., ground-dwelling mammals, small reptiles, insects, etc. (Wolf *et al.*, 2019).

The literature on the non-extractive use of wild species for medicine and hygiene shows many positive benefits on human individuals, but there is an absence of research on the effects of wild species on human community health (Nesbitt *et al.*, 2017). There is almost no information on the global or regional trends in the non-extractive use of wild species for human health. No research has looked at the sustained, long-term effects of nature-based therapies (Rajoo *et al.*, 2020).

(xiv) Gaps in inter-practice trade-offs and synergy. It is well known that different practices interact themselves and are connected with each other; however, the knowledge gap involves the lack of inter-practice trade-offs and synergies, such as between and among fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices across global, regional, national and local policy and program.

(xv) Lack of critical linkages between nature's contributions to people and quality of life and benefit gaps. There has been broad uptake of the critical linkages between nature's contributions to people and quality of life. However, knowledge gap exists on the status of species and nature's contribution to people linked to specific ecosystem functions, and interrelationships between gender equality, nature and nature's contribution to people (IPBES, 2019). Therefore, enhanced attention is needed to develop specific variables and indicators to understand the multiple intricate ways in which peoples' well-being / quality of life and nature's contributions to people influence each other in a two-way feedback-oriented process (Chaplin-Kramer *et al.*, 2019; Diaz, Demissew, Joly, Lonsdale, & Larigauderie, 2015; IPBES, 2019). It is also important to ascertain that such a connection draws on integration of indigenous and local knowledge and their effective participation pays judicious attention to scientific knowledge and strengthens linkage between nature and nature's contribution to people ((Diaz *et al.*, 2015).

There are important methodological limitations to many of the studies exploring nature-based therapy or the presence of wild species on human health. Furthermore, the majority of the studies are correlative and the involvement of medical professionals is encouraged, as well as an increased diversity of study participants (Rajoo *et al.*, 2020; Sandifer *et al.*, 2015). The causal mechanisms that underlie the benefits people receive from health-based use of wild species is underexplored (Sandifer *et al.*, 2015). Currently, there is limited evidence for environmental microbial exposure boosting human immune system response and no causal evidence for the phytoncides hypothesis was identified.

Another important aspect to consider is that there is a poor understanding of how biodiversity affects people's well-being and health through cultural pathways, and how that is being affected by changes in the status and trends in sustainable use. A better understanding by linking biodiversity change with human culture values, well-being, and health might be profoundly important for biodiversity conservation and public health (N. E. Clark *et al.*, 2014). It is believed that diversity of positive values is important for countering negative values and support conservation action when needed.

(xvi) Inadequate economic valuation of wild species. A considerable body of valuation studies focuses on the economics of nature's contributions to people at the global scale (e.g., carbon stocks and flows) delivered to people outside the countries where natural ecosystems and wild species occur (IPBES, 2019). However, the societal values of the gathering and use of wild species in local markets have not been properly addressed. Wild species are an integral component of ecosystems, and the value they provide in terms of services should be a standard part of ecosystem assessments (Puri, Yadav, & Joshi, 2019). Though, it needs to be recognized that there is no distinct division between wild (unmanaged) biodiversity and human managed biodiversity (Tisdell, 2015). A comprehensive assessment of the contributions (current or potential) of wild species in protected areas (terrestrial and marine), such as watching of animals, recreational tourism, recreational fishing, trophy hunting, among others to promote social and economic sustainability, besides ecological sustainability is lacking. Further, several species of frogs in Africa, including endemic species (*Conraua* sp, *Trichobatrachus* sp. and *Astylosternus* sp.) are mainly harvested from wild used for local consumption and local trading; however, assessments of the value chains are poor, especially Central Africa regions (See section 3.3.3.3.3).

(xvii) Knowledge gap on global scale of sustainable use of wild species among indigenous people and local communities. The importance of wild species that contribute to livelihood strategies, in particular for indigenous people and local communities is well recognized. However, little information exist in the available global indicator sets to comprehensively quantify the spatial and temporal scales of sustainable use of wild species occurring specifically in indigenous people and local communities across the globe; and the United Nations are aware of this gap.

(xviii) Knowledge gap on quality assurance, safety and efficacy to assess traditional medicine. Wild species have been used in traditional medicinal practice for millennia. To control quality and to ensure safety and efficacy in production of traditional medicines is difficult. The World Health Organization has produced a series of technical documents in this field, including publications on good agricultural and collection practices and good manufacturing practices, along with other technical support, to assist with standardization and creation of high-quality products (WHO, 2013). The World Health Organization urges member states to cooperate with each other and to share knowledge while working to strengthen communication between conventional and traditional practitioners. Evaluation of quality, safety and efficacy based on research is needed to improve approaches to assessment of traditional medicines, a situation made difficult to remedy in light of historically inadequate public and private funding to address this growing concern (WHO, 2013).

(xix) Insufficient bridging of indigenous and science-based knowledge. The incorporation of multiple types of knowledge (e.g., science, indigenous knowledge, traditional ecological knowledge) is especially critical for the sustainable use of wild species, which can strengthen the evidence-base for policy advice, decision making, and environmental management (R. Hill *et al.*, 2017). While the benefits of incorporating multiple types of knowledge in environmental research and management are many, successfully doing so has remained a challenge. In response there have been a number of recent reviews that have sought to better understand the bridging of indigenous, local, and science-based knowledge (Barron *et al.*, 2015; Berkes, 2010; Berkes & Berkes, 2009). Yet there continues to be a need for methods, models, and approaches for integrative work (Barron *et al.*, 2020; R. Hill *et al.*, 2017). This approach seeks to examine the extent, range, and nature of the published literature (i.e., peer-reviewed and grey) that integrates and/or includes indigenous, local, and science-based knowledge in sustainable use of wild species research, monitoring, or management (Alexander, Provencher, Henri, Taylor, & Cooke, 2019).

There is no solid mechanism developed for knowledge transfer from indigenous communities to scientific communities and vice versa, and as discussed in section 3.3.2, in many cases attempts to do so have led to issues of intellectual property and biopiracy (Barron *et al.*, 2015; Berkes & Berkes, 2009; S. Devkota, 2006). Wild species are being used as a rich source of medicine because they produce a host of bioactive molecules, most of which probably evolved as chemical defenses against predation or infection. Wild plant species are chosen for pharmaceutical studies through different methods, one of the methods include ethnobotanical approach, i.e., indigenous uses of plant species based on indigenous and local knowledge that can offer strong clues to the biological activities of those plants (P. Cox & Balick, 1994). There are well-established drugs that were developed after scientists began to analyze the chemical constituents of plants used by indigenous peoples and local communities for medicinal or other biological effects.

3.6 CHALLENGES AND RESEARCH PRIORITIES

3.6.1 Challenges

Major challenges related to status of and trends in sustainable use of wild species have been discussed.

3.6.1.1 Global scale and scope

Fundamental challenges evaluating the role of sustainable use in biodiversity conservation and sustainable economic development pertain to the lack of guiding principles derived from analysis of spatial and temporal applications (Rands *et al.*, 2010; Tierney *et al.*, 2014). The scale and scope of these challenges involving sustainable use across regions and countries is immensely diverse and context specific. Studies that integrate and harmonize information from various sources and programs, where sustainable use has and has not been achieved, are needed to evaluate in order to better understand the likelihood of benefits and costs for both nature and people. However, these datasets, published from a variety of sources, are not sufficient in terms of quantity or quality or both for an assessment of sustainability of harvest. Data need to be integrated and harmonized to evaluate status and trends in global use of many species.

3.6.1.2 Informal trade of wild species

Informal trade of wild species in small quantities that do not enter the national trade or export statistics takes place through informal markets in most developing countries. Informal trade mainly includes subsistence small-scale coastal and freshwater fisheries, terrestrial animal harvesting, gathering of wild foodstuffs, medicinal plants, mushroom, and berry picking (FAO, 2019b). A challenge in such informal and largely unreported trade is that its ecological, economic and social impacts and importance to society remain invisible to decision-makers, hence unlikely to mainstream into policy-making. More research would be desirable to assess informal trade of wild species.

3.6.1.3 Fishing

Among fishing, small-scale fisheries are strongly connected with activities by local communities for their own consumption; and employ over 90 percent of fisheries workforce. Despite their importance, small-scale fisheries around the world are facing major challenges due to large-scale fisheries and increased global development activities as well as climate change. There is lack of data to evaluate the sustainability of small-scale fisheries on catches and measures of exploited stocks (i.e., size, proportion of juveniles caught, among others), especially over broader spatial or temporal scales. These challenges, in many cases, have placed the livelihoods, economy, food security, values and identity, and the viability of small-scale fisheries communities at risk.

3.6.1.4 Gathering

A wide range of organisms are gathered worldwide for meeting a variety of needs (i.e., income, livelihoods, subsistence, social safety, identity), which are also traded in both domestic and international markets. A major challenge is that gathering practices are selective and based on specific organisms/group of organisms (e.g., ornamental fish and coral, orchids, cacti, bromeliads, succulent, palms and bamboos, medicinal plants and other wild algae, fungi and plants, wild biomass energy, edible insects and small terrestrial invertebrates, etc.). As organisms become more popular to harvest because of changing commodity chains or popular fads or trends, overharvesting can occur. The mix of temporal and spatial drivers and their direct effects on wild species are difficult to quantify since these same changes in demand lead to innovations in domestication and synthesizing similar materials.

3.6.1.5 Terrestrial animal harvesting

Throughout history human populations have been engaged in hunting and trapping to meet a range of nutritional, economic, medicinal, cultural and recreational needs. A major challenge is that overhunting, which is taking place at varying degrees of hunting pressure, often results in faunal biomass collapses, mainly through declines of large-bodied species with low intrinsic rates of population increase, especially in Oceania, Africa and Asia. Trophy hunting is currently the subject of intense debate. However, some trophy hunting can produce simultaneous benefits of economic gains, and sustainable wild species exploitation and biodiversity conservation, even though well managed trophy hunting is rarely documented (Coad *et al.*, 2019), and unsustainable hunting is common. Hunting becomes unsustainable when it causes species abundance on a trajectory of ongoing declines.

3.6.1.6 Logging

Harvesting of timber for wood carvings is a challenge because it involves destructive processes, which is not carefully monitored and remain somewhat hidden. Most commercial carving enterprises are based in homes or small production units (Cifor, 2002). In the past, wood carvings were mainly carried out to attain cultural materials, often as symbols of particular cultures or regions.

Tree retention has the potential to reduce impact of logging on forest biodiversity, though determining exact levels that are required to secure long-term viable populations of different species in a natural forest in most cost-efficient conservation measures remains a major challenge for future research (Gustafsson *et al.*, 2010).

Another challenge is that harvesting has long been affected by changing tools and technology i.e., availability of axes, adzes and chisels made of iron, for example, increased both the speed with which wood could be carved and the range of species used. This includes endangered/threatened, for example sandalwood, whose use and trade are restricted by both national and international regulations.

New policy instruments are emerging in some countries, such as in the United States of America, Australia and many European countries to prohibit the sale of illegally harvested wood and wood products. These regulations require operators to provide proof of certification of the identity of the species traded and the origin of their products. However, there is a mismatch between the legislated requirements and the capacity of importers to comply fully because existing methods for documenting species identity (wood anatomy and chemistry) and origin (mostly paper-based documentation, tagging) are insufficient, ambiguous and easily falsifiable (FAO, 2014c). While extensive literatures on the using of DNA analysis for forensic investigations in animal species exist, there is unfortunately a serious lack of information on wild plant species (Iyengar, 2014).

3.6.1.7 Non-extractive uses

In the context of sustainable utilization of nature for economic and other benefits, nature tourism has created a growing demand for 'watching wild species', 'un-spoilt habitat', and 'pristine nature' in combination with high levels of comfort, accessibility and high-quality experiences. The 'flagship' species – most often the megafauna, 'charismatic' mammals and birds, the 'cute and cuddly', dangerous predators and species that are believed to display intelligence, play an important for tourism and recreation practices. The tourists' preference of visiting a pristine natural habitat contributes to new challenges and creates pressure on the ecosystems in general and wild species in particular. Consequently, special attention needs to be paid to the aspects of sustainability in these processes.

3.6.2 Research priorities

An attempt has been made to identify common research priorities for status of and trends in sustainable use of wild species. This analysis is based on the assessment of: (i) key knowledge gaps to achieve global sustainability goals (Mastrángelo *et al.*, 2019); (ii) knowledge gaps and challenges mentioned in this assessment; and (iii) selection of pertinent research questions that would substantially advance the goals of biodiversity conservation and sustainable development (Coleman *et al.*, 2019).

3.6.2.1 Practices and uses

In the practices and uses sectors, key prioritized areas include sustainable practices in fishing, gathering, terrestrial animal harvesting and logging as well as assessment of combined impact of wild species harvesting, fishing and hunting practices leading to habitat and global biodiversity loss. For example, gaps in fishing comprise: (i) amount of freshwater wild species harvested, consumed locally, and traded nationally and internationally; (ii) assessment of conservation status and sustainable small-scale fishery, and economically-important fish for food, live fish trade; and (iii) impact of international trade on fisheries and marine biodiversity, globally and regionally. Similarly, an emerging major challenge for future in logging remains to determine exact levels that are required to secure long-term viable populations of different species, as well as most cost-efficient implementation of these conservation measures (Gustafsson *et al.* 2010). It is estimated that Reduced Impact Logging provides guidelines to reduce environmental impact of logging, but it is unclear what intensity can sometimes result perverse effects; and more research is needed to clarify this type of practice.

3.6.2.2 Nature's contributions to people & human well-being

Some prioritized areas of research include: (i) evaluation of contributions of sustainable use of wild species including urban gathering to nature's contributions to people that play key roles in regional and national scales; (ii) analysis of maximum benefits of nature tourism while minimizing adverse impacts on terrestrial, aquatic and marine ecosystems; (iv) assessment of effective livelihood support programs that meaningfully support nature conservation among marginalized communities and indigenous peoples and local communities; and (v) identification of key factors underlying win-win outcomes for sustainable use of wild species and poverty alleviation.

3.6.2.3 Documenting under-researched taxa

The emphasis should be on taxonomic assessment of under-researched taxa (e.g., invertebrates, insects, fungi, species that are pollinators or pest regulators, species or habitats with cultural value, rare or endemic species that are often viewed as the most important targets for biodiversity conservation) being overlooked due to gaps in data, as well as inadequate enforcement of laws and principles that are particularly missing in the countries action plans.

3.6.2.4 Social norms that affect uses and practices

There is growing interest in how socio-ecological dynamics relate to obtaining interdisciplinary and reliable data in research priorities, such as: (i) social science methods and approaches to obtaining reliable data on scale and patterns of uses of wild species; and (ii) evaluation of social norms (at local, regional and national scales) that affect use and practices including gathering and harvesting, fishing, logging, and hunting & poaching pressure.

3.6.2.5 Integrating indigenous local knowledge

Indigenous and local knowledge research is increasingly being used to generate more accurate data on species trends, non-iconic species data and geospatially relevant data using technology. Participatory monitoring of use of wild species in close collaboration with local resource users can provide large amounts of reliable and much needed data to inform policy and management approaches in data-poor social-ecological systems. Biocultural approaches are being adopted by governments to policy that recognize both indigenous people and local communities' territorial management practices and customary governance, thus countering the drivers of unsustainable resource use and offering alternative conceptualizations of the interrelations between people and nature (Brondízio *et al.*, 2021).

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Chapter 4

THE DRIVERS OF THE SUSTAINABLE USE OF WILD SPECIES[1]

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Chapter 4

Chapter 4

THE DRIVERS OF THE SUSTAINABLE USE OF WILD SPECIES

EXECUTIVE SUMMARY

Scope of the chapter

Policy changes to reverse the trend in declining wild species are required in many regions of the globe. To be most effective, these policy changes must be based on evidence about the drivers of both sustainable and unsustainable use of wild species. A comprehensive review and analysis of this evidence led to the identification of the core drivers and mediating factors (or issues of context, that affect the impact of each driver in different regions and jurisdictions) that should be considered by policymakers. These core drivers and a synthesis of evidence for each are presented in this chapter in the categories of environmental, political, social, economic, cultural, science, technology and education drivers. The aim is to illustrate the opportunities and challenges for policymakers seeking to improve sustainable use outcomes. The chapter also addresses the interactions between these drivers with the intention of providing an integrated understanding of how these drivers, as well as mediating factors, are interrelated and the outcomes that result from these interactions.

Definition of Driver

Drivers are defined (for the purposes of this report) as the factors that, directly or indirectly, cause or influence wild species use patterns. This chapter seeks to illustrate both the drivers that are leading to unsustainable use as well as those that are resulting in sustainable use. Evidence includes data about the causal, correlated and descriptive relationships between each driver and outcomes of the use of wild species (e.g., altered use through the practices, such as terrestrial animal harvesting, fishing, logging, gathering and non-extractive activities. This includes quantitative changes (e.g., increased/decreased use) and considers how drivers may lead to qualitative changes in use and practices (e.g., spiritual value). The aim is to show where, how and under what conditions core drivers significantly influence the patterns of wild species to use and where policy development or adaptation can moderate or exaggerate the impact of these drivers. Disentangling evidence about the impact of one driver from others can be complicated in complex systems (where there are many interrelated drivers, effects and feedbacks). The analysis and presentation of findings on drivers and mediating factors also consider how drivers, use and impacts may be defined and evaluated differently in different contexts, depending on values, experience and knowledge systems, including indigenous and local knowledge.

The drivers addressed throughout the chapter are grouped into six main categories:

- Environmental
- Political
- Social
- Economic
- Cultural values/religious beliefs, and
- Science, technology and education

For the understanding of the influence of drivers on the sustainable use of wild species, an analysis of data and information collected from published literature and other available sources was conducted, and a synthesis was done. Specifically, a literature review using major online bibliographic databases (e.g., Web of Science) was undertaken to employ a variety of queries and search terms. Outcomes of these searches were analyzed and synthesized according to the main conceptual/disciplinary typologies of inquiry of this assessment and this chapter. This included consideration of the typologies of practices defined in Chapter 1 (fishing, gathering, terrestrial animal harvesting and non-extractive practices) and the characteristics of the wild species involved.

The team synthesized evidence about a diversity of practices and uses of wild species over time (from 1950-2021) and identified patterns and trends in different drivers in different socio-political, economic and cultural contexts (e.g., regional similarities and differences). From this secondary analysis, the experts could determine similarities and differences in how each driver's impact was mediated (e.g., compounded or diminished) in different contexts. The insights were synthesized into key conclusions and summarized into critical messages for each section of this chapter. Attention was paid to the quality and quantity of evidence related to these conclusions and messages. A confidence determination (scoring) was made based on such quantitative indicators (e.g., number of publications) and the source and quality of the publication. Recognizing that there are significant biases in institutional publication patterns, additional efforts were made to identify sources attributed to indigenous peoples and local knowledge or focused on evidence from indigenous and local knowledge. Consideration was also given to racial, regional and gender bias in patterns of published data; recognizing gaps in quantitative data, case studies were used in this chapter to illustrate the impact of drivers on use patterns qualitatively.

This review and analysis revealed the following insights about core drivers and mediating factors influencing wild species use patterns:

Environmental drivers

Numerous environmental drivers are directly and indirectly impacting the use of wild species. These include habitat disturbance (e.g., deforestation, pollution) and climate change:

- **Habitat loss and disturbance** is a leading driver of the unsustainable use of wild species. Evidence points to declines in the health, population and distribution of wild species (owing to deforestation, pollution, extractive development and land clearing associated with agriculture and urbanization); these declines are problematic in almost all regions and concerning all practices defined in this assessment. Trends towards habitat loss and disturbance and their impacts on wild species are being halted or slowed in some regions as a result of improvements in land use planning, creation/adaptation of harvest regulations, the creation of protected and conserved areas, and banning pollutants that affect species health. Although rigid limitations against wild species use and habitats can appear effective, they can lead to the creation of illegal use patterns and inequitably impact vulnerable populations, including indigenous peoples and local knowledge *(well established)* {4.2.1.5}.

  - Deforestation is a significant cause of habitat degradation and loss. Deforestation and forest fragmentation negatively affect the health of many wild species populations associated with food-related hunting and fishing. It also affects the abundance and availability of non-timber forest products *(established but incomplete)* {4.2.1}.

  - Urbanization is among the major causes of habitat loss and disturbance. The loss of species habitat (due to land clearing and development) has had an adverse impact on the population and health of terrestrial, freshwater and marine species, and there is an upward trend in human – wild species conflict *(well established)* {4.2.1.5}.

  - Expansion and intensification of agriculture (including agroforestry and aquaculture) have been a major driver of wild species decline and, in turn unstainable use globally *(well established)* {4.2.1.5.3}. Agriculture in some contexts relieves pressure on some wild species (e.g., by creating alternatives for food provisioning) *(established but incomplete)* {4.2.1.5}.

  - Rangeland degradation reduces various nature's contributions to people but mainly affects sustainable use of wild species as it has decreased capacity to provide forage for large herbivores, including domestic livestock *(established but incomplete)* {4.2.1.5}.

  - Pollution, be it from anthropogenic or natural sources, negatively impacts the abundance, distribution, availability, harvesting, gathering, and value chain of wild species in different ways and at different spatial and temporal scales *(well established),* {4.2.1.6}.

  - Hydroelectric power development is a significant cause of habitat loss and degradation of aquatic species. Globally, the number of dam constructions has increased dramatically over the past six decades to meet energy demands and flood control; it is estimated that dams have altered ecological flows in 48% of the rivers worldwide. Dams adversely affect aquatic and terrestrial biodiversity by altering or eliminating habitats, including blocking migratory patterns *(well established)* {4.2.1.5}.

- **Climate change** is, directly and indirectly, affecting the sustainability of wild species use. Global temperature in 2020 was one of the three warmest years on record and the last decade was the warmest on record in a long-term climate change trend according to World Meteorological Organization (1.2 degrees C +/- 0.1) above the pre-industrial level *(well established)* {4.2.1.2}.

  - Climate change impacts on hydrological cycles and precipitation patterns have created stress on the health, population and habitats of wild species (inclusive of marine, terrestrial or freshwater ecosystems), which has, in turn, affected all practices and uses. These changes in hydrological cycles as well as warming temperatures are also affecting species productivity and distribution which in term affects use patterns. In some cases, species productivity has declined; in other instances productivity has increased due to warming conditions *(established but incomplete)* {4.2.1.2}.

- Climate change is also directly affecting patterns of wild species use. For example, a northerly shift in commercial fish harvesting (over the last 40 years) can be correlated with the northerly shift in distribution of valued fish species. A growing number of climate change hazards have also become barriers to use and had adverse impacts on communities who depend on wild species for food provisioning. In some cases (e.g., in arctic ecosystems) climate change is opening up previously inaccessible regions *(established but incomplete)* {4.2.1.2}

- Climate change disproportionately impacts the poor, local and indigenous communities. Because the current pandemic has impacted everyone to varying degrees {4.2.1.2} global efforts to reduce carbon emissions coupled with investments in the capacity of those most vulnerable to cope and adapt to climate change is seen as a major mediating factor that influences the extent of climate change impact on wild species use *(well established)*. Climate-related impacts include changes in forest productivity and forest fire dynamics; where productivity decreases and forest fire frequency increases (due to declining precipitation and warming temperatures), the most significant impacts on wild species and use are anticipated. National and sub-national efforts to manage climate change impacts on forests can mitigate these impacts in the short-medium term (e.g., Reducing Emissions from Deforestation and Forest Degradation, REDD/REDD+) species {4.2.1.2.3}. Climate change is expected to decrease maximum fisheries catch by 7.7% globally and about 35% in tropical oceans, while creating new opportunities in mid- to high-latitude oceans because of marine species shifting range polewards *(established but incomplete)* {4.2.1.2.2}.

- Although there is general evidence that climate change is leading to more unsustainable use, there are gaps in understanding of the specific impacts of climate change on sustainable use in many regions and more many practices *(established but incomplete)* {4.2.1.2}.

- The effects of climate change are compounded and complicated by interactions with other environmental, socio-cultural, political, and economic drivers *(established but incomplete)* {4.2.1.2}.

Biological hazards: Zoonotic disease and the use of wild species are interconnected. Species for wild meat {4.2.1.4}, which in turn leads to increased health risks, food insecurity and poverty for vulnerable communities {4.2.1.7}. Initial evidence reveals that the COVID-19 crisis has disproportionately impacted the poor, local and indigenous communities and their ability to sustain themselves. Intensified contact between people and wild species arising from the encroachment of human activities into forest ecosystems and increased demand for meat and medicine from wild species are the cause of zoonotic diseases, which constitute about 70% of known emerging diseases {4.2.1.4., 4.2.1.7}. Although the evidence is well-established that the emergence and spread of zoonotic diseases are due to increased contact between wild species and people, the evidence to link the use of wild species with zoonotic risks is unresolved *(established, but incomplete)* {4.2.1.4, 4.2.1.7}.

- Invasive alien species have both negative and positive impacts on the sustainable use of wild species; however, the negative impacts such as deteriorating ecosystem health, decline or even extinction of native species are more prevalent *(well established)* {4.2.1.4}.

- Small tropical islands and coastal mainland regions are the hotspots of established alien species richness *(well established)* {4.2.1.4}. However, compared to the impact of invasive alien species in terrestrial ecosystems, there is a significant gap in knowledge about the ecological effects of invasive species in marine ecosystems globally *(established but incomplete)* {4.2.1.4}. Invasive species have negatively impacted the livelihoods and economies of indigenous and local communities. Key impacts include changes or abandonment of key practices necessary for food provisioning. However, in some instances, introduced species have contributed positively to the economy and livelihoods of indigenous people supplementing the provision of harvested fish and game as well as fuelwood, fodder, food products, timber and medicinal products *(well established)*, {4.2.1.4}.

Political drivers

The capacity of governance systems (including formal and informal institutions, statutory and customary laws) to prevent, mitigate or manage problems of unsustainable use varies around the globe. Where governance systems are informed by monitoring of species health and use, equitable public participation of those dependent on wild species (mainly for food provisioning) and include robust mechanisms for dispute resolution, there is evidence of sustainable use *(well established)* {4.2.2.2}.

- In many regions, institutions and policies that regulate direct uses of wild species are weak (i.e., do not exist, lack clarity or are poorly enforced). Indirect impacts on sustainable use (e.g., habitat loss, contamination) are also poorly recognized and regulated but have significant implications for use in many regions and for many species *(well established)* {4.2.2.2}.

- Pluralistic governance arrangements that reflect a broad spectrum of use values, create more significant opportunities for inclusive and equitable decision-making. Lack of attention to issues of equity in managing the use, has led to other unsustainable outcomes, including food insecurity and vulnerability, particularly for those who depend on wild species to meet basic needs. Such pluralism offers a more significant opportunity to learn from users (e.g., indigenous peoples and local knowledge). Where there are barriers to learning from indigenous peoples and local knowledge (including institutional learning and adaptation) and other local users of wild species, there are fewer tools and opportunities for preventing, mitigating and managing unsustainable use (when compared to centralized and rigid institutions) *(well established)* {4.2.2.3, 4.2.2.4, 4.2.2.7}.

- Decentralized *versus* centralized governance arrangements can be more effective at ensuring sustainable use, particularly for wild species considered to be 'commons' and/or where rules/regulations of centralized institutions are not easily communicated or enforced. These are most successful where local users are engaged in rulemaking, where there are clear boundaries, secure property rights, mechanisms for monitoring, sanctions, and enforcement are in place *(well established)* {4.2.2.4, 4.2.2.5}.

- Institutions that are flexible and adaptive to new information from monitoring the health, population and distribution dynamics of wild species are better able to ensure sustainable use *(well established)* {4.2.2.2}.

- A robust civil society and culture of collective action have been influential in catalyzing management and policy change towards sustainable use. This advocacy has, in other cases, led to unsustainable use outcomes *(well established)* {4.2.2.2, 4.2.2.7}.

- The values of indigenous peoples and local knowledge have historically not been well represented in the mainstream governance of wild species. However, global recognitions (i.e., United Nations Declaration on the Rights of Indigenous Peoples) are catalyzing some changes at the national and sub-national levels as are legal challenges in some regions *(well established)* {4.2.2.2.5, 4.2.2.2.7}.

- Where there is greater interaction of government, communities, the private sector and academia and the quality of stakeholder contributions to policy making, sustainable use is more feasible *(established but incomplete)* {4.2.2.2, 4.2.2.3}.

- Where there is greater interaction between national and sub-national governments with indigenous peoples and local knowledge, industry and those involved in science, there are greater opportunities for ensuring regulation and management decisions accountable to users' needs. This kind of pluralistic governance approach can also better support multi-scale solutions to sustainable use problems (i.e., that are transboundary). There is also a greater potential for successfully managing conflicts between user groups (and ensuring coordination and collaborative solutions) {4.2.2.2.2}. However, this requires ensuring that conflicts are adequately addressed, overlapping mandates are avoided, and coordination and complementarity are encouraged *(well established)* {4.2.2.3}.

- The approaches to addressing unstainable use and coordinating sustainable use are often poorly coordinated across scales and institutions. Different levels of governance are often poorly aligned and coordinated, which undermines keeping the use within a sustainable level—the lack of alignment limits protections of sustainable use. Lack of clarity and consistency (security) in recognizing and protecting use rights (i.e., including local and indigenous rights and customary rights) create problems of "open access" and, by extension perverse disincentives for conservation *(established but incomplete)* {4.2.2.3, 4.2.2.6}.

- Tenure security contributes to sustainable use *(well established)* {4.2.2.6}. Tenure arrangements that foster secure rights over land and resource use and trade can incentivize resource conservation, sustainable use, and diverse livelihoods, partly because there are more opportunities for effective regulation of use patterns *(established but incomplete)* {4.2.2.3} and they allow for longer-term planning. In regions where tenure insecurity has been reduced, there is evidence of improved food security and positive conservation outcomes for wild species *(well established)* {4.2.2.3, 4.2.2.6}.

- Where management is based on long-term relationships to place, practices of monitoring changes in species health, population and distribution tend to be well developed. These monitoring practices contribute to sustainable use in that they facilitate learning and adaptation. Such norms and practices of stewardship and adaptive learning are well documented in the case of indigenous peoples and local communities *(well established)* {4.2.2.2, 4.2.2.4}.

Social drivers: Various demographic and social factors influence the sustainable (or unsustainable) use of wild species: migration and urbanization, social organization and reproduction, empowerment, effective participation and accountability, poverty and process of marginalization, gender equity and, rural development (roads, infrastructure, access to material assets and immaterial goods-market, credit, internet) *(well established)* {4.2.2.7}.

- Population growth, demographic change and mobility are affecting use patterns of wild species. Specifically:
  - Population density and growth are leading to increased demand/consumption of wild species in some regions, particularly in urbanized areas of the global south *(well established)* {4.2.3.2}.
  - Increased mobility is leading to unsustainable use of wild species in critical areas. Such mobility is associated with displacement (i.e., from conflict, environmental degradation) as well as economic opportunity (e.g., transnational labor movements). In addition to increasing pressure on species, there is growing displacement of local uses (e.g., of indigenous peoples and local knowledge) *(well established)* {4.2.3.2}.
  - Mobility across political and ecological borders, may be leading to unsustainable use, particularly where such mobility is accompanied by lack of attachment to the place(s) *(established but incomplete)* {4.2.3.2, 4.2.3.2.2}.
- Urbanization tends to lead to decreased consumption of wild species due to access to the market economy for food *(established but incomplete)* {4.2.3.2.3}.
  - Mobility of peoples across political and ecological borders, may be leading to unsustainable use, particularly where such mobility is accompanied by lack of attachment to the place(s) *(established but incomplete)* {4.2.3.2, 4.2.3.2.2}.
- Social organization and networks affect how the benefits and costs of wild species use are distributed. Societies that are more equitable tend to experience less poverty, conflict and social inequality, which are factors correlated with sustainable use patterns *(well established)* {4.2.3.5}.
  - Social inequity and poverty are a growing trend globally, particularly in the global south. In many regions, where alternatives to basic needs (e.g., shelter, food) and economic and social supports (e.g., education) are limited, there is greater dependence on wild species. However, it is an over-simplification at attribute unsustainable use of wild species to those living facing poverty *(well established)* {4.2.3.5}
  - Although some evidence points to those living in poverty are culpable for increasing unsustainable use of wild species, the socio-economic and political systems that have created and perpetuated poverty and inequity are the underlying driver *(well established)* {4.2.3.5}.
  - Given that poverty is multidimensional, eradicating it requires a multifaceted approach. Access to food, shelter, education, employment, and health can lift people out of poverty and make them less dependent on wild species *(well established)* {4.2.3.5}.
  - Equitable distribution of benefits from the sustainable use of wild species is a stated goal of many governance and institutional frameworks. However, implementation of these goals is often flawed. This directly impacts sustainability, creates incentives to over-harvest species, undermines long-term management of species, and can support unsustainable commercial extraction *(well established)* {4.2.3.4, 4.2.3.5}.
  - Use of wild species by women and indigenous peoples is under-recognized and poorly protected and consequently creates / aggravates problems of food insecurity and poor health for vulnerable populations (e.g., poor nutrition) and increases dependency on commercially produced food resources *(well established)* {4.2.3.4; 4.2.3.5}.
- Social values and norms influence how wild species are used, and many aspects of their sustainability are interpreted:
  - Social groups who are most dependent on wild species tend to experience more significant concern and anxiety about their health and unsustainable use (i.e., have heightened risk perception *(well established)* {4.2.3.3.6}. These groups thus tend to be critical stakeholders in identifying sustainable use solutions *(well established)* {4.2.3.7}; among the groups with long-term dependencies and support for sustainable use are indigenous peoples *(well established)* {4.2.2.2.5}.
  - Many indigenous peoples and local communities who have long-term relationships with wild species have well-developed relationships, knowledge systems, practices, and rules (i.e., customary

laws) which ensure their sustainable use *(well established)* {4.2.3.5}.

- Social norms create the social context in which wild species use is structured/organized, and interpreted by users. Where practices of hunting, fishing and gathering are fundamental to food provisioning and support livelihood and social identity, these practices and uses tend to be more sustainable *(established but incomplete)* {4.2.3.3}.

- The harvest of wild species is recognized as essential to food security, health and well-being in many regions; where there is increasing risk (both reported and perceived) of bioaccumulation of contaminants, presence of disease (including transmissible disease to humans), hunting, fishing and gathering of wild species tend to decrease. However, trust in the actors involved in risk communication is a mediating factor *(well established)* {4.2.3.7}.

- Gender inequity in how the costs/benefits of wild species use are distributed is visible in key regions of the globe *(well established)* {4.2.3.6}.

Economic drivers

- The economic drivers of sustainable use of wild species can be understood through evidence-based research on both formal and informal economies, at different scales (from local to global) and in respect of particular economic activities. While the greatest concerns with economic trends are those that are large in scale and involve exploitation of wild species for growing urban markets, the value and uses of wild species within local economies meet the needs of rural peoples, including indigenous peoples and local communities, are also essential considerations in a discussion on economic drivers *(well established)* {4.2.3.3.5, 4.2.4.2.2}.

- Global trade in wild species can create disincentives for sustainable use and lead to significant losses in some species in the absence of local, regional, and national regulation and management plans. Wild product trade often forms part of income diversification and risk reduction strategy for households living in poverty in developing countries *(well established)* {4.2.4.3.1}.

- Trade revenues can facilitate and incentivize conservation, but if regulation is absent or not enforced, it often encourages overexploitation and unsustainable use, including local extinction. Sustainability outcomes depend on mediating factors such as the total demand and scale of trade, governance arrangements, trade relations and local incentives for conservation, and species characteristics *(established but incomplete)* {4.2.4.3.1}.

- Sustainability outcomes depend on the enforcement of local management plans, national laws, and international cooperation. Lack of enforcement and monitoring bears the risk of undermining the potential for sustainable use that may provide critically needed revenue and incentives for conservation while at the same time failing to discourage illegal harvests and trade *(established but incomplete)* {4.2.4.3.1}.

- Strictly regulated trade, including trade bans, have played an important role in halting unsustainable use of threatened species, but in some cases, blanket trade bans have had unintended consequences on sustainability outcomes *(established but incomplete)* {4.2.4.3.1}

- Empowering local communities to capture the benefits from wild species conservation with legal user rights over wild species and co-design regulation contributes positively to sustainable use *(established but incomplete)* {4.2.4.3.1}.

- “Tax havens” and global crime facilitate unsustainable use of wild species *(established but incomplete)* {4.2.4.3.2}.

- Micro-credits and foreign investments can play a positive role in enabling sustainable uses if combined adequately with wider enabling factors such as human and social capital investments. In some cases, remittances support livelihoods and may reduce pressure on resources but provide the capital to enable unsustainable uses and practices *(established but incomplete)* {4.2.4.3.2}.

- Activities related to tourism and supporting infrastructure may disturb wild species and undermine sustainability outcomes. At the same time, revenues from tourism can be used for conservation projects which positively impact sustainable use of wild species *(established but incomplete)* {4.2.4.3.3}.

- Traditional ecologically more sustainable but economically less profitable practices may be supported when linked to tourism activities that generate additional revenues. At the same time, certain tourism-related activities, such as the sale of wildlife parts and the use of live animals in entertainment, incentivizes unsustainable and sometimes illegal practices. *(established but incomplete)* {4.2.4.3.3}.

- In some cases, extractive forms of tourism (i.e., terrestrial animal harvesting and fishing) positively impact ecological, social, and economic sustainability by generating revenues for conservation and livelihoods. However, in many cases, the revenues do not reach local communities and do not contribute to conservation, in which case the extractive tourism can be unsustainable *(established but incomplete)* {4.2.4.3.3}.

Cultural values/religious beliefs

- World views, religions, customs and belief systems directly and indirectly influence the practices and uses of wild flora and fauna *(established but incomplete)* {4.2.5}.

- Indigenous and local knowledge includes cultural norms and ethics that support sustainable use *(established but incomplete)* {4.2.5}.

    - Observation is central to sustainable use, allowing indigenous peoples and local knowledge to closely monitor and assess resources over time and providing a solid foundation for building sustainable management plans *(well established)* {4.2.5.2.5}.

    - Indigenous and local knowledge is poorly documented compared to other knowledges; where it has been documented and embraced, there are greater sustainable use outcomes. It also offers a crucial foundation for sustainable use in and beyond indigenous peoples and local communities. Realizing its full benefits will require enhanced documentation and greater recognition of Indigenous rights *(well established)* {4.2.5}.

- Cultural norms often mediate practices and uses of wild species; where there are long-term relationships between people-nature, examples around stewardship and care of wild species are more common *(well established)* {4.2.5.2}. Cultural taboos against harvest, consumption and other uses of wild species play an essential role in the conservation of some key species (e.g., sacred groves) *(well established)*, {4.2.5.2.2}.

- Beliefs about the perceived medicinal value of wild species (coupled with clinical evidence about improved health outcomes) are a driver of the harvest and use of some flora and fauna *(well established)* {4.2.5.7}.

- Spiritual beliefs that wild species have an equal value to humans (e.g., are relatives or are gifts from the spirit world) are common in some cultures, particularly those of indigenous peoples. These beliefs often include recognitions or demonstrations of respect (e.g., ceremonies) when flora-fauna are harvested or used *(well established)* {4.2.5.2.5}.

- In many indigenous cultures, practices that facilitate good relationships with wild species (e.g., take only what you need) are interconnected with cultural values and norms of community well-being of communities *(established but incomplete)* {4.2.5.2}. "Take only what you need" is not a common principle or value in cultures tied to globalization and industrialization; these tend to focus more on the accumulation of wild species for profit.

- Many indigenous peoples and local knowledge have traditional norms and practices to ensure appropriate or sustainable, relationships with wild species. These norms and procedures are based on indigenous and local knowledge and are frequently central to spiritual practices. Often, they include significant sanctions or punishments when violated *(established but incomplete)* {4.2.5.2.7}.

- Human treatment of wild species in a humane way is also highlighted in the Convention on Biological Diversity's Addis Ababa Principles and Guidelines for the sustainable use of components of biodiversity *(established but incomplete)* {4.2.5.2.4}.

Scientific and technological innovation and education

- Rapid transformations in the life sciences and modern biology have changed how the natural world is studied and understood, with enormous implications for managing wild species and conservation across all sectors and practices – including fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices like observing. Genomic technologies and bioinformatics have generated enormous data and analysis, and the trend is a continued and accelerated expansion of scientific understanding *(well established)* {4.2.6.2}.

- Advances in science and technology can contribute to and undermine the sustainable use of wild species. Positive contributions include an enormous expansion of invaluable scientific understanding and knowledge directly useful for the sustainable use and conservation of species, including new ways to identify, characterize, manage, and monitor species and set priorities for conservation. This knowledge and resulting tools are employed across practices, including fishing, gathering, terrestrial animal harvesting and logging, as illustrated in hundreds of studies in recent years *(well established)* {4.2.6.2}.

- Positive contributions of advances in science and technology also include information/knowledge and technical support for implementing policies and laws that regulate the use and trade of wild species. Conservation and sustainable use laws based on a deep understanding of species, populations, and ecosystems have proven more effective, as documented in numerous studies and policy evaluations. The indirect and direct negative impacts of destructive laws and policies are also illustrated by advanced scientific research *(established but incomplete)* {4.2.6.2}.

- Fishing, gathering, terrestrial animal harvesting, logging, and non-extractive uses all take place within the context of broader ecosystems, the health of which impacts the sustainable use of species and populations. Advances in science and technology also have direct impacts on sustainable use by impacting ecosystems from which species are harvested, including erosion and degradation of ecosystems, and nature's contributions to people, resulting from feedstocks for new 'biological factories,' as well as the positive impact of bioremediation *(established but incomplete)* {4.2.6.2}.

- Science and technology create conditions that support or undermine sustainable use and local livelihoods, indirectly or directly. Biotechnology and 'biological factories',' for example, can provide substitutes for unsustainably harvested species – plants, animals, and marine – thereby taking pressure off wild populations, but they can also negatively impact small-scale producers and harvesters who depend on those species to make a living in a range country *(established but incomplete)* {4.2.6.2}.

- Information and communication technologies improve managers' decision-making processes by improving their ability to acquire timely and relevant data related to the population movement, scale, and management of wild species *(established but incomplete)* {4.2.6.3}.

- Information and communication technologies support managers and decision-makers ability to collaboratively analyze, access and share data and to work in partnership with colleagues, peers, decision-makers and public members *(well established)* {4.2.6.3}.

- It is well established that technology and urbanization contribute to decreased contact with biodiversity, leading to a decline in biodiversity-related knowledge and lack of awareness of its loss, unsustainable use, and importance in our lives *(well established)* {4.2.6.4}.

- Global trends toward standardization of education are decreasing attention to, and understanding of, local biodiversity and a decline in community resilience *(well established)* {4.2.6.4}.

- Research and practice demonstrate that indigenous, place-based, and experiential learning builds bonds between community members and their ecosystems, leading to a more robust environmental ethic *(established but incomplete)* {4.2.6.4}.

- Institutional disincentives within academic and research organizations discourage broad audiences' communication of relevant research results about biodiversity. Reform of academic incentive structures is needed that reward on-the-ground engagement with local groups and in biologically and culturally diverse regions and broader communication of findings beyond the scientific community *(established but incomplete)* {4.2.6.4}.

- Initiatives such as communication for social change, social learning, citizen science, and health-related sciences demonstrating links between human health and biodiversity can serve as a model; these fields are building bridges between science and the public, and their methods could improve understanding of the value of biodiversity and promote sustainable use of wild species *(well established)* {4.2.6.4}.

- Many local and indigenous groups are calling for systemic changes in educational systems to respect their cultures' traditions, knowledge, languages, values, history, and identities. Formal recognition by national educational systems of cross-generational knowledge transmission and a more comprehensive range of approaches to learning would support local stewardship and sustainable use of wild species *(established but incomplete)* {4.2.6.4}.

- Biodiversity education and communication can nurture a conservation consciousness which is fundamental to supporting the sustainable use of wild species. There is an emerging consensus that effective education programs respect local cultures, languages, and land, including women, elders, and youth, and promote inter-generational transmission of knowledge *(established but incomplete)* {4.2.6.4}.

Interactions among drivers

In most instances of resource use, there is interaction amongst drivers leading to either synergistic or antagonistic effects. Interactions among the various drivers make use of a species sustainable or unsustainable and are shared. The level of interaction is often case-specific and depends on whether:

- Use is restricted to a single jurisdiction *versus* being regional or transboundary.

- Technology is relatively simple and stable *versus* highly mechanized and frequently innovated.

- Alternative sources of food or livelihoods are of limited or ample availability.
- Governance processes are robust or contested.
- There are multiple competing uses, or
- Little is known about the species.

- Whether a practice of using wild species is sustainable or not is highly complex and may be influenced by how drivers (i.e., environmental, social, economic, cultural, political and science and technology and education) interact, which is often also influenced by mediating factors such as species ecology, value systems, indigenous and local knowledge and context *(well established)* {4.3.2, 4.3.4}.

- The sustainability of fishing and fisheries is widely driven by the complexity of the web of interactions among environmental, social, economic and technology drivers, where species biology, ecosystem and multi-species interactions also matter significantly *(well established)* {4.3.2.1}.

- The economic trade driver interacts with environmental, cultural and social drivers to affect the sustainability of gathering and collecting wild species. Such effects may be mediated by the use of technology and tools to impact further the collection of fantastic resources *(well established)* {4.3.2.2}.

- Cultural and social drivers often interact with economic drivers, which are further mediated by factors such as species biology to shape the sustainability outcome of hunting, with the bulk of the studies coming from the tropics *(well established)* {4.3.2.3}.

- Political and economic trade drivers and mediating factors such as species management interact to determine if logging practices are sustainable, but regional differences are apparent *(well established)* {4.3.2.4}.

- Compared to other practices, the non-extractive use of wild species is relatively sustainable, though not as widely studied. Multiple drivers have been documented to interact to affect the sustainable management of species *(established but incomplete)* {4.3.2.5}.

- The ecological settings, species rarity, and the resilience of ecosystems can influence the sustainability of the practices. Understanding species biology and ecology and how they interact with drivers can affect the management and sustainability outcome of the practice *(established but incomplete)* {4.3.3}

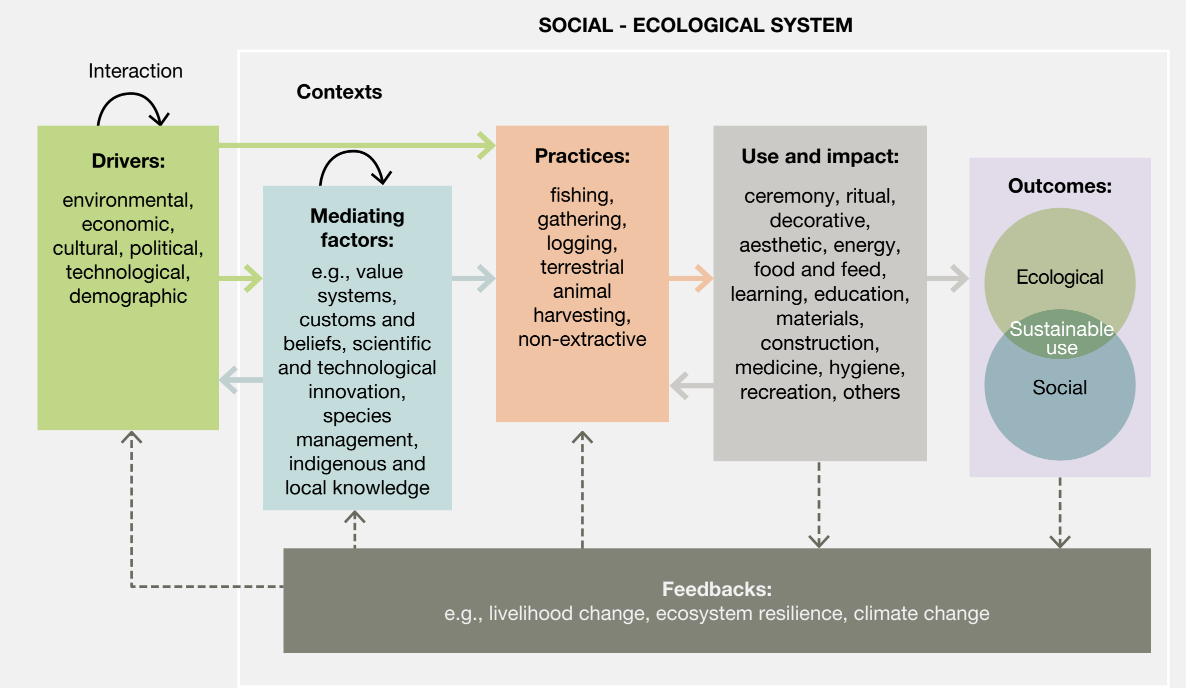


Figure 4 1 **Conceptual approach to the drivers of sustainable use of wild species.**

- Long-term, spatially explicit studies are essential for the assessment of the sustainability of the use of wild species. The interactions of drivers change with time and conditions, particularly when subjected to external shocks (e.g., economic or environmental) and perturbations, which may impact the sustainable use of a species in the future *(established but incomplete)* {4.3.4}.

The schematic below illustrates how drivers ultimately influence the sustainability outcomes of wild species use and the complexity and interactions among the key drivers in producing sustainability outcomes of practices such as hunting and fisheries throughout the world **(Figure 4.1)**.

4.1 INTRODUCTION

Human societies across the globe, since time immemorial, have relied on natural resources, including water, plants, animals, and minerals, to sustain themselves and their wellbeing. Over time, however, with increases in population and growing consumerism, the levels of natural resource extraction have increased exponentially without due consideration to the sustainability of their use (Bergstrom & Randall, 2016). As a result, natural resources are depleting and wild species face an increased risk of extinction (see Chapter 3). For example, Estrada *et al.* (2017) estimated that almost 60% of primate species face a high risk of extinction and 75% suffer from decreasing populations due to human-induced pressures on their habitats. Global and local market demands are causing significant habitat loss due to the expansion in industrialized agriculture, logging, livestock operations, oil and gas drilling, the establishment of road networks, and mining in primate ranges. At the same time, other key drivers include the growing demand for wild meat, including aquatic wild meat and the illegal trade in primate species for use as pets or in their body parts for other purposes. These impacts show how the combination of drivers may affect the abundance of species being used and whether they are used sustainably. The effects on nature's contributions to people arising from these changes are severe for indigenous people and local communities who, due to their intimate relationships with nature, rely on natural resources and have developed knowledge and customs that can help protect nature and sustainably use wild species.

Against this background, the need to achieve sustainable development in general, and the sustainable use of wild species in particular, is now a matter of urgency. The conceptualization of sustainable use is assessed in detail in Chapter 2. This chapter aims to assess the factors that contribute to sustainable use with a particular focus on what drives resource use. In the context of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), drivers of change are all the factors that, directly or indirectly, cause changes in nature, anthropogenic assets, nature's contributions to people and good quality of life. This chapter deals with direct and indirect drivers of sustainable use of wild species, interactions among drivers, and their impact on the human population in general and on indigenous and local communities in particular. IPBES defines these drivers in the following way:

- Direct drivers of change can be both natural and anthropogenic. Direct drivers have direct physical (mechanical, chemical, noise, light, etc.) and behavior-affecting impacts on nature. They include, among other things, climate change, armed conflict and war, pollution, different types of land use change, invasive alien species and zoonosis, and exploitation.

- Indirect drivers are drivers that operate diffusely by altering and influencing direct drivers, as well as other indirect drivers. They do not impact nature directly. Instead, they do it by affecting the level, direction or rate of direct drivers.

- Interactions between indirect and direct drivers create different chains of relationship, attribution, and impacts, which may vary according to type, intensity, duration, and distance. These relationships can also lead to different kinds of spill-over effects.

- Global indirect drivers include economic, demographic, governance, technological and cultural ones. Special attention is given, among indirect drivers, to the role of institutions (both formal and informal) and impacts of the patterns of production, supply and consumption on nature, nature's contributions to people and good quality of life.

The framework this assessment follows (outlined in Chapter 1) does not deal separately with direct and indirect drivers. These can be difficult to separate due to their interactions when they are applied to sustainable use as an outcome of the resource use system. Understanding the drivers will set the stage for determining the appropriate mechanisms to ensure the sustainable use of wild species.

This chapter builds on the assessments undertaken in Chapter 3, which focused on the status and trends in sustainable use, the consequences for wild species in nature, and nature's contribution to people. The Chapter will define drivers of the sustainable use of wild species and develop the following areas.

- Provide a classification of different drivers in environmental, political, social, economic, cultural, scientific and educational themes based on the IPBES framework.

- Explain different worldviews (concept of drivers), intrinsic values (charismatic species, keystone species, flagship species), systems and practices of looking at other drivers of sustainable use of wild species.

- Show linkage between drivers of use of wild species, sustainable use of wild species and human well-being.

- Provide a brief explanation of the interaction among different drivers of the use of wild species as well as the impact on indigenous and local communities

- Show schematics of drivers of sustainable use of wild species.

The Chapter starts with a description of the different drivers, followed by an assessment of how these drivers affect the sustainable use of wild species.

Methodology

Drivers in this chapter are, the factors that, directly or indirectly, influence the sustainability of wild species use. Based on a conceptual framework illustrated in **Figure 4.1**, drivers have been divided into main categories (environmental, political, social, economic, cultural and educational). For addressing how each driver influences positively/negatively the sustainable use of wild species across the different practices (fishing/ gathering/terrestrial animal harvesting/logging/non-extractive practices); the following points were considered relevant:

Driver X

- Overview and definition

- Accounting for how **driver X** influences (positively/ negatively) sustainable use of wild species across the different practices (fishing/gathering/terrestrial animal harvesting/logging/non-extractive practices).

- What are the trends and patterns of the influence of **driver X** globally, regionally, etc., on each of the practices over the assessment period (last 50 years)?

    a. Explain how **driver X** has contributed (positively/ negatively) to the sustainability of fishing, and hunting globally?

    b. Explain how **driver X** influences gathering and harvesting of wild species (for fuel, medicinal plants, etc.) in non-forested lands (e.g., deserts, grasslands, wetlands, etc.).

    c. Explain how **driver X** in forested regions has influenced the sustainability of timber harvest regionally and globally.

    d. Explain how **driver x** influences sustainability of non-extractive practices that involve the use of wild species (e.g., observing such as bird watching) across different regions, and how that differs in developed countries *versus* developing countries?

A discussion on the Mediating Factors that operate across different scales and shape the influence of driver X will be included as relevant. Some of the questions that may be answered include:

- What are the exceptions to the major trends/patterns depicted? Why are there exceptions?

- What do these mediating factors tell us about solutions to unsustainable use (policy options, etc.)?
- What is some case studies that illustrate these issues?

The relevance and the significance of the drivers to the practices dictated the inclusion of these practices/ examples of use in the discussion. A literature review was conducted to gather evidence on the drivers and how each influence the sustainability of wild species use. A database of relevant sources, including peer-reviewed research papers, articles, book chapters and reports, has been compiled. The database was compiled mainly by conducting literature searches on international scientific databases and bibliographic search engines. Authors also worked on diversifying the sources of information they relied on to include grey literature, government reports, conference proceedings, diversified bibliographical resources including sources written in languages other than English, and searching for information by directly contacting experts and field workers (see data management report https://doi.org/10.5281/zenodo.6453228).

To achieve a balance between conventional scientific knowledge and local & traditional knowledge, the authors collected sources of indigenous and local knowledge. These sources included accessing information from reports of the indigenous and local knowledge-dialogue workshops along with the input from experts working directly with the indigenous peoples and local communities and some authors reached out directly to members of indigenous peoples and local communities. Sources collected covered the five practices (fishing, gathering, terrestrial animal harvesting, logging and non-extractive methods) and their drivers for in-depth analyses. Each of the main drivers has been disaggregated to the extent possible in each driver section. Analysis of the key drivers in producing sustainability outcomes of the use of wild species across the globe based on evidence from the data collected is still underway. Identification of the trends in these drivers at spatial and temporal scales will be provided.

4.2 THE DRIVERS OF SUSTAINABLE USE OF WILD SPECIES

The Chapter is based on the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services framework of nature's contribution to people. Further, it develops ideas within this framework that are relevant to understanding the drivers of the use of wild species. This chapter in particular assesses the status and trends of drivers of use of wild species that lead to sustainable or unsustainable outcomes. The most important factors that contribute to ecosystem degradation are technological advances and changing social dynamics and may be equated with the five major indirect drivers of ecosystem degradation identified by the Millennium Ecosystem Assessment, namely changes in population, economic activity (which increased nearly sevenfold between 1950 and 2000), socio-political factors, cultural factors, and technological changes. These factors do not directly degrade ecosystems but operate more diffusely by amplifying and promoting the direct drivers of ecosystem degradation.

4.2.1 Environmental drivers

4.2.1.1 Overview

This section discusses drivers directly linked with the so-called "natural" environment: climate change and hydrometeorological hazards, land and ecosystem degradation, invasive alien species, land and seascape change, pollution, and environmental hazards. Climate change and related hazards have adversely impacted biodiversity and terrestrial, marine, and freshwater ecosystems. Although there is little direct evidence to show how climate change has, and will, affect wild species use, climate change and associated hazards have already, and are expected to further affect, food production systems, energy systems, water availability, and human health (Hoegh-Guldberg *et al.*, 2018), which in turn impact how wild species are used. Land degradation, especially degradation of forests, rangelands, and croplands worldwide, has affected the capacity of nature to produce provisioning services and the availability and abundance of wild species. Conversion of grassland, savanna, and forests, mainly tropical forests, to agriculture, aquaculture, and urban development, has destroyed the primary habitats of species causing many species to be endangered. It also leads to the decline of commercially traded species. The expansion and intensification of agricultural and grazing lands have positive and negative impacts on the sustainable use of wild species. Intensification increases production capacity and reduces the dependence on wild resources while it also has costs—release of pollutants into the environment and increased greenhouse gases. In marine and freshwater ecosystems, many pollutants accumulate in organisms, and when humans consume food from polluted waters, they are exposed to pollutants (Sonne *et al.*, 2018). This has serious implications for people who consume large amounts of fish and seafood, such as indigenous peoples and local communities who consume the blubber of marine mammals (Donaldson *et al.*, 2012). Globally, urban areas are expanding at twice the rate of their population. Residential development is a leading driver of land-use change that has severe implications for biodiversity and wild species populations. Urbanization has negatively affected the abundance of species and caused even micro-evolutionary changes. Urbanization in coastal areas has adversely affected the diversity, life history, survival, reproduction and growth of many aquatic species. Likewise, dam building has substantially impacted riverine ecosystems, affected forests, and caused species losses.

On the other hand, there has been a growth in urban greenery, an increase in production and consumption of organic foods, and agroforestry practice worldwide. This positively impacts resource use, but the scale is very small compared to the degradation of natural habitats. Natural hazards, including geological or geophysical hazards that originate from internal earth processes (earthquakes, volcanic activities, landslides, tsunamis), and biological hazards, including zoonotic diseases, have had significant impacts on ecosystems and species and, by consequence, use of wild species. These hazard events arise from, or are exacerbated by, increased human interactions with their environment and prompt us to re-examine the relationship between people and wild species.

4.2.1.2 Climate change and hydrometeorological hazards

4.2.1.2.1 Overview

It is estimated that our planet has experienced human-induced warming of approximately 1° degree C since 1880 (Hoegh-Guldberg *et al.*, 2018), with widespread impacts on biodiversity, which are accelerating in marine, freshwater, and terrestrial ecosystems, as well as increased frequency and intensity of extreme weather events resulting in hydrometeorological hazards (IPBES, 2019a). Further, climate change is projected to become an increasingly significant direct driver of change in nature and human well-being. Although predictions vary depending on the scenario and geographic region, the adverse impacts of climate change on biodiversity will become more pronounced in the next decades and will worsen with global warming (IPBES, 2019a). Adverse impacts on biodiversity and ecosystem functioning are expected to profoundly alter habitat for wild species, as species ranges shrink, and thus significantly influence the risk of global extinctions (IPBES, 2019a). For example, according to the Intergovernmental Panel on Climate Change, with an average increase in temperature of 1.5°C above pre-industrial levels, 6% of insects, 8% of plants and 4% of vertebrates will lose over half of their climatically determined geographic range. These figures will increase to 18% of insects, 16% of plants and 8% of vertebrates for global warming of 2°C. Coastal ecosystems such as mangroves, tidal marshes and seagrass meadows are affected by the multiple impacts of ocean warming, including sea-level rise, with a particular impact on loss of biodiversity and ecosystem services (IPCC, 2019). Evidence for marine ecosystems indicates that the majority (70-90%) of tropical coral reefs will go extinct, even if global warming is constrained to a 1.5°C (Hoegh-Guldberg *et al.*, 2018), with dire consequences for the biodiversity (IPCC, 2019).

Increased frequency, intensity, and amounts of hydrometeorological hazards—such as heatwaves, heavy rainfall, drought, flooding, storms, and cold spells—are further expected at both 1.5°C and 2°C global warming, with risks projected to be lower at 1.5 °C compared to those at 2°C (Hoegh-Guldberg *et al.*, 2018). Storms and severe weather events can destroy or severely damage infrastructure and productive assets such as boats, landing sites, post-harvesting facilities and roads. This can lead to decreased harvesting capacity and access to markets, reducing the availability of food products and increasing their prices, resulting in higher incidences of malnutrition in communities, thus having severe consequences for food security, nutrition and health (Niiya, 1998). This, in turn would affect livelihood activities, including harvesting of wild species. Although hydrometeorological hazards differ from slow-onset climate change impacts on temporal scale, this section reviews climate change and associated risks together as a driver affecting the use of wild species.

Although climate change and associated hazards will be a significant driver of biodiversity and wild species loss, there is little direct evidence to show how this driver will affect wild species use. It is clear that climate change will impact not only different ecosystems and their biodiversity but also, food production systems, energy systems, water availability, and human health (Hoegh-Guldberg *et al.*, 2018), which will all affect the use of wild species. In terms of food systems, there is well-established evidence to support that climate change is likely to have negative impacts on agricultural productivity (Challinor *et al.*, 2007; Chavas *et al.*, 2009; Cline, 2007; Rötter & van de Geijn, 1999), though exactly how agricultural production will change has not been reliably quantified (Gornall *et al.*, 2010). Along with other drivers, the impacts of climate change and associated hazards will increasingly exacerbate negative implications for use of wild species.

4.2.1.2.2 Fishing

Climate change is a driver that will likely shape the future of fisheries globally (Lam *et al.*, 2016). Overfishing is seen as the biggest threat to the sustainable use of wild species in the earth's bodies of water (Auber *et al.* 2015; Frisk *et al.* 2018, Cisneros-Mata *et al.* 2019)—whether commercial or recreational—with scenarios and models predicting the increasingly significant threat of climate change to marine and freshwater ecosystems and their biodiversity (Cheung *et al.*, 2018; Olsen *et al.*, 2018; Reygondeau, 2019).

The evidence is well-established that climate change impacts waterbodies. Increasing temperatures, ocean acidification, sea-level rise, and changes in river flows have had impacts on the spawning period and stock size (Chandrapavan *et al.*, 2019; Kaeriyama *et al.*, 2014; Rogers & Dougherty, 2019; Tanimoto *et al.*, 2012), growth and metabolism rates (Catalán, 2019; Martino *et al.*, 2019; Shan *et al.*, 2011), biomass (Bentley *et al.*, 2017; Howell *et al.*, 2013), mortality (Bartolino *et al.*, 2014; Catalán, 2019; Hupfeld *et al.*, 2015; Huserbråten *et al.*, 2019; Ohlberger *et al.*, 2018; Rodgers *et al.*, 2018; Voss *et al.*, 2019), and diseases (Carraro *et al.*, 2018; Rowley *et al.*, 2014; Vivekanandan *et al.*, 2016; Yue *et al.*, 2018) of fish, from the Arctic to tropical areas, including coral reefs. These, in turn, alter fish abundance (Genner *et al.*, 2010; Hare *et al.*, 2010; Jacobson *et al.*, 2017), distribution (Dell *et al.*, 2015; Hare *et al.*, 2010; Healey, 2011; Reygondeau, 2019; H. Welch *et al.*, 2019; Woodworth-Jefcoats *et al.*, 2017), assemblages (Hoey *et al.*, 2016), and migration and movement patterns (McLean *et al.*, 2018; R. E. Scott *et al.*, 2019), and these impacts vary considerably within and between populations (Fernandes *et al.*, 2016; Genner *et al.*, 2010; A. R. Hughes *et al.*, 2019) as well as life stages (Dahlke *et al.*, 2020).

The evidence is also well-established that these changes affect how commercially important wild species are exploited through fishing (Howell *et al.*, 2013; Meynecke *et al.*, 2006; Pinsky & Fogarty, 2012) and as a result, the global seafood market and food security (Hobday *et al.*, 2016; Paukert *et al.*, 2017; Reygondeau, 2019). Hindcast models indicate that the maximum sustainable yield of marine fish populations decreased globally by 4.1% from 1930 to 2010, with some regions experiencing losses of 15 to 35% (Free *et al.*, 2019). Between 2000 and 2050, maximum catch potential is projected to decrease globally by 7.7%, with global fisheries revenue projected to decrease by 10.4%, under high carbon dioxide emission scenarios. Figures in the tropics are projected to decrease by 38% and 33%, respectively (Lam *et al.*, 2016). A study of fisheries in the northeastern United Sates over the past 40 years of warming temperatures shows a northward shift in fisheries, which corresponds to northward shifts in species distributions; further, the proportion of warm-water species caught increased (Pinsky & Fogarty, 2012). Studies predict that under warming temperatures, fisheries that target widely distributed species spanning large geographic areas and habitats would increase (Coleman *et al.*, 2019), as is already evident with the case of the Atlantic cod (Kjesbu *et al.*, 2010), while fisheries of species that reproduce rapidly may be more adaptable than fisheries focused on longer-lived species (Perry *et al.* 2010).

Evidence is well-established that climate change could further contribute to changes in the use of wild species through fishing, for example, through modification of fishing vessels to follow shifts in the spatial distribution of marine resources (Dell *et al.*, 2015), fleet types and fishing regulations (Cheung *et al.*, 2012). Climate and ocean currents in the early 20th century led to enhanced opportunities for fishing in West Greenland; this example demonstrates how climate change can provide opportunities and benefits in some regions (Thuesen, 1999). Similarly, increased interest in oil, gas, and fisheries in previously unreached places such as the Arctic due to decreasing ice cover (Harris *et al.* 2018; Lam *et al.* 2016) and the deep sea (see Glover and Smith 2003) could impact the use of wild species in these places.

The link between hydrometeorological hazards and the use of wild species through fishing is also well-established (Brander, 2007; Martino *et al.*, 2019). Extreme events can decrease safety at sea and increase the prevalence of injuries and mortalities (Birkmann, Fernando, N., 2008.; De Silva and Yamao 2007). Hazards non only damage gear, boats, and landing sites (Musinguzi *et al.*, 2016), but they can lead to changes in fish catch, size, and catch structure (Monteiro *et al.*, 2016; Musinguzi *et al.*, 2016; Santos *et al.*, 2016). A study in Australia found a substantial decline in fisheries after an extreme marine heat wave in 2011, leading to fishery closure the following year (Chandrapavan *et al.*, 2019), while a study in Denmark showed the rapid decline of eel fishery after a winter storm in the 19th Century (Poulsen *et al.*, 2007). Moreover, studies show how coastal communities in Vanuatu that suffered from a tropical storm and El-Nino-induced prolonged drought (Eriksson *et al.*, 2017) and lakeside communities in Tanzania whose economy changed as a result of drought (Kimirei *et al.*, 2008) increased their reliance on fishing for their livelihoods. In Antigua and Barbuda, 16% of the fishing fleet was destroyed or lost and 18% damaged due to Hurricane Luis in 1995, resulting in an estimated decrease of 24% in gross revenues (Mahon, 2002). During Hurricane Katrina in 2005, the businesses of about 95% of the 62 seafood dealers in Mississippi were destroyed or their infrastructure so severely damaged that commercial fisher folk were unable to sell their catch or buy fuel or ice from them (Buck, 2005).

4.2.1.2.3 Gathering

Evidence of the linkage between climate change and hydrometeorological hazards and the gathering of wild species is inconclusive. In conjunction with other factors such as land use change and overharvesting, climate change has led to, for example, changes in communities and geographical distribution of seaweed due to warming sea temperatures in Australia (Wernberg *et al.*, 2011) and in Japan (Kumagai *et al.*, 2018; Vergés *et al.*, 2014) and decrease in populations of medicinal plants (Hopping *et al.*, 2018) and thus, loss of associated indigenous knowledge (Hong *et al.*, 2015). These impacts can have severe consequences for people with long histories of interaction with their natural surroundings, such as indigenous peoples and local communities, mainly pastoralists, who have had to adapt their livelihood strategies. A study points to climate change and drought as reasons why pastoralists in Tanzania have had to start farming (Tibuhwa, 2012), while other studies point to conflict induced by climate change, especially droughts and floods, as the primary reason behind changes in livelihood activities of pastoralists in Kenya (Omolo, 2010).

4.2.1.2.4 Terrestrial and marine animal harvesting

The evidence that links climate change and trends in climatic conditions with population densities, growth, diseases, mortality and distribution of hunted wild species is well-established. Changes in, for example, population densities of hares (Schai-Braun *et al.*, 2019) quail phenology (Nadal *et al.*, 2018), breeding patterns of ducks, increased biomass of seals and belugas (Hoover *et al.*, 2013), mortality and distribution of walrus (MacCracken, 2012), imply a link between climate change and how wild species are hunted, but the evidence on this is incomplete. For example, studies in the Arctic region show a clear link between impacts of climate change, such as changes in weather, ice, and oceanographic conditions, with variation in the hunting season of walrus and whales (Metcalf & Robards, 2008) and melting sea ice for the increased catch of narwhals (Nielsen, 2009). The relationship between climate change, hunting, and conservation of polar bears has received more attention than other hunted wild species; the evidence is clear that the melting of the sea ice due to climate change threatens the habitat of polar bears.

In some cases, habitat changes affect bear distribution with increased incidence of human-bear conflict as polar bears move nearer to human settlements searching for food. Indigenous knowledge is clear that harvesting of bears is sustainable, however, scientific evidence is unresolved. Whether polar bears can be sustainably hunted (Regehr *et al.*, 2017; Stirling *et al.*, 2008, 2011; Tyrrell & Clark, 2014).

Evidence that hydrometeorological hazards have contributed to the use of wild species through hunting is scarce. A study conducted after a tropical cyclone in Tonga shows the relationship between tropical cyclones and increased mortality of fruit bats due to increased hunting and destruction of trees that bats feed from (McConkey *et al.*, 2004). What can be inferred from this study is another link between wild species use and hazards: that changes in the climate and the frequency and intensity of hydrometeorological hazards will have negative impacts on agriculture, aquaculture and other livelihood activities, which would then lead to communities increasing other activities to obtain food, most notably by hunting, fishing, and gathering wild species. But the evidence on this is inconclusive.

4.2.1.2.5 Logging

The evidence of the link between climate change and logging is established but incomplete. Although agricultural land encroachment and unsustainable forest management practices are the biggest threats to forests and their biodiversity, forests are impacted by changes in the climate and thus, how products are harvested from them. Models predict a decline in commercially important trees in the taiga (Bu *et al.*, 2008; Ma *et al.*, 2019; Steenberg *et al.*, 2013), while the opposite is predicted in warmer parts of the world (increased southern species in Northeastern China increase in some temperate and pioneer species in the Canadian Maritimes (Steenberg *et al.*, 2013); increased forest productivity in the Pacific Northwest (Creutzburg *et al.*, 2017); higher profits from forestry predicted in Lithuania (Mozgeris *et al.*, 2019), while estimates from models in other studies are more ambiguous (De Cauwer *et al.*, 2014; Halofsky *et al.*, 2014).

Natural disturbances have shaped the development of structure and function of forest ecosystems (Attiwill, 1994b)). The link between hydrometeorological hazards and logging is well-established. Wildfires, floods and droughts are hazards most likely to impact the sustainable use of wild species on both land and in water. There is sufficient evidence on how wildfires in particular define the supply of trees and non-timber forest products, thus impacting their use. Fire has been used as a forest management tool in many parts of the world to maintain, for example, a balance between vegetation in desert grasslands and stimulate herbs and seeds production (Bock & Block, 2005), impact tree distributions (Halofsky *et al.*, 2014) and species composition (Attiwill, 1994a) and rehabilitate forest diversity (Kelly, 2017; Vanha-Majamaa *et al.*, 2007). Regular fire regimes that are a natural part of the lifecycle of some forests have positive impacts on the use of wild species in forests. For example, they can increase essential oil content of lemongrass (Darabant *et al.*, 2016), maintain or increase abundance of morel mushrooms (Larson *et al.*, 2016), sustain large hardwood trees (Long *et al.*, 2018), contribute to the natural regeneration of forests rich in brazil nut (Porcher *et al.*, 2018), and support the regeneration of eucalyptus forests (Attiwill, 1994a; Burton *et al.*, 2019). However, evidence is well-established that altered or intensified disturbance regimes, most notably fire but also floods and droughts—which are expected to increase in intensity and frequency with climate change—will have negative impacts on forests and their products, and thus, how they are used. Frequent and severe wildfires will be devastating for particular vegetation types, causing land degradation, loss of habitats, deforestation, and the proliferation of alien invasive plant species. Frequent wildfires, especially during prolonged dry conditions, may disturb forest and savanna ecosystems (Kganyago & Shikwambana, 2019). Examples of negative impacts of changes in disturbance regimes on the use of wild species include a record-breaking flood in the Amazon that killed Brazil nut trees (Harraiz *et al.* 2017), while an extreme drought in the Amazon in 2010 decreased biomass and timber volumes (Vidal *et al.*, 2016). A model predicts that the increased frequency of fires in India's Western Ghats will decrease the recruitment of a traditional medicinal plant (Varghese *et al.*, 2015). These will impact how these forest products are used; a model for timber production in the Brazilian Amazon shows that fire losses can reach up to 183 United States Dollars +/- 30 ha/year in areas hit by recurrent fires that would be harvested between 2012 and 2041 (de Oliveira *et al.*, 2019), while another estimates the vulnerability of timber supply in Canadian forest management areas to increase in some regions (Gauthier *et al.*, 2015). Another model estimated timber supply could be reduced by up to 79% due to climate change and fire in the eastern Canadian boreal forest, using the most extreme projected climate scenario, (Dhital *et al.*, 2015).

On the other hand, there is established but incomplete evidence that climate change and hydrometeorological hazards have contributed to the sustainable use of forests and their products. Efforts to mitigate climate change have focused on forests in the global North through sustainable forest management, while in the global South, this has taken the form of Reducing Emissions from Deforestation and Forest Degradation (REDD/REDD+) projects. These have contributed to the sustainable use of wild species. Positive impacts of Reducing Emissions from Deforestation and Forest Degradation (REDD/REDD+) include minimizing human-wild species conflicts (Entenmann *et al.*, 2014), biodiversity conservation and livelihoods opportunities. However, there have been concerns raised about the rights and forest-access by indigenous peoples and local communities (see also Chapter 2 of this assessment). Further, in recognition of the important role forests can play to reduce impacts of hazards such as storms, floods, and landslides, as well as impacts of climate change in coastal areas such as sea-level rise and coastal erosion (Ghosh *et al.*, 2016; Hiwasaki *et al.*, 2015), efforts to preserve forests have been implemented, for example, the Natural Forest Conservation Project in China, which put in place measures to ban commercial logging in some forests (Zhu *et al.*, 2018).

4.2.1.2.6 Non-extractive uses

There is an increasing amount of work that explores the impacts that climate change and hydrometeorological hazards will have on tourism, especially nature-based tourism (Amelung *et al.*, 2007; Becken & Hay, 2007; Hall & Higham, 2005; Hamilton *et al.*, 2005; D. Scott *et al.*, 2012). The implications for the use of wild species from wild species tourism are established but incomplete, with emerging evidence of negative impacts of climate change on Wild species tourism among pastoralists in Africa (Barnes *et al.*, 2012; Bedelian & Ogutu, 2017).

4.2.1.2.7 Mediating factors

Climate change is a driver that is increasingly exacerbating the impact of other stressors on nature and human well-being (IPBES, 2019a). The difficulty of isolating the impacts of climate change on species with those of other stressors is well established in the literature. In the case of fishing, other stressors include overfishing, invasive species, habitat degradation and loss, pollution and eutrophication, and shipping (Cardinale *et al.*, 2008; Collingsworth *et al.*, 2017; Diop & Scheren, 2016; Halpern *et al.*, 2019; Jacobson *et al.*, 2017; McGreavy *et al.*, 2018; R. I. Perry *et al.*, 2010; Pratchett *et al.*, 2011; Ustin *et al.*, 2015). Studies in the Atlantic (Mullon *et al.*, 2016) and in California (Aguilera *et al.*, 2015) predict that governance, trade and market decisions will have a bigger impact on sustainable use of marine species than climate change. Another scenario predicts that the sustainable use of small pelagic fish depends more on how people respond to climate change rather than the climate change itself (Le Bris *et al.*, 2018; Merino *et al.*, 2010; Niiranen *et al.*, 2013). What emerges from the existing literature is that climate change will interact with other environmental, socio-cultural, political, and economic drivers to negatively impact the marine, freshwater, and forest ecosystems, which in turn affect how humans use wild species. Climate change needs to be considered together with other multiple and interacting drivers of sustainable use, with possibilities resulting in "non-linear abrupt change" (S. H. Schneider, 2004), so-called "tipping points."

The negative impacts of climate change and hydrometeorological hazards on the sustainable use of wild species will have more severe implications for countries in the global South. Increased intensity and frequency of extreme climate and weather events from global warming will disproportionately affect vulnerable and poor people, especially in Africa and Asia (Hoegh-Guldberg *et al.*, 2018). In particular, Small Island Development States are expected to be particularly at risk from impacts of multiple hazards, which can compound the effects each other. Small Island Development States and populations in the global South have limited capacities to adapt, thus making the impacts from climate change and related hazards more serious (Hoegh-Guldberg *et al.*, 2018). This will have severe implications for the case for fishing, for which there are not many studies being done, and thus insufficient data, for countries in the global South (Comte & Pendleton, 2018). Many fisheries-dependent tropical regions are more at risk of climate change impacts (Cheung *et al.*, 2018; Lam *et al.*, 2016; Perry *et al.*, 2010; Reygondeau, 2019) and have experienced significant declines in fish stocks since the 1990s (Golden *et al.*, 2016), with the most significant projected decrease in catch potential and revenue decrease in the world (Lam *et al.*, 2016). Thus, food security is expected to be an issue in countries in the global South due to the impacts of climate change on fisheries (Ficke *et al.*, 2007; White *et al.*, 2018). Similarly, it is well-established that communities that rely on fishing for their livelihoods would suffer more from the impacts of climate change, such as smaller fishing communities (Frusher *et al.*, 2016; Tull *et al.*, 2016) and traditional fisheries (Vivekanandan *et al.*, 2016). This is also the case for low-income food-deficit countries, which heavily depend on fisheries for their national (Lam *et al.*, 2016). The increasing vulnerability of coastal fishing communities, especially in the South global point to a need for adaptation planning to mitigate the impacts of climate change and related hazards on unsustainable use of wild species. Multi-level coordination across stakeholders on conserving fisheries and associated species and ecosystems would need to include interventions on land as well as in the ocean and freshwater water bodies, using, for example, ecosystem-based approaches (IPBES, 2019a).

Furthermore, it is necessary to consider how climate change impacts indigenous peoples, who usually live in areas that are more exposed to impacts of climate change and associated hazards, and thus, are experiencing profound, negative effects on their cultures, health, well-being, livelihoods, rights and ultimately, their survival (Galloway McLean *et al.*, 2009). While the well-established evidence of indigenous communities using their traditional ecological knowledge to adapt how they harvest wild species as the climate changes (Berkes & Jolly, 2002; Berman & Kofinas, 2004; Sabo, 1991) or how they could adapt (Gautam *et al.*, 2013), impacts of climate change—along with other endogenous and exogenous factors—on how wild species can be used will have serious repercussions, especially for indigenous peoples and local communities who rely on these species for their nutritional needs, as well as for social and economic well-being, health, and cultural survival (Nuttall, 2005). Further, there is established but incomplete evidence that indigenous and local knowledge can play a role in mitigating the negative impacts of unsustainable use of wild species exacerbated by climate change (Schmitt *et al.*, 2013), thus underlining the importance of co-management of areas with local communities and integrating local and indigenous knowledge to develop strategies to build resilience.

4.2.1.3 Land/ecosystem degradation

According to the IPBES assessment, "Land degradation" is defined as the human-caused processes that drive the decline or loss in biodiversity, ecosystem functions or ecosystem services in any terrestrial and associated aquatic ecosystems (IPBES, 2018b). Specifically, land degradation is the reduction or loss of biological or economic productivity and complexity (including soil erosion, deterioration in physical, chemical, biological or economic properties of soils and long-term loss of vegetation) of cropland, rangeland, pastureland, forest and woodlands in arid, semi-arid and dry sub-humid areas, that results from land uses or from a combination of processes, including those arising from human activities and habitation patterns (IPBES, 2018b). Land degradation is occurring in all land cover, land use and landscape types in all countries.

Although a national-level framework for assessing and reversing ecosystem degradation to support the national implementation of Aichi Biodiversity Target 15 and European Union Biodiversity Strategy Target 2 is available (Kotiaho *et al.*, 2016), unfortunately, assessing ecosystem degradation and recovery at the global scale is not feasible (IPBES, 2018b). To assess anthropogenic ecosystem degradation, the reference condition of the pre-degradation state, also known as its natural state, is necessary. Still, it is a challenge to determine the natural state for an ecosystem because humans have been influencing the system for such a long time.

Multiple drivers including land use change, agricultural intensification, pollution, and invasive alien species drive land degradation (IPBES, 2018b). For instance, the damage cost of environmental degradation in the Middle East and North Africa is estimated at 9 billion United States Dollars per year, with a mean estimate of 5.7% of gross domestic product (Hussein, 2008). Land degradation in Syria due to high soil salinity resulted in a 37% decline in cotton and wheat yields (the main irrigated crops), representing the total annual loss in agricultural productivity at around 80 million United States Dollars. The wild meat hunting for food and medicinal products is driving a global crisis whereby 301 terrestrial mammal species are threatened with extinction, exacerbated by threats such as deforestation, agricultural expansion, human encroachment and competition with livestock Fields (Ripple, Chapron, *et al.*, 2016). Degradation of habitat negatively impacts the faunal community as a whole in Southeast Asia (Tilker *et al.*, 2019), resulting in decreased community hunting practices. Further, spatially explicit models at the global scale revealed that 121–219 species in Borneo, the central Amazon and the Congo Basin will become threatened under current rates of forest loss over the following 30 years (Betts *et al.*, 2017). In marine systems, coral habitat degradation due to anthropogenic pressures can have varying effects on reef fisheries.
For instance, habitat degradation and plastic pollution

compounds the impact of fishing on coral reefs as increased fishing reduces large-bodied target species, while habitat loss results in fewer small-bodied juveniles and prey that replenish stocks and provide dietary resources for predatory target species (Wilson *et al.*, 2010).

Drylands worldwide are undergoing rapid land degradation and shifts in vegetation composition in response to climate change and anthropogenic disturbances. Accelerated hydrological–aeolian erosion processes and rapid vegetation shifts are important drivers of land degradation. Soil erosion is a major concern for the environment and natural resources leading to the reduction in field productivity and soil quality, resulting in land degradation. The erosion reduces biomass and productivity by diminishing soil organic matter and quality, which ultimately influences the diversity of plants, animals, and microbes in an entire ecosystem. It is estimated that each year about 10 million ha of cropland worldwide is lost due to soil erosion, thus reducing the cropland available for food production (Pimentel, 2006). However, the rate of erosion differs across the continents. For example, soil erosion has little impact on crop productivity in Europe (Bakker *et al.*, 2007), while losses associated with erosion are highest in agroecosystems of Asia, Africa, and South America (30-40 tons per hectare every year; Taddese, 2001).

4.2.1.4 Invasive alien species

Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem and which may cause economic or environmental harm or adversely affect human health (https://www.cbd.int/idb/2009/about/what/). They can impact on the sustainable use of wild species, both positively and negatively, by altering the abundance of the wild species, by providing a substitute to the species that have historically been used by indigenous peoples and local communities, and by impacting alternative resources such as when crops or livestock are negatively affected by invasive species.

Invasive alien species are key drivers of human-caused global environmental change (Vitousek *et al.*, 1997). The number of invasive alien species belonging to the different taxonomic groups except for microorganisms and many invertebrates is relatively well known. Almost 4% of the global plants (~14000 plant species) have become naturalized in ecosystems other than their native ones (Pyšek *et al.*, 2020; Van Kleunen *et al.*, 2015). Of the 1,517 recorded invasive alien species, 39% were introduced intentionally and 26% unintentionally, 22% both intentionally and unintentionally, while 13% had no information available (Turbelin *et al.*, 2017). About 0.5% and 0.7% of the world's tree and shrub species (622 species) are currently invasive outside their natural range. Still, woody plant invasions are rapidly increasing worldwide (Richardson & Rejmánek, 2011). Alien insect species outnumber attacks of all other animal taxa; North America alone has 3,200 species of non-native insects (Liebhold *et al.*, 2018; Pyšek *et al.*, 2020). At least 175 species of gastropods have become established across 56 countries (Capinha *et al.*, 2015), and 745 alien species of freshwater fish species have led to established alien populations (Tedesco *et al.*, 2017). At least 78 species of alien amphibians and 198 species of alien reptiles were established outside their native range (Capinha *et al.*, 2017). Likewise, 3,661 alien bird introduction records were reported, of which 37% of these species have become established (Dyer *et al.*, 2017). The cumulative number of alien species richness across six taxonomic groups is given in **Figure 4.2**.

A wide range of invasive alien species either introduced deliberately (fish farming, pet trade, horticulture, forestry, agriculture, biocontrol) or unintentionally (transportation, travel and scientific research) through human transport and commerce has caused a loss in the global economy, human health, agriculture and overall wellbeing of humans. There are six broad introduction mechanisms of alien species: a) deliberate release (e.g., game animals, sport fishes, pets); b) escape from captivity (e.g., ornamental garden plants, pets); c) contaminants of commodities (e.g., weed seeds, pest insects, microbial pathogens); d) stowaways on transport vectors (e.g., marine organisms fouling ship hulls or in ballast water, latent endophytic pathogens in plants); e) via anthropogenic corridors (such as through the Suez and Panama Canals); or f) unaided spread from other invaded regions (Hulme, 2009). Species escape from Horticulture, forestry and agroforestry and the nursery are the dominant pathway for species invasions accounting for 31% of the species introduced outside their natural geographical range (Turbelin *et al.*, 2017). The recent growth in the trade of exotic pets is another growing threat to species biological invasion (Lockwood *et al.*, 2019). Some of these pet species cause zoonotic diseases, particularly those pets sourced from the wild (Day, 2011).

Invasive species generally have higher performance-related traits characterizing physiology, leaf-area allocation, shoot allocation, growth rate, size, and fitness than non-invasive plant species. These traits promote invasiveness under many different circumstances (Van Kleunen *et al.*, 2010). Invasive species also have greater plasticity in their response to greater resource availability than non-invasive, but this plasticity is only sometimes associated with a fitness benefit (Davidson *et al.*, 2011). Individual plants and animals are also less frequently infected (prevalence minus percent of individuals infected) in introduced compared to native conspecific populations; and introduced animals and plants may escape 75% or more of the parasite and pathogen species from their native range (Torchin & Mitchell, 2004).

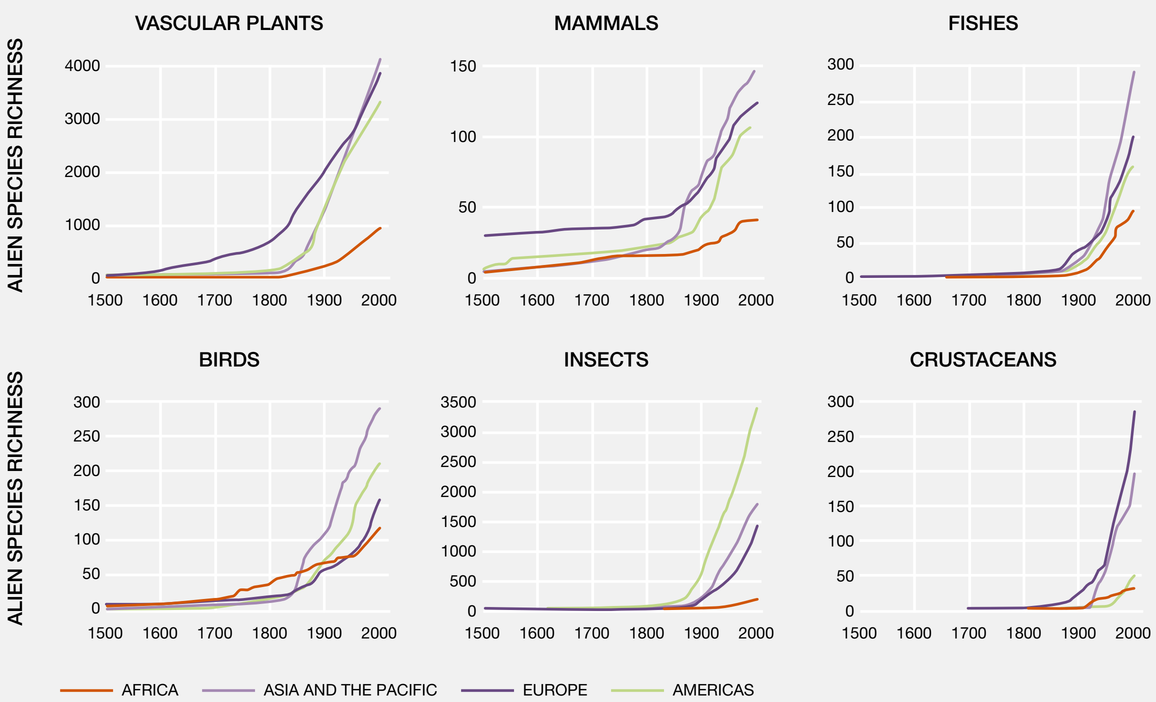


Figure 4 2 **Trends in established alien species across six taxonomic groups in four world regions.**

Source: Pyšek *et al.* (2020) under license CC BY-4.0.

Invasive species may not have equal impacts on the sustainable use of wild species across all environments. Substantial variation in the spatial patterns of invasion was observed; small tropical islands and coastal mainland regions are the main recipients of invasive alien species and hotspots of established alien species richness across multiple taxonomic groups (Dawson *et al.*, 2017; Turbelin *et al.*, 2017). However, the impacts of invasions on nature's contributions to people, ecosystem services and human wellbeing are high in developing countries as those countries have limited options for preventing and managing invasive species (Pyšek *et al.*, 2020). Regions within newly industrialized countries in the Global North, with high population densities and large surface areas support the most established alien species (Pyšek *et al.*, 2020). In the world's islands, where valued species have often evolved without strong competition, herbivory, parasitism or predation, biological invasions cause a loss of biodiversity (Courchamp *et al.*, 2003). Island endemics have limited experience with mammalian predators or herbivores and nowhere to escape (Pyšek *et al.*, 2017). On islands, biological invasion is considered the second greatest agent of species endangerment and extinction after habitat destruction (Pejchar & Mooney, 2009; Wilcove *et al.*, 1998). For example, about half New Zealand's flora comprises alien plants (Hulme, 2020). In freshwater ecosystems, the invasion rates are likely to continue to be high (Strayer, 2010). Marine non-indigenous fishes have increased alarmingly within a short period, causing structural changes and the decline of native species (Arndt *et al.*, 2018). Invasive species also disrupt trophic cascades causing the mismatch of evolutionarily based strategies among predators and prey (Kimbro *et al.*, 2009).

Invasive alien species have devastating impacts on biodiversity and ecosystem health, causing declines or even extinctions of native species and impairment of nature's contributions to people worldwide (Pejchar & Mooney, 2009; Traveset & Richardson, 2006). An alien invasion is regarded as one of the major drivers of biotic homogenization (Colléony & Shwartz, 2020) and wild species extinction (Bellard *et al.*, 2016) mainly through the introduction of novel traits, genes and behaviors by new alien species (McGeoch & Jetz, 2019). Bellard *et al.* (2016) reported that 1372 vertebrates are threatened by more than 200 invasive alien species, mainly in the Americas, India, Indonesia, Australia and New Zealand. Invasive species proliferation in primate habitats cause habitat loss and population declines, and extirpation of primate species, in addition to hunting for meat and culturally valued body parts (Estrada *et al.*, 2018). Based on a recent analysis of data on global extinction in the International Union for Conservation of Nature Red List database (IUCN, 2017), invasive alien species contributed to the extinction of 261 (39%) out of 782 species of terrestrial and freshwater animal and 39 (25%) species of total 153 plant species worldwide (Blackburn *et al.*, 2019). Invasive species negatively affect native species richness, abundance, fitness, and productivity (Cameron *et al.*, 2016; Pyšek *et al.*, 2012) and hinder ecosystem functioning such as regime shifts (Gaertner *et al.*, 2014) and provision of ecosystem services (Castro-Díez *et al.*, 2019). Other notable impacts of invasive alien species are eutrophication, expansion of natural fire regime, increased soil erosion, hydrological control, and alteration of soil stability (Rai & Singh, 2020).

The impacts of invasive alien species on local livelihoods are negative and positive. Some of the negative impacts of invasive alien species on local livelihoods include a decreased supply of natural resources, particularly non-timber forest products, due to the loss of biodiversity and change in abundance of species, reduced agricultural production (livestock and crops and fisheries), harm to human health and safety, and reduce the cultural value of landscapes resulting in reduced resilience and adaptive capacity of households and communities along with loss of incomes (financial capital) and increased labor times (Shackleton *et al.*, 2019). For example, people abandoned farming (Zavaleta 2000) or fishing (Cho & Tifuh, 2012; J. Travis, 1993) and emigrated from their areas due to the adverse effects of invasive species. A global analysis of the threat to crop production by almost 1300 known invasive insect pests and pathogens on a country-by-country basis for 124 countries revealed significant variations in countries regarding the potential threat from invasive species (Paini *et al.*, 2016). Introduced species have positive impacts on the economy and livelihoods. For example, introduced species act as hosts, food sources, pollinators and seed dispersers for native species and provide herbivory predatory or parasite release (Goodenough, 2010). Invasive species provide the provision of fuelwood, fodder, food products, timber and medicinal products, as well as other livelihood benefits such as soil improvement through green manure and nitrogen fixation, live fencing, and cultural services, such as recreation and aesthetic values. (Shackleton *et al.*, 2019)

Introduced species may also positively impact ecosystems, agriculture and food security. For example, an invasive tree in Florida *(Melaleuca quinquenervia)* has increased honey production that is worth 15 million United States Dollars per year (Serbesoff-King, 2003). The introduction of brush-tailed possums *(Trichosurus vulpecula)* to New Zealand was considered profitable for the 'eco-friendly' industry (at least 20 million United States Dollars per year), although it has resulted in massive defoliation and negative impacts on the biodiversity (Clout & Barlow, 1982; Forsyth *et al.*, 2018). Indigenous Māori people of New Zealand also use fur and skins of brush-tailed possums for economic benefit. Still, the most economically-sustainable possum fur harvest strategy is unlikely to achieve even modest conservation outcomes (C. Jones *et al.*, 2012) and a program to eradicate possum has started (Owens, 2017). Locals in Nepal used several species of invasive alien plants to produce compost, charcoal, bio-briquette, and forage for livestock and medicinal purposes (Shrestha *et al.*, 2019). Overall, positive impacts of invasive alien species include provisioning services (fuelwood, fodder, timber and food products) and regulating services (soil improvement and shade). Cultural services (recreation and spiritual values) (Shackleton *et al.*, 2019) For example, there are examples of small initiatives to make use of an invasive like *Lantana camara* as a substitute for rattan in making furniture in Male Mahadeshwara Hills, Karnataka (Kannan *et al.*, 2016). However, the number of species causing negative impacts is double (37%) the number of beneficial species (16%) (Shackleton *et al.*, 2019).

Some invasive species (e.g., green crab in Canada, Chinese mitten crab in China) have become a source of meat, common food and an omega-6 fatty acid. They can enhance the fishing industry's value chain and improve profitability while addressing waste management issues and environmental sustainability (Dave & Routray, 2018). Many other species, such as wild pigs *(Sus scrofa)*, are considered the desired species for hunting (Engeman *et al.*, 2013). Hunting invasive or introduced mammals, pigs, and monkeys may benefit native fauna and flora (Carvalho *et al.*, 2015). In the ranches of Mexico, exotic species were introduced to provide year-round hunting opportunities for tourists (Barthel & Schuett, 2014).

Biological invasions and wild species disease are inextricably linked. Biological invasions can spread new diseases to wild species and humans. Biological invasions lead to novel parasite-host interactions and transmission opportunities, potentially affecting humans, wild species, ecosystem health and resilience (Pyšek & Richardson, 2010). Several potential zoonoses have originated from biological invasions in Europe and potentially elsewhere (Hulme, 2014). Zoonotic pathogens and parasites transmitted from animals to humans are a significant public health risk, and three-quarters of emerging human pathogens are zoonotic (White & Razgour, 2020). Invasive species directly affect human health; several species of invasive alien plants cause allergies, phytotoxicity, disease, eczematous dermatitis and asthma in humans (Rai & Singh, 2020). On the other hand, invasive species act as a vector for transmitting several diseases. Several human diseases and their sudden outbreak across continents are linked to biological invasions (Pyšek & Richardson, 2010; Rai & Singh, 2020). For example, an invasive mosquito called the Asian tiger mosquito *(Aedes albopictus)*, spread through the transportation of eggs via the international trade of used tiger, is a vector for transmission of many viruses, including dengue, LaCrosse, Yellow fever, chikungunya and

West Nile (Benedict *et al.*, 2007). Some invasive species affect human health through environmental contamination, such as air pollutants (Jones *et al.*, 2018). Invasive species also cause disease to native animal species. For example, the worldwide amphibian decline is driven by the emerging infectious diseases chytridiomycosis caused by *Batrachochtrium dendrobatidis*, an invasive fungus (Crawford *et al.*, 2010). Invasive species also increase the outbreak of fungal pathogens, which adversely affect the health of native plants (Beckstead *et al.*, 2010). For example, the amphibian pet trade is linked with the global spread of chytrid fungus *(Batrachochyrtium dendrobatidis)*, which has led to a significant decline of amphibians (Alroy, 2015; Auliya, Altherr, *et al.*, 2016; Thumsová *et al.*, 2021). However, a few positive health impacts of invasive species are reported. For instance, extracts from *Lantana camara* are used as a mosquito repellent (Mng'ong'o *et al.*, 2011). Additionally, ethnobotanical surveys on invasive alien plant species can provide benefits (e.g., *Lantana camara, Opuntia ficus-indica and Ricinus communis*) (Rahmatullah *et al.*, 2010). Hunting and biological invasion are interconnected with each other. Removing invasive species affects hunting practices.

Hunting has been a significant pathway for introducing invasive species into Europe in the last century. About 24.3% of the mammals (36 species) and 30.2% of the birds (63 species) introduced into Europe in the previous century were released primarily for hunting purposes (Carpio *et al.*, 2017). Likewise, around 30% of species of invasive introduced mammals in southern South America were introduced for hunting (Ballari *et al.*, 2016). However, introduced game species have various negative impacts on the local ecosystems, such as predation (Barrios-Garcia & Ballari, 2012), competition with native wild species (Bartos *et al.*, 2002; Bertolino & Lurz, 2013; Kumschick *et al.*, 2011), diseases and their related consequences (Králová-Hromadová *et al.*, 2011), hybridization (Baker *et al.*, 2014; Barbanera *et al.*, 2010), and habitat alteration (Kumschick *et al.*, 2011). In some places of the world, vehicle-mounted and aerial or ground-based hunting has been used to cull or reduce populations of invasive animals (Barron, 2011; Bengsen & Sparkes, 2016; Capizzi, 2020; McLeod & Saunders, 2011). In some cases, the ground-based culling efforts have controlled overabundant mammal population and bird populations, such as the white-headed duck in UK and France (Henderson, 2009). In New Zealand, hunting is a primary strategy to control introduced wild deer (Latham *et al.*, 2018).

Globally, the introduction and spread of marine non-indigenous fish species are facilitated by several anthropogenic factors such as building canals, shipping, intentionally introduced for fishery purposes, and aquarium trade (Arndt *et al.*, 2018). In a freshwater environment, the introduction of non-native freshwater fishes for economic purposes, including aquaculture and aquarium trade, as well as improvement for wild stocks (Wei *et al.*, 2019). About 23.6% of the freshwater fish introduced into Europe during the last century were released primarily for angling purposes. This suggests that angling was a significant pathway for introducing invasive fish species into Europe (Carpio *et al.*, 2019). In some islands like Puerto Rico, around 80% (46 species) of fish in the inland waters are non-native and are imported for sport fishing and pet trade (Rodríguez-Barreras *et al.*, 2020).

Introducing non-native freshwater fishes has adverse environmental and socio-economic effects (Wei *et al.*, 2019). Invasive aquatic species eliminate native amphipod species in freshwater habitats in Europe and North America (Dick & Platvoet, 2000). The spread of invasive species also introduces novel pathogens to new areas (Bacela-Spychalska *et al.*, 2013). Alien invasive species are the second most prevalent threat after habitat loss and degradation for freshwater fisheries in Canada, affecting 26 of 41 listed fish species and 6 of 11 listed mollusc species (Dextrase & Mandrak, 2006). In some regions, the harvest of invasive species provides economic benefits (Pienkowski *et al.*, 2015), while in other areas, invasive species are a problem (e.g., commercial fishing in the United States of America) (Dudgeon *et al.*, 2006). Despite the beneficial effects of angling by introduced fish, making angling sustainable, it hurts native fish species (Carpio *et al.*, 2019). *Micropterus salmoides*, typically introduced for sport fishing purposes worldwide, is now listed by the International Union for Conservation of Nature as one of the 100 of the world's worst invasive alien species (Pereira *et al.*, 2010). This species causes negative impacts on the local population, such as local extirpation of native species and food web changes (Pereira *et al.*, 2010).

Invasive species in the marine environment may cause an alteration of benthic habitat structure, leading to the disruption of food webs, changes in nutrient cycles and energy transfer, or changes in the community structure, population decline and local replacement of native species through competition and predation and transmission of disease and potential hosts of parasites to native fishes (Arndt *et al.*, 2018). Negative impacts of invasive species in aquatic ecosystems range from an abundance of marine communities, particularly macrophytes, zooplankton and fish (Gallardo *et al.*, 2016).

Aquaculture also has negative impacts such as elevated input of nutrients and organic matter in habitat and water quality, the spread of diseases, biotic homogenization, loss of population viability resulting from hybridization and outbreeding depression, and the local extirpation of native species (Lima *et al.*, 2018) and the conversion of natural infrastructure such as coastal wetlands into (fish, shrimp, etc.) farm (Hoanh *et al.*, 2006). Additionally, an increase in water turbidity, nitrogen and organic matter concentration due to invasive species is consistent across the habitats and scales. However, there is little evidence of a decline in species diversity in invaded habitats (Gallardo *et al.*, 2016). Salmon farming in Chile has faced several challenges such as sanitary crisis, social conflicts, market problems, lack of good governance (Chavez *et al.* 2019) along with ecological and environmental issues including eutrophication, adverse effect of pesticides on non-target species (Gerhart, 2017; Quiñones *et al.*, 2019) and disease outbreak (Mardones *et al.*, 2018). The knowledge of the ecological impact of invasive marine fishes is still rudimentary globally despite the extensive literature on identifying new records, geographic spread, and pathways (Arndt *et al.*, 2018). This might be why biological invasions are being widely disregarded when planning for conservation in the marine environment across local to global scales (Giakoumi *et al.*, 2016).

4.2.1.5 Land and seascape change

This section will provide an overview of significant changes in landscape/seascape. It will start with a summary of where (urban, forest, agricultural and rangelands) changes have been occurring and how these have affected biodiversity and sustainable use of wild species.

4.2.1.5.1 Change in urban areas and impacts on biodiversity and sustainable use

Although urban areas cover less than 3% of the earth's surface, urbanization is a significant driver of global environmental change such as climate change, pollution, alteration of both abiotic and biotic ecosystem properties within, surrounding, and even at a great distance from urban areas (Grimm *et al.*, 2008). Globally, the urban areas are expanding at twice the rate of their population (Seto *et al.*, 2012). The urban population has increased from ~200 million in 1900 to about 4 billion in 2014 and is expected to reach 5 billion in 2030 (United Nations, 2014). Currently, more than two-thirds (75%) of the population of high-income countries live in urban areas. Still, the rapid growth of the urban population is observed in the low-income and lower-middle-income countries (IPBES, 2019a).

Residential development is a leading driver of land use change, with important implications for biodiversity, ecosystem processes, and human well-being (Pejchar *et al.*, 2015). Urban land expansion modifies habitats causing biodiversity loss, alters biomass, natural processes, biogeochemistry, hydrology, land cover and surface energy balance, carbon storage, and causes climate change and pollution (d'Amour *et al.*, 2017; Seto *et al.*, 2012). Light pollution in urban areas also has behavioral and ecological effects on wildlife (Schirmer *et al.*, 2019). Urbanization affects primary production in terrestrial and aquatic ecosystems by replacing and fragmenting natural areas with impervious cover, increasing nutrient supply, changing hydrological regimes, and altering the composition (decreasing the abundance of apex predators) and seasonality of primary producers (El-Sabaawi, 2018). Urbanization has both lethal (e.g., vehicle collisions and bird strikes) and sub-lethal effects (physiological and behavioral changes) on animals (Birnie-Gauvin *et al.*, 2016). Increasing urban sprawl has contributed to the extensive fragmentation and reduction of natural habitats worldwide (Gelmi-Candusso & Hämäläinen, 2019). Urbanization has various adverse effects on ecosystem functioning, including the disruption of plant dispersal processes that animals mediate across the landscape (Gelmi-Candusso & Hämäläinen, 2019). The density and extent of housing are strong predictors of the decline of native species of birds (Lepczyk *et al.*, 2008). Likewise, urbanization is cited as a potential contributor to amphibian population declines (Riley *et al.*, 2005; Scheffers *et al.*, 2012). Urbanization influences species traits and micro-evolutionary changes in many species of mammals, birds, fishes, and insects (Alberti *et al.*, 2017). In response to urbanization, some plant traits (e.g., woodiness, seed mass, and height) tended to increase (Williams, Hahs, and Vesk 2015).

Urban sprawl is expanding into marine environments with the construction of artificial structures. In Europe, the United States, Australia, and Asia, more than 50% of the shoreline is now modified by hard engineering, including groins and breakwaters, to protect against erosion and wave action (Dafforn *et al.*, 2015). Urbanization, mainly coastal urbanization, increased pressure on the surf zones of ocean beaches that provide habitat for a diversity of fishes and are prime sites for recreational angling and commercial net fisheries (Olds *et al.*, 2018). Coastal development, including buildings construction, also poses risks to marine turtles coming to beaches to lay eggs (e.g., Rushikulia and Gaharmatha in Odisha/Orissa where Olive Ridleys lay eggs). In an aquatic ecosystem, urban point sources of nutrients are the leading cause of hypoxia (decline in oxygen supply), resulting in adverse impacts on species' physiology, life history, survival, reproduction, growth of aquatic invertebrates (Galic *et al.*, 2018; Jenny *et al.*, 2016).

In recent years, sustainable urbanization, the concept of nature-based solutions and urban nature have been increasing as urban landscapes constitute the future environment for most of the world's human population. Urban forests are dynamic systems of trees, shrubs, green space, soil, and water, which provide many functions, services and benefits needed for the sustainable development of urban areas (Solomou *et al.*, 2019). Urban nature has the potential to improve air and water quality, mitigate flooding, enhance physical and mental health and promote social and cultural well-being (Keeler *et al.*, 2019). Urban greenery plays a significant role in reducing energy use for both heating and cooling (Ko, 2018). Urban green and blue spaces promote health by offering areas for physical activity, stress relief and social interaction (Kabisch *et al.*, 2017). Green roofs in urban areas also deliver selected nature's contributions to people, such as the removal of pollution and reduced annual energy consumption (Francis & Jensen, 2017). Urban trees and grassland also provide habitats for different species of animals, including birds, bees, butterflies and hoverflies (Dylewski *et al.*, 2019; Y. Han *et al.*, 2019).

Overall, urban trees provide nature's contributions to people, including carbon sequestration, air quality improvement, storm water attenuation, food production, microclimate control, soil infiltration, visual quality, recreation, social capital, and energy conservation (Kabisch *et al.*, 2017; Lovell & Taylor, 2013; Roy *et al.*, 2012). However, little is known about how these trends affect the sustainable use of wild species.

More recently, rooftop gardens have become an essential part of urban agriculture. Urban rooftop agriculture can improve various nature's contributions to people, enrich urban biodiversity and reduce food insecurity (Walters & Stoelzle Midden, 2018). Urban and peri-urban agriculture contribute to 10 key societal challenges of urbanization: climate change, food security, biodiversity and nature's contributions to people ecosystem services, agricultural intensification, resource efficiency, urban renewal and regeneration, land management, public health, social cohesion, and economic growth (Artmann & Sartison, 2018). Urban agriculture impacts food security, nutrition, physical and mental health, and social capital (Audate *et al.*, 2019).

Although urban development in developing counties is seemingly chaotic with high levels of poverty, there are opportunities to realize urban green infrastructure in those areas (Lindley *et al.*, 2018).

Urban development (population growth, in-migration) also leads to decongestion and depopulation of rural areas that may have a beneficial impact on biodiversity, ecosystem services and populations of certain wild species in the rural areas. In and around urban areas, human-wild species conflict is responsible for billions of dollars of damage and costs associated with mitigation and prevention (Conover, 2001). Urban environments are a notorious source of mortality of Wild species, including roads, collisions with buildings, depredation and disease (Forman & Alexander, 1998; Loss *et al.*, 2014; Nyhus, 2016).

4.2.1.5.2 Infrastructure development (dams and roads construction)

Humans have been modifying rivers for thousands of years for flood regulation, water supply, transportation, irrigation and, more recently, for settlements and industries, recreation, and hydropower generation (Ripl, 2003). Globally the number of dam constructions has increased dramatically over the past six decades to meet the energy demands and flood control. Dams have altered flows (fragmentation, flow regulation or both) of 48% of the rivers at various degrees worldwide (Grill *et al.*, 2015). Only 37% of rivers over 1,000 kilometers remain free-flowing over their entire length, and 23% flow uninterrupted to the ocean (Grill *et al.*, 2019). Currently, about 50,000 large dams (higher than 15 m) and an estimated 16.7 million reservoirs (larger than 0.01 ha) hold approximately 8,070 km^3 of water (Lehner *et al.*, 2011). Dam building substantially impacts riverine ecosystems and freshwater biodiversity, causing population loss (Dynesius & Nilsson, 1994). Dams have substantially modified ecosystems causing extirpation of fish migration (Liu *et al.*, 2019), loss of native fish species, increases in non-native fish (Loures & Pompeu, 2019) and decreases in the diversity of benthic macroinvertebrate (Linares *et al.*, 2019). The Himalayan region particularly in China and India, has approximately 55% of the world's larger dams and is considered as the region with the highest dam density in the world (Grumbine & Pandit, 2013; Pandit & Grumbine, 2012; WCD., 2000). The proposed dam locations in the Indian Himalayas are in areas of high species richness for angiosperms, birds, fishes, and butterflies (Grumbine & Pandit, 2013). Models showed that dam building could lead to the loss of 22 angiosperm and seven vertebrate taxa by 2025 due to the submergence and habitat degradation (Pandit & Grumbine, 2012). Dam construction alters the survival, phenology and growth of floodplain vegetation and reduces field yields below the dams (Forsberg *et al.*, 2017). The reported effects of dams on fish and other aquatic mammals include blocking migration routes, habitat fragmentation and, changing from lotic to lentic water in the impounded areas, changes of water flow in downstream reaches (Wu *et al.*, 2019). Although reservoir fish yields will compensate for some downstream losses, an increase in mercury contamination due to dams could offset the benefits (Forsberg *et al.*, 2017).

Roads are the seeds of tropical forest destruction (Laurance, 2012). Rapid road constructions in the tropics affect many species, particularly those susceptible to hunting, roadkill, elevated predation and species invasions near roads. Road building increases forest disturbances and edge effects, facilitates legal and illegal logging and increases hunting pressure on wild species (Laporte *et al.*, 2007).

Linear infrastructure such as roads, fences, walls, railways and pipelines create barriers that prevent species movements (Wingard *et al.*, 2014). Linear infrastructure has caused habitat fragmentation, split populations, changed migration, nomadism and dispersal and altered behaviors (Mueller & Fagan, 2008; Olson *et al.*, 2011; Wingard *et al.*, 2014). Structures like border fences cause direct mortality of wildlife particularly large carnivores and large herbivores, due to entanglement (Trouwborst *et al.*, 2017). The border wall between US-Mexico reduces the area, quality, and connectivity of plant and animal habitats (H. Peters *et al.*, 2016).

4.2.1.5.3 Change in agricultural land and impacts on biodiversity and sustainable use

Agricultural expansion and intensification has been proliferating across the globe since the 1700s; crops provide food, fibre, and biofuels, as does livestock farming, aquaculture and the cultivation of trees (Dudley & Sasha, 2017; Grassini *et al.*, 2013; Ramankutty *et al.*, 2018). Worldwide, agriculture has already cleared or converted 70% of grassland, 50% of savanna, 45% of the temperate deciduous forest, and 27% of the tropical forest (J. A. Foley *et al.*, 2011). Between 1980 and 2000, more than 55% of new agricultural land came at the expense of intact forests, and another 28% came from disturbed forests across the tropics (Gibbs *et al.*, 2010). The demand for food, feed and other products is expected to increase in the future resulting in 10 billion hectares of natural ecosystems being converted to agriculture by 2050 (Alexandratos & Bruinsma, 2012; Tilman *et al.*, 2001b).

Agriculture as conventionally practiced is one of the greatest environmental drivers of wild species habitat loss, soil erosion, pollution, water stress, sedimentation of waterways, pesticide poisoning of humans and non-target species, and greenhouse-gas emissions (Power, 2010; Tayleur *et al.*, 2017; Tilman *et al.*, 2001a). Agriculture affects biodiversity mainly through converting natural habitats into cropland and pasture, intensifying management in long-established cultural landscapes and releasing pesticides and pollutants, including greenhouse gases (Dudley & Sasha, 2017). Across biomes and taxonomic groups, conversion to farms and ranches results in losses of average reduction of 13.6% of local species richness and 10.7% of species abundance (Newbold *et al.*, 2015). Species losses result from habitat loss and fragmentation, and the use of pesticides, herbicides, fungicides and fertilizers (Brittain & Potts, 2011; Chagnon *et al.*, 2015; Chiron *et al.*, 2014; Geiger *et al.*, 2010; Luzardo *et al.*, 2014; Stevens *et al.*, 2004).

Agriculture is also a major cause of global endangerment of flora and fauna, including pollinators (Alfaro-Shigueto *et al.*, 2005; Green *et al.*, 2005; Norris, 2008) **(Figure 4.3)**. Deforestation caused by agricultural expansion in the tropics has led to population declines in commercially traded wild species (Symes *et al.*, 2018). The sharp decline or extinctions of several species of farmland birds in Europe was attributed to agricultural intensification encouraged by the Common Agricultural Policy (Pain & Pienkowski, 1997).

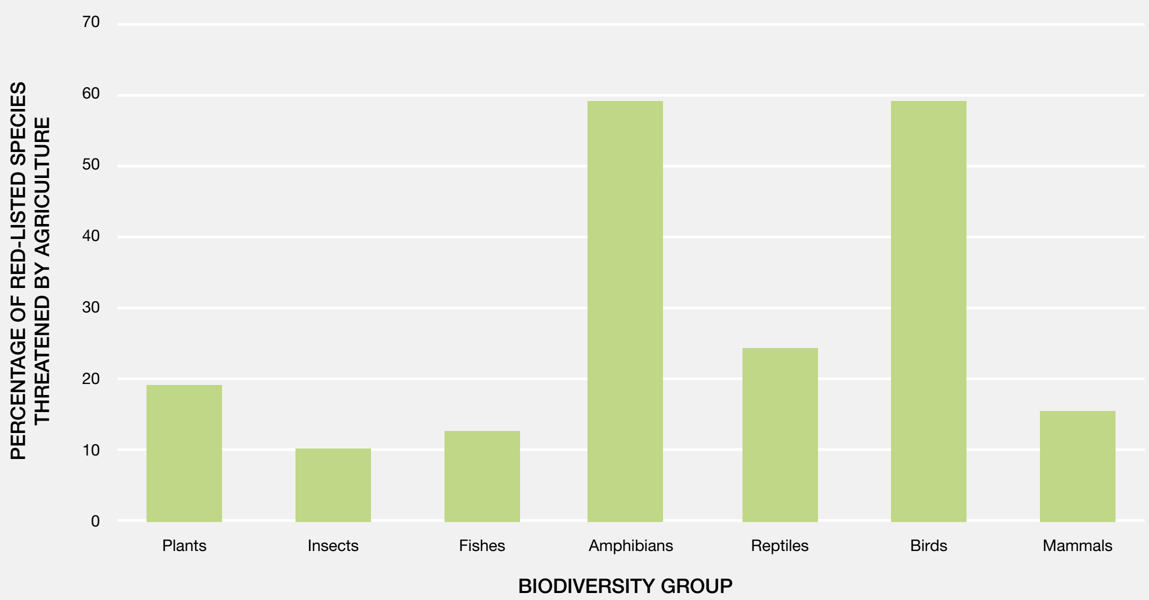


Figure 4 3 **IUCN red-listed species threatened by agriculture (CR= Critically Endangered, EN= Endangered, VU= Vulnerable) in a range of biodiversity groups.**

Data are from the International Union for Conservation of Nature (IUCN) Red List database (http://www.iucnredlist.org/search/search-basic). Least concern (LC) species were excluded from the analysis. IUCN threat codes used to assess agricultural threats were 1.1, 6.2.1, 6.3.1, and 6.3.7.
Source: Norris, (2008) @ 2008 Blackwell Publishing, Inc. license number 515479115045.

The combined effect of deforestation and commercial trade of wild species further increases the average losses of species (Symes *et al.*, 2018). Species loss affects productivity (biomass production by plants) and decomposition (mass loss of plant litter) impacts the sustainable use of wild species (Hooper *et al.*, 2012). However, the plant species identity is also important in affecting the decomposition (Vivanco & Austin, 2008).

Agricultural expansion, particularly in the tropics, negatively impacts biodiversity and the territories occupied by indigenous people (Laurance *et al.*, 2014; Scariot, 2013). Approximately 11% of the world's forested lands are included within territories occupied by indigenous peoples (Sobrevila, 2008). At least 36% of intact forest landscapes are within indigenous people's lands (Fa *et al.*, 2020). Such peoples, as well as smallholder farmers and traditional peoples, derive life's necessities and monetary income from subsistence farming and hunting, fishing, and harvesting of wild products, including non-timber forest products from those indigenous lands maintaining biodiversity and ecosystem services (Scariot, 2013). Diverse agricultural systems exist (with combinations of short-lived and perennial crops and timber and non-timber products) developed over centuries in rural areas, including by indigenous peoples and local communities (IPBES, 2019a). Some indigenous communities, such as those of Australia, have complex systems of land management (e.g., seasonal and adaptive savanna burning), which ensure plentiful wildlife and plant foods (Gammage, 2011; McKemey *et al.*, 2020).

There has been a call for improved practices and certification to reduce agriculture's social and environmental impacts. The codification of sustainable agricultural standards is growing, albeit worldwide coverage of certification is relatively small (Milder *et al.*, 2015; Tayleur *et al.*, 2017). Certification for sustainable agriculture has reduced inputs of chemical pesticides, fertilizers, and herbicides increased adoption of shade trees and soil conservation practices, and reduced water use and pollution (Blackman & Naranjo, 2012; Ibanez & Blackman, 2016; Rueda *et al.*, 2015). A project such as Future Resources, Agriculture and Nature Conservation in Germany was initiated to develop and test measures to preserve and increase biodiversity in the agricultural landscape. Positive and potentially indirect effects of certification on biodiversity were reported (Tscharntke *et al.*, 2015). For example, sustainable certification schemes of palm oil significantly reduce deforestation but not fire or peatland clearance (Carlson *et al.*, 2018). Hunting of small game is also increasingly becoming a driver of de-intensification of farming in ways which improve the food chains of the hunted species and many other species, notably pollinators (Brewin *et al.*, 2020; Ewald *et al.*, 2012; Sotherton, 1991). However, some complex trade-offs and unintended consequences of certification were also reported (Tayleur *et al.*, 2017).

Despite being considered inefficient, the market size of organic foods has been growing (Trewavas, 2001) (Willer & Lernoud, 2017). Although being critized as ideologically driven, organic farming systems produce lower yields than conventional agriculture, they are more profitable and environmentally friendly. They deliver equally or more nutritious foods that contain less (or no) pesticide residues than traditional farming (Regnold & Wachter, 2016). On average organic farming has increased species richness by about 30% (Tuck *et al.*, 2014).

Agroforestry and small-scale farms (<2ha) also play a crucial role in maintaining the genetic diversity of managed species and agrobiodiversity (IPBES, 2018b; Ricciardi *et al.*, 2018). Agroforestry has the potential for providing habitats outside formally protected land, connecting nature reserves and alleviating resource-use pressure on conservation areas (Bhagwat *et al.*, 2008). Agroforestry also enhances functional biodiversity, carbon sequestration, soil fertility, drought resistance, and weed and biological pest control (Tscharntke *et al.*, 2011). However, species selection is essential; agroforestry can promote undesirable species, including invasive species, if proper measures are not implemented (Udawatta *et al.*, 2019). The knowledge of indigenous peoples and local communities, also influences decisions to preserve biodiversity in the agroforestry systems (Vallejo-Ramos *et al.*, 2016).

In summary, there is no direct evidence of how agroforestry affects sustainable and unsustainable use. Although cultivation of medicinal plants is widely considered a means for relieving harvesting pressure on wild populations and can fulfil the demand for plant-based drugs and herbal remedies, a clear analysis of how they may offset pressure on wild species remains still unclear (Chen *et al.*, 2016; Schippmann *et al.*, 2002).

4.2.1.5.4 Change in forest areas and impacts on biodiversity and sustainable use

Forested ecosystems support a significant proportion of terrestrial biodiversity (Pimm *et al.*, 2014). About 25% (40 million km^2) of the earth's terrestrial surface is covered by forests, of which as much as 82% is now degraded (MacDicken *et al.*, 2016; Watson *et al.*, 2018). Globally tree cover has increased by 2.24 million km^2 (7.1% relative to the 1982 level) during the period 1982–2016 as a result of a net loss in the tropics being outweighed by a net gain in the extratropics (Song *et al.*, 2018). The deforestation rates of tropical-dense forests continue to be high (i.e., 74,400 km^2/year) (Hansen *et al.*, 2013). Nevertheless, about 129 million ha of global forest have been lost since 1990 (FAO, 2015). However, the intact forest landscapes, which are critical for stabilizing terrestrial carbon sequestration and storage, harboring biodiversity, water provision, indigenous culture and the maintenance of human health, shrunk globally by

7.2% from 2000–2013 due to industrial logging, agricultural expansion, fire, and mining/resource extraction (Potapov *et al.*, 2017; Watson *et al.*, 2018). Deforestation substantially increased the odds of a species being listed as threatened, undergoing recent upgrading to a higher threat category and exhibiting declining populations (Betts *et al.*, 2017). Forest or habitat loss also coincides with overhunting, wildfires, selective logging, biological invasions, and other stressors (Barlow *et al.*, 2016; Betts *et al.*, 2017).

These risks were disproportionately high in relatively intact landscapes; even minimal deforestation has severely affected vertebrate biodiversity (Betts *et al.*, 2017). In high-risk hotspots such as Amazon, Borneo and Congo Basin, 121–219 species will become threatened under current rates of forest loss over the next 30 years (Betts *et al.*, 2017). Likewise, there is a positive relationship between the global extinction risk of forest-dependent birds and the global intact forest landscapes. However, only 22.5% of global hotspots of range-rarity for forest-dependent birds are found within intact forests (Donald *et al.*, 2018). Primary forest loss from 2002–2014 has been the highest in rainforest countries of Brazil, the Democratic Republic of the Congo, and Indonesia (Turubanova *et al.*, 2018).

A study predicted substantial declines in suitable habitats for approximately 17000 species out of 19400 species of amphibians, birds and mammals studied due to land-use change alone (Powers & Jetz, 2019). The decline is disproportionately higher in South American, Southeast Asian and African countries (Powers & Jetz, 2019).

Deforestation and forest fragmentation negatively affect the abundance and availability of non-timber forest products and decrease the hunting success rate. Fragmentation has negative impacts on the genetic diversity of birds (Athrey *et al.*, 2012) and fish population (Pavlova *et al.*, 2017) and population fitness, threatening endangered species on land (Athrey *et al.*, 2012). In contrast, in the aquatic ecosystem, alteration of habitat such as dam building is associated with a change in the genetic composition (Thompson *et al.*, 2019). Deforestation restricts the availability of non-timber forest products, which in turn adversely affects local communities (Schmidt *et al.*, 2020). Commercial deforestation negatively affects the rural people who depend on wild animals like a snail, wild meat, wild honey and wild and cultivated vegetables for subsistence (Appiah *et al.*, 2009). A fragmented or declining environmental quality is likely to support lower populations and produce lower yields of some plants, algae and fungi and simultaneously affect what land use and livelihood options might be viable or not. Deforestation is also associated with declining consumption and diversity of nutritious fruits and wild foods (Ickowitz *et al.*, 2013). Indigenous local community reported a decline in hunting success rates and fruit harvests after logging (Araujo Lima Constantino, 2016; Menton *et al.*, 2009). Deforestation causes a reduction in the generation of hunting products, particularly the diversity of bushmeat, which reduces household dietary intake and cash income (Gillet *et al.*, 2016). However, bushmeat hunting is more widespread in fragmented forests (Torres *et al.*, 2018). Infrastructure development makes remote forested areas accessible, exacerbating the hunting and trapping pressure (Barlow *et al.*, 2016). Additionally, hunting practice has evolved to meet urban market demand after urbanization and the opening of the roads (Ickowitz *et al.*, 2013; Torres *et al.*, 2018).

Forest expansion continues to occur in most industrialized countries, on lands abandoned by farming and animal husbandry and areas that continue to mature on land that was deforested in the past century but have not been converted to a different land use since then (Keenan *et al.*, 2015). Planted forests account for 25-100% of gains and increasingly substitute for natural forests, particularly in Africa, Southeast Asia, and Europe. The global rate of planted-forest expansion since 1990 is close to a target of 2.4% per annum necessary to replace wood supplied from natural forests in the medium term, although the rate has declined to 1.5% since 2005 (Sloan & Sayer, 2015). Although natural forests are usually more suitable as biodiversity habitat for a broader range of native forest species than plantations, plantation forests can provide valuable habitat even for some threatened and endangered species and may contribute to the conservation of biodiversity (Brockerhoff *et al.*, 2008). Nevertheless, large-scale tree plantations also have negative impacts on biodiversity, quality and quantity of water and livelihoods, particularly loss of or restriction to previous livelihoods, and reduced access (Malkamäki *et al.*, 2018). Furthermore, tree plantations, particularly monocultures, displaced native forests (Hua *et al.*, 2018).

4.2.1.5.5 Change in rangelands and impacts on biodiversity and sustainable use

The rangeland condition affects biodiversity directly and indirectly because rangeland comprises high biodiversity values (Harris 2010). Rangelands are the most dominant land cover types on Earth, covering 25-45% of the land surface, depending on how these lands are defined (Reid *et al.*, 2014). Globally, 4,734 mammal species are less endangered in rangelands and wildlands compared to croplands and urban areas (Pekin & Pijanowski, 2012). Grasslands are among the ecosystems with the highest species richness in the world (Wilson *et al.*, 2012). Globally both expansions of rangeland and intensification of rangelands are caused by the increasing demand for livestock production that depends on grazing systems requiring grazing lands (Godde *et al.*, 2018). This has led to unsustainable use, exemplified by deforestation and land degradation. On a global scale, almost half (49%) of grassland ecosystems were degraded and nearly 5%

of this grassland experienced strong to extreme levels of degradation (Gang *et al.*, 2014).

The major causes of the rangeland degradation are climate change, overgrazing, land-use change (converting pastureland to cropland), and shrub encroachment (R. B. Harris, 2010; Knapp *et al.*, 2008; Reid *et al.*, 2014; Tiscornia *et al.*, 2019; Walker *et al.*, 2006). Overgrazing occurs when stocking rates exceed the carrying capacity of grassland; this can be particularly in developing countries and lead to rangeland degradation (Bai *et al.*, 2002; Fedrigo *et al.*, 2018; Liu *et al.*, 2013; Yao *et al.*, 2016). In some regions, management of over-grazing stress is allowing for the reestablishment of forest areas (Navarro & Pereira, 2015).- Warming and the increased frequency of prolonged droughts are the major climatic changes that cause rangeland degradation (Gang *et al.*, 2014; Tiscornia *et al.*, 2019). Rangeland degradation reduces various ecosystem services but particularly affect the sustainable use of wild species as it has decreased capacity to provide forage for large herbivores, including domestic livestock (Hoppe *et al.*, 2016; Liu *et al.*, 2013; Paudel *et al.*, 2010; Yao *et al.*, 2016) and lower forage quality (Cao *et al.*, 2013; Li *et al.*, 2008; Pallarés *et al.*, 2005).

Rangeland management systems are diverse, ranging from nomadic pastoral activities in sub-Saharan native savannas to sedentary Dutch dairy farming to industrial-scale farming in North America and Australia (Godde *et al.*, 2018). Most global rangelands are still common pool resources (except some privately owned in North America and Australia) and are used by indigenous pastoralists/ranchers, agropastoralists, hunters, conservationists, recreationists, and others (Reid *et al.*, 2014). There have been shifts in pastoral land-use practices causing various changes in rangelands themselves, from contraction, loss, and fragmentation to expansion and reaggregation (Reid *et al.*, 2014). These changes lead to either income diversification at the household level (Homewood *et al.*, 2009; Reid, 2012) or intensification of the rangelands (BurnSilver, 2009; Nkedianye *et al.*, 2009). Rangeland changes cause species decline. In North American grasslands, bird populations have experienced drastic declines over the past half century, particularly due to the land-use change and a rapid loss of habitat (Correll *et al.*, 2019; Grand *et al.*, 2019). Conversion of grasslands into other land uses is the major threat for grassland birds in Brazil (Jacoboski *et al.*, 2017). Future climate change added vulnerability to these grassland birds in North America (Wilsey *et al.*, 2019).

There is some evidence that indigenous pastoralist communities are displaced to create protected areas (Reid, 2012; Tang & Gavin, 2010) and to prohibit traditional management practices such as burning grassland to produce a new flush of nutrient-rich grass and remove old moribund grass material (Fernández-Giménez & Estaque, 2012; M. U. Johansson *et al.*, 2012). The forced eviction of pastoralist communities to establish protected areas sometimes has led to an increase in wild species poaching (Reid, 2012; Scharf *et al.*, 2010).

4.2.1.5.6 Habitat conversion

The conversion of natural ecosystems into anthropogenic ecosystems (such as farmlands, pastures, and plantations) is the most important direct driver of change in terrestrial ecosystems. This is driven indirectly by changing social dynamics–notably the drive for economic development. This significant expansion of agricultural land has been the critical factor that has enabled the human population to continue growing. While an estimated 1 billion people remain malnourished, the supply of food per capita has continued to increase steadily, largely due to improved technology and the intensification of cropland. Poor governance, however, has prevented a more equitable distribution of the benefits from food-producing plants. Additionally, about 1.3 billion tons of food produced for human consumption is wasted annually, and the loss per capita is higher in the industrialized world than in developing countries (FAO, 2011b).

Habitat loss and fragmentation, and the consequent reduction of much of the Earth's biodiversity, have been caused by the increasing human population density and energy use, mainly after the 19th and 20th centuries (Sala *et al.* 2000; Fahrig, 2003). The drivers of species loss include pollution and habitat conversion. Habitat conversion for human development directly trades economic profit for habitat loss. Economic activity that causes habitat loss includes urbanization, mining, water development, and agriculture. However, a leading cause of global change is likely the growing human modification of environments for agriculture (Keitt, 2009). The Cerrado is the richest savanna ecosystem in the world. Still, the intensive human occupation process has also transformed it into one of the most critical regions for cattle ranching and commodity crops in Brazil (Myers *et al.*, 2000). The proportion of remaining habitats in the Cerrado varies from 39% to 55% (Eva *et al.*, 2004; Machado *et al.*, 2004; Mantovani & Pereira, 1998; Sano *et al.*, 2008).

Cattle ranching and intensive farming in the Cerrado ecoregion have caused a tremendous decline in natural habitat cover (Diniz-Filho *et al.*, 2009). According to a study by Hermann and colleagues, land conversion rates far outweigh preservation attempts in the area. Collecting data from satellite images, silviculture in the area was expanded by 94% over the six-year study, and grassland was the main target for agricultural land conversion. On a larger scale, this reflects global developments in temperate grasslands (Hermann *et al.*, 2016). An overwhelming number of studies have looked at the impact of agricultural habitat conversion on birds, often used as indicators of biodiversity status. They play vital roles in many ecosystems, ranging from pollination and seed dispersal to insect control and nutrient cycling. It has been estimated that approximately a fifth to a quarter of pre-agricultural bird numbers has been lost due to agricultural development (Gaston *et al.*, 2003). In particular, avian breeding success is impacted by agricultural land conversion.

A study conducted by Cartwright *et al.* concluded that the formerly critically endangered Mauritius kestrel *Falco punctatus* experiences a decline in breeding success as the area of agriculture near a nest site is increased (Cartwright *et al.*, 2014). This may be attributable to the increasing spatial variation in the availability of native prey, which is reduced by land conversion. In addition, loss of farmland bird populations has been observed in Europe. For example, farmland bird populations dependent on key aspects of these agroecosystems experienced a 40% decline between 1980 and 2000 (Cao *et al.* 2010). Cattle ranching and intensive farming in the Cerrado ecoregion have caused tremendous decline in natural habitat cover (Diniz-Filho *et al.*, 2009). The drastic loss of spatially consistent natural cover in the Cerrado ecoregion denotes the decline of many endemic plant species, mirrored in the Atlantic rain forest ecoregion. The forest-grassland mosaic of Rio Grande do Sul, Brazil has been largely converted for agri- and silviculture. Due to extensive logging practices, the area's Araucaria broadleaf forest is only a mere fraction of its original extension, and the *Araucaria angustifolia* species has been recently placed on the International Union for Conservation of Nature and Natural Resources Red List of Endangered Species (Hermann *et al.*, 2016).

4.2.1.6 Pollution and eutrophication

Key messages:

- Pollution, be it from anthropogenic or natural sources, brings negative consequences on the abundance, distribution, availability, harvesting, gathering, and value chain of wild species in different ways and at different spatial and temporal scales *(well established)*.

- The interaction of state, indigenous peoples and local communities, different forms of conservation bodies (national and international, governmental and non-governmental organizations, and community-based organizations, and other stakeholders are central to the safeguarding of wild species and minimizing every possible cause and threat posed by pollution *(established but incomplete)*.

- Acts and regulations are often inadequate or poorly addressed in terms of local evaluation methods such as Initial Environmental Examination and Environmental Impact Assessment – where in the majority of cases, the effects of pollution on wild species are hardly understood. A better understanding of pollution-induced changes in wild species dynamics, effective implementation of regulations, and building capacity and awareness are paramount *(established but incomplete)*.

Key points for policymaking:

- Sufficient support by governments for more research and better understanding of the pollution-induced changes in wild species and their sustainable use is paramount.

- More serious international pollution mitigation commitments and emission curtailment agreements are needed vis-a-vis checking the unsustainable exploitation of wild species, including their illegal trade.

- Developing a global policy framework for post-2020 achievable targets, with specific regional guidelines, to minimize and eventually stop the impact of pollution on the sustainable use of wild species is essential.

4.2.1.6.1 Overview

This section reviews environmental pollution, specifically air, water and land pollution, vis-à-vis the impacts on sustainable use of wild species. The pollution could either be anthropogenic or natural and is characterized as being due to chemical, physical or biological pollutants emanating from point or non-point sources.

Air pollution decreases the native populations of animals with serious negative impacts on wild birds, insects, reptiles, and wild mammals. The anthropogenic variables of air pollution are also responsible for the decline in lichens, wild-growing medicinal plants and many other wild species. Air pollution from industry harms wild species in different ways, such as bioaccumulation, causing diseases, mortality and physiological stress. The pollutants originate from human activities such as combustion of burnable waste, fossil fuels in thermal power plants and automobiles, which increases the concentration of gaseous and particulate pollutants in the atmosphere. The resulting air pollution and subsequent acid deposition change the chemistry of the lakes and damage wild plants. Air pollutants affect wild species by entering the food chain and damaging the supply and quality of food through bioaccumulation. The oxides of sulphur (sulphur oxide, sulphur dioxide, and sulphate), noxious nitrogen gas (nitrogen monoxide, nitrous oxide, nitrogen dioxide) ammonia (NH_3), volatile organic compounds, and carbon monoxide (CO) are the important chemical pollutants emitted from various anthropogenic activities, the effects of which on ecosystems and wild species therein are growing with the growth of urbanization and industrialization.

A major threat to wild aquatic species is the contamination of water bodies by different pollutants (physical, biological, chemical and radioactive) resulting from many sources (mining activities, industrial effluents, domestic sewage and agricultural runoff). Domestic and industrial waste, livestock waste, and agrochemicals are predominant pollutants in waterbodies. Oil pollution enters the ocean and severely contaminates beaches and sediment and causes serious harm to wild marine species. Oil spills in freshwater ecosystems, also have grave impacts on wild species. Phosphorus, nitrogen and many other nutrients are added to aquatic ecosystems continuously by agriculture and urban activities, which in turn cause diverse problems, such as oxygen limitation, toxic algal blooms, loss of biodiversity and threat to important wild species of recreational value. It affects the quality of the environment or habitat in which they live and the availability and quality of the food supply. Acid rain, heavy metals, persistent organic pollutants and other toxic substances are issues of major concern, the effects of which on fish, fisheries and other wild aquatic species are felt across the world, especially in the developing world due to increasing population, urbanization and modernization. The elevated concentration of nutrients in freshwater bodies (eutrophication) triggers blooms, invasions and biodiversity loss in lakes, rivers and wetlands, thereby pushing the useful wild species to the brink of rarity or extinction. Plastic accumulation in the oceans severely impacts marine life, increasing the likelihood of coral reefs being affected by diseases and threatening overall ecosystem health and human livelihoods. Ingestion of microplastics is being reported in several marine invertebrate species. Microfibre ingestion in crabs affects food consumption and energy balance, while in marine worms, the ingestion of microscopic unplasticized polyvinylchloride reduces growth and energy reserves.

Soil pollution caused by a myriad of human activities (e.g., leakage of oil and chemicals, excessive use of chemical pesticides and fertilizers, etc.) negatively effects soil health and consequently the soil biota. Excessive fertilizers, pesticides, and even nutrients, especially nitrogen, phosphorous and heavy metals composition in terrestrial soils, freshwater sediments and coastal ecosystems with cascading effects on wild species diversity, ecosystem function and human wellbeing. In the last few decades, there is some evidence that various types of xenobiotics have adversely affected wild species through soil-based impacts, thereby contributing quite a great deal to push these species to the brink of extinction. Whether soil microbes also go extinct many times without even being ever identified and how such extinctions are related to the extinction of wild species above-ground are some unanswered questions.

4.2.1.6.2 Key Gaps

- Some extremely harmful pollutants such as polychlorinated biphenyls, despite a near-global ban over the past three decades, are still found to bioaccumulate in some wild species, indicating their presence and use in the environment.

- The rising global decline of insects, especially pollinators, due to air pollution-induced mortality or climate change-driven plant-pollinator mismatch needs more evidence, and effective intervention, given its huge implications for horticulture and agriculture sectors that comprise the backbone of the economy of developing countries.

- Lack of focused, in-depth studies on the impact of pollution on keystone wild species despite the dire need to understand their biology, ecology and conservation in the context of growing pollution, especially in developing countries.

4.2.1.6.3 Methodology

The experts used about 30 keywords in different permutations and combinations to search the relevant literature. Each term pertaining to different types and forms of pollution was paired with different words or terms used for wild species. For instance, terms such as pollution, pollutants, toxic chemicals, contaminants, environmental pollution, air pollution, water pollution, soil pollution, noise pollution, toxic elements, heavy metals, organic contaminants, inorganic pollutants, automobile pollution, biotic pollution, etc., were paired with terms such as sustainable use of wild species, wild species, wild resources, birds, fish, reptiles, freshwater life, marine species, forest species, wilderness, extinction, habitat modification, keystone species, global patterns of impact of pollution on wild species, regional changes in wild resources by pollution, etc. **(Figure 4.4)**. Over 200 searches were performed that resulted in a large number of research articles, policy documents, book chapters and other papers, which in turn were refined to select the most relevant articles/sources in English since 1950 for inclusion. References cited in these articles were also considered, if appropriate, to ensure as comprehensive coverage of related research as possible.

4.2.1.6.4 Air pollution

Air pollution is one of the major global environmental concerns, with serious human health impacts and equally serious effects on myriad wild species. Gaseous air pollutants are emitted from various natural sources, such as volcanoes and forest fires, or anthropogenic activities that have significantly increased with population growth and industrialization (Kemp *et al.*, 2011). Air pollution comprises

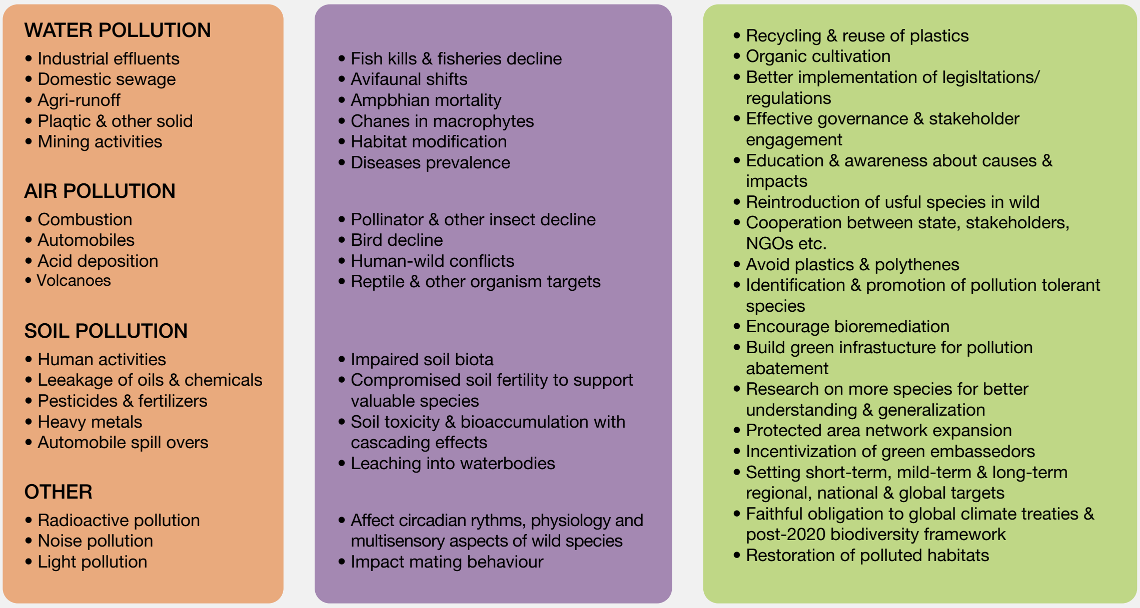


Figure 4 4 **Typology of pollution and causes.**

The impact of pollution on the sustainable use of wild species is quite varied, and a suite of mitigation measures against pollution vis-à-vis wild species could be used, in isolation or combination, in context-specific situations.

a mixture of gases and particles (such as CO_2, CO, O_3, SO_2, CH_3, smoke and mixture of urban and industrial emissions) in undesirable and harmful amounts. Human beings have produced facilities that use many of the Earth's energy resources to make their life easier. Burning fuels such as coal, oil and natural gases result in pollution by releasing harmful substances into the environment. Burning fossil fuels in industries and the transport sector, industrialization and urbanization have led to increased concentrations of gaseous and particulate pollutants in the atmosphere leading to air pollution (Tripathi and Gautam, 2007; Dwivedi and Tripathi 2007). These constituents interact with reactants in the atmosphere and result in secondary pollutants such as acid deposition.

Acid rain has negative impacts on aquatic organisms, including fishes. The marine ecosystems found in Belgium, Denmark, West Germany and the Netherland (Whelpdale, 1983) are affected by acid rain. Acidification of surface waters has been reported in many, including Great Britain, Northern, Central and Eastern Europe, southwestern China, southeastern Canada, the Northeast, Upper Midwest and Appalachian Mountain regions of the United States of America. Large portions of the high elevation western North America are also potentially sensitive to acidic deposition, however. However, atmospheric deposition in this region is relatively low. Concern over the effects of acidic residue in the Mountain West and California may be overshadowed by potential effects of elevated nitrogen deposition, including eutrophication of naturally nitrogen-limited lakes (Fenn *et al.*, 2003). Decreases in pH and elevated concentrations of dissolved inorganic aluminum have resulted in physiological changes to organisms, direct mortality of sensitive life history stages, and reduced the species diversity and abundance of aquatic life in many streams and lakes in acid-impacted areas (Driscol *et al.* 2019).

Top-level predators such as bears and eagles, among many others, are particularly susceptible to the bioaccumulation of these types of air pollutants. Changes in the abundance of any species because of air pollution can dramatically influence the abundance and health of dependent species. The loss of some species of fish because of higher levels of aluminum may allow insect populations to increase, which may benefit certain types of ducks that feed on insects. But the same loss of fish could be detrimental to eagles, ospreys and many other animals that depend on fish as a source of food.

The major effects of industrial air pollution on wild species include direct mortality, debilitating industrial-related injury and disease, physiological stress, anemia, and bioaccumulation. Some air pollutants have caused a change in the distribution of specific wild species (Newman, 1979). The African urban centers have grown tremendously in the last thirty years and are still on a continuous rise (Obeng-Odoom, 2013). Motor vehicles, power generation plants and other industrial machinery produce toxic gases. Nitrous oxide, Sulphur oxide and Carbon monoxide pollution in the tropics may exert more adverse effects on sensitive species of diverse plants and animals, and photo-chemicals have resulted in shifts of vegetation from ozone sensitive to ozone tolerant ones (Barker & Tingey, 2012). Sulphur dioxide and hydrogen sulphide emitted from power plants, especially the coal-fired ones and paper and mill factories, have already resulted in acid rains in various parts of Africa (Europe & WHO., 2006; Josipovic *et al.*, 2010; Nduka *et al.*, 2008). The sources of NH_3 in Africa are municipal effluent, farmyard/feedlot manure, and inorganic mineral fertilizers (Carmichael *et al.*, 2003). There have been many reported air pollution episodes involving injury or death to animals since the end of the nineteenth century (Newman, 1980; Newman & Schreiber, 1985). Some of the incidents involving the adverse effects of these airborne pollutants on mammals and birds have been recorded quite earlier. For instance, the earliest incident involving arsenic poisoning of fallow deer *(Dama dama)* in Germany was recorded in 1887. Among birds, there are examples of granivores, insectivores, and carnivores being affected in various ways by air emissions. Effects may range from subtle, such as a reduction in genetic diversity, to dramatic, such as a change in population numbers (Newman, 1980; Newman & Schreiber, 1985). A review of decades of research on lead contamination in vultures across the world found 72% of articles from North America and Europe, with the rest corresponding to Asia (13%), South America (8%), and Africa (7%). Of these, 88% of studies showed the lead concentration beyond threshold limits (Plaza & Lambertucci, 2019). This corroborates with a series of case studies demonstrating the sustained impact of contaminants, such as dichloro-diphenyl-trichloroethane, dieldrin and diclofenac on vultures (Shore & Taggart, 2019).

The rising global decline of insects, especially pollinators and birds, due to air pollution-induced mortality is evidenced by the significant correlation between the increase in pollutants such as respirable suspended particulate matter and changes in pollinator bee survival (Thimmegowda, 2020). Similarly, high avian mortality due to fly ash calls for controlling sources such as atmospheric geo-engineering and industrial emissions (Dutta, 2017; Whiteside & Herndon, 2018). Sanderfoot and Holloway (2017) found consistent evidence for the adverse effect of air pollution on birds, primarily attributable to CO, O_3, SO_2, smoke and a mixture of urban and industrial emissions. One of the first case reports using monkeys as model systems recently linked animal social conflict to air pollution and global warming (Xu *et al.*, 2021), the results of which indicate more daily social fighting behaviors under the polluted air. Even mate choice at different stages can be affected by pollution, which can influence individual fitness, population dynamics and community structure of wild animals (Candolin & Wong, 2019).

The anthropogenic variables of air pollution are responsible for the lichen decline (Giordani, 2007). The lichens can indiscriminately absorb a large range from the ambient air through their entire surface (Aznar *et al.*, 2008; Conti *et al.*, 2011). Accumulated pollutants in their thallus in line with atmospheric concentrations show a close correlation with their atmospheric levels and have proved the lichen's capability as an effective biomonitor (Adamo *et al.*, 2008; Godinho *et al.*, 2009; Wolterbeek *et al.*, 2003). The loss of lichen diversity in response to environmental conditions is widely used as an indicator for several complex phenomena, including air pollution (Giordani, 2007). Gombert, Asta, and Seaward (2004) determined the decreased lichen abundance and spatial trends of lichen diversity around urban and industrial areas based on the fact that anthropogenic variables are responsible for lichen decline, irrespective of natural succession of epiphytic communities (Purvis *et al.*, 2003). A study conducted by Douglas *et al.* (2017) indicated that samples from the Las Vegas valley are a good baseline of pollutants in lichens. Furthermore, lichen collected within the valley contained higher concentrations of target pollutants, suggesting that the accumulation of pollution is likely anthropogenic in nature (e.g., industries, vehicular traffic). Douglas *et al.* (2017) documented that vehicle emissions are a source of nitrate. Findings show NO_3-is lower in lichen biomass located in the South and East sectors while higher in the North and West sectors of Las Vegas Valley. It is possible that the South and East sectors with elevated copper, perhaps, are a contributing factor to lower NO_3- in lichen biomass.

4.2.1.6.5 Water pollution

Pollutants are a major driver of species declines in freshwater systems (Dudgeon *et al.*, 2006). Water pollution is brought about by various sources such as domestic and industrial sewage, agricultural runoff, waste dumping, oil spills, sediment runoff, etc. Water pollutants have been found to be lethal to fish and other aquatic fauna or cause a range of sub-lethal effects, such as physiological stress, dysfunction of iono-regulatory and immune system, histopathological deformities, change in population dynamics and community structure (Luebke *et al.*, 1997; Ozmen *et al.*, 2008; Sodergren, 1992).

Acidification

Acid precipitation and consequent acidification of waterbodies is a major cause of concern for wild aquatic bioresources and their sustainable use with substantial economic impacts (as estimated recently in UK by Mangi *et al.* (2018), for instance). Ndubuisi *et al.* (2015) reported 100% mortality of fingerlings of *Clarais gariepinus* at pH 3. Acidification, in conjecture with other drivers such as climate change, ultraviolet radiation radiations, etc., has serious impacts on phytoplankton (Bach *et al.*, 2017), macrophytes (Jackson & Charles, 1988; Tucker *et al.*, 2021); and amphibians (Alton & Franklin, 2017). According to the United States of America, Fish and Wildlife Service sources, around 3,000 to 4,000 birds, such as snow geese, perished in December 2016 in the Berkeley Pit's toxic water due to heavy metals and sulfuric acid. In Hong Kong, the Mai Po and Inner Deep Bay ecosystem is under threat from a range of contaminants, especially high levels of chlorinated pesticides in marine sediments (Richardson and Zheng 1999; Richardson *et al.* 2000). The lower reaches of the Pearl River, which drain into Deep Bay receive 2 million tons of various types of wastes and wastewater annually, and are heavily polluted by domestic, industrial and livestock waste, and agrochemicals (Neller & Lam, 1994). River Nile from Aswan to Cairo involved severely polluted points resulting from sewage drains, and industrial and agricultural sources (Fishar, Kamel, and Wissa 2003; Fishar & Williams 2006) that reduced the richness of wild taxa. Pollution, together with monoculture palm oil plantation in Borneo, Malaysia (Zieritz *et al.*, 2017), reduces the diversity of useful wild aquatic species with serious implications for livelihoods.

Oil spills

Petroleum hydrocarbons are considered as hazardous wastes and the most frequent organic pollutants of aquatic ecosystems (Margesin and Schinnur 1997). The ingestion of oil by some wild aquatic species often causes mortality, while surviving organisms often show developmental and reproductive abnormalities (Jiang *et al.*, 2010). The aquatic organisms that live within and around the coral reefs are at risk of exposure to the toxic substances within oil and smothering thereby suffering significant changes in diversity, species abundance and habitat structure worldwide (Hughes *et al.* 2007). In a study using coral nubbins in coral reef ecotoxicology testing, (Shafir *et al.*, 2003) found that dispersed oil and oil dispersants are harmful to soft and hard coral species at early life stages. They found that the dispersant concentrations recommended by the manufacturer were highly toxic and resulted in mortality of all nubbins.

Eutrophication and Agricultural Runoff

Nutrient pollution from improper and excessive fertilizer use has several negative consequences for ecosystems. Of the 63 large marine ecosystems evaluated under the Transboundary Waters Assessment Programme, 16% of the ecosystems are in the "high" or "highest" risk categories for coastal eutrophication due to nutrient run-off16 (ECOSOC, 2017). African aquatic ecosystems are already suffering the wrath of application of pesticides upstream (Hecky *et al.*, 2006; Odada *et al.*, 2004). Toxic levels of pesticides capable of altering health of aquatic organisms have been found in several lakes and rivers in Africa (Mugachia, Kanja, and Gitau 1992; Kidd *et al.* 2001; Ezemonye and Ikpesu, 2008.; Okeniyia *et al.* 2009; Kohler and Triebskorn 2013). Along coastlines, rivers' low oxygen levels and hypoxic "dead zones" are due to large nitrogen and phosphorus loads draining from fertilized agricultural watersheds, or from sewage and atmospheric nitrogen deposition (Diaz & Rosenberg, 2008; Rabalais *et al.*, 2014; Schmidtko *et al.*, 2017). The dead zone has been significantly expanded due to the anthropocentric contributions of nutrients from mostly agricultural, municipal, and industrial sources. Nutrient-fed hypoxia is ranked as an important threat to the health of aquatic ecosystems, including oceans (Rockström *et al.*, 2009). Challenging threats to the environment exist in the Gulf of Mexico region, and chief among them is the seasonal hypoxic or "dead" zone that occurs annually off the coast of Louisiana and Texas (Diaz & Rosenberg, 2008). The presence of a large hypoxic water mass off the coast of Louisiana in mid-summer may concentrate brown shrimp into shallower coastal waters (Craig *et al.* 2005) making them more susceptible to predators, including humans with trawls resulting in increased catches, but the overall productivity of the brown shrimp population is diminished by the removal of these smaller shrimp from further increase in size before capture in farther offshore areas later in the season.

Coral bleaching and some mortality in reefs within Bahia Almirante, extensive necrosis of sponges, and dead bodies of crustaceans, gastropods, and echinoderms suggested that the extreme stress leading to mortality had occurred and that hypoxia likely excluded consumers that otherwise would have targeted dead and moribund prey (Altieri, 2008).

Plastic pollution

Plastic pollution in aquatic ecosystems is generating huge impacts. Plastic pollution enters the ocean via rivers, sewage, fishing and other sources. About 90% of all the plastic that reaches the world's oceans gets flushed through just 10 rivers: Eight of them are in Asia: the Yangtze; Indus; Yellow; Hai He; Ganges; Pearl; Amur; Mekong; and two in Africa – the Nile and the Niger (Schmidt *et al.*, 2017). Plastics kill or harm biodiversity, from zooplankton to fish, shellfish, sea turtles, seabirds and marine mammals. Impacts on wild marine species include entanglement, ingestion, and contamination of a wide variety of species. Battisti *et al.* (2019) recently prepared a 'black-list' of 258 species impacted by anthropogenic litter. They found that most of the species (including 79.8% seabirds) are impacted by ingestion rather than by entanglement. The number of marine species affected by contaminants increased from 247 to 680 within a few years (Gall & Thompson, 2015). Marine plastic pollution impacts marine biota and ecosystems at many different levels (Fossi *et al.*, 2017; Moore *et al.*, 2020; Ryan, 2016). Wilcox, Van Sebille, and Hardesty (2015) suggested that nearly all species of seabirds will eventually be found ingesting plastic. 21% of surveyed wedge-tailed shearwater *(Ardenna pacifica)* chicks on Heron Island in the southern Great Barrier Reef were fed plastic fragments by their parents, ingesting 3.2 fragments on average (Verlisa *et al.* 2013). Seabird species feeding at the sea surface are more susceptible to plastic ingestion than diving species(Ryan & Jackson, 1987). Sea turtles are exposed to various anthropogenic stressors, including marine plastic pollution, because of their use of diverse habitats, migratory behavior, and complex life histories (Nelms *et al.*, 2016). Procellariiform seabirds and marine turtles may be particularly risky because marine plastic debris's chemicals may imitate natural foraging stimuli (Pfaller *et al.*, 2020).

Litter ingestion and entanglement in plastic debris have been recognized as serious threats to turtle species worldwide (Clukey *et al.*, 2017; Duncan *et al.*, 2017; Nelms *et al.*, 2016). Five sea turtle species inhabit the SE Pacific (*Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata*, and *Lepidochelys olivacea*); all are listed as vulnerable to critically endangered on the International Union for Conservation of Nature Red List (IUCN, 2021) with documented interactions with marine litter. The green turtle *(C. mydas)* is the species most commonly mentioned to have ingested plastic items, with a frequency ranging from 28% in the Ecuadorian part of the northern Humboldt Current upwelling system (Alemán, 2014) to 56 and 91% in Peru (Alfaro-Shigueto *et al.*, 2005; Jiménez *et al.*, 2017). The olive ridley turtle *(L. olivacea)* also has a high incidence of plastic ingestion, reaching up to 43% in Ecuador (Alemán, 2014), but this species has a lower incidence in other parts of the northern Humboldt Current upwelling system (8%), both in Peru and southern Chile (Brito *et al.*, 2007; Paz *et al.*, 2005). Furthermore, specific cases of plastic ingestion have been reported for leatherback turtles *(D. coriacea)* from the northern Humboldt Current upwelling system in southern Peru and central Chile (Brito 2001) and a hawksbill turtle *(E. imbricata)* in Rapa Nui (Brain *et al.*, 2015). Items most commonly found in stomachs or intestines of sea turtles are plastic pieces of intermediate size, including plastic bags, monofilament nylon, rope, and fishing nets (Brito, 2001; Guerra-Correa *et al.*, 2007; Jiménez *et al.*, 2017). Several authors suggested that plastic ingestion has been the cause of death of stranded turtles in Ecuador and Chile (Brito *et al.* 2007; Silva, Retamal, and Guerra-Correa 2007; Alemán 2014). Many different seabird species have been entangled in marine debris or have ingested plastic (Luna-Jorquera *et al.*, 2012). Six species were found to have ingested plastic litter (*Pelecanoides garnotii, P. urinatrix, Phalacrocorax bougainvillii*, and *Spheniscus humboldti*); one is a true diving species, and one a plunge diver *(Pelecanus thagus)*. One species with a relatively high frequency of plastic ingestion is the kelp gull *Larus dominicanus*, which is commonly observed feeding in fishing ports, garbage containers, and waste disposal facilities. Ingestion of microplastics is being reported in several marine invertebrate species (Cole *et al.* 2013; Foley *et al.* 2018; Wright, Thompson, and Galloway 2013). Several harmful effects have been reported due to microplastic ingestion, ranging from stomach ulcers, intestinal obstruction, reduced body condition, and increased contaminant load (Derraik, 2002; Lavers *et al.*, 2014). Notwithstanding some local scale efforts to check the plastic influx into the aquatic ecosystems, the volume of marine plastic debris, for instance, is increasing at an alarming rate of 4.8 to 12.7 million metric tons every year (Jambeck *et al.*, 2015). The polychlorinated biphenyls threaten the long-term viability of >50% of the world's Killer whales' (Orcinus orca) populations with strong impacts on reproduction and immune function (Desforges *et al.*, 2018). This is despite a near-global ban on polychlorinated biphenyls over the past three decades. Recent molecular investigation in mangroves revealed lower species population sizes in polluted sites when compared with those in protected area (i.e., higher geneflow may help them counteract the effect of pollution on genetic diversity and differentiation) (Rumisha *et al.*, 2018). Whether hunting waterfowl is a sustainable use or not is not clear. While game hunting is considered sustainable use of waterfowl species in many countries, in the Argentinian context, for instance, this is not considered so due to many reasons (Uhart *et al.*, 2019). The use of lead ammunition, questionable hunting quotas, lack of information on waterfowl population status, breeding sites, etc., are some of the critical concerns in this regard. The evidence above substantiates the significant impact of pollution on survival, dynamics and sustainable use of wild species that merit urgent policy intervention and management action.

4.2.1.6.6 Soil pollution

Various studies have shown that excessive use of pesticides and insecticides leads to loss of wild species and causes ecosystem degradation (Green *et al.*, 2005; Kleijn *et al.*, 2009; Rundlöf *et al.*, 2015). In particular, pesticide use has contributed to reducing populations of birds, insects, amphibians and aquatic and soil communities, either through direct exposure or reduction in food and habitat availability (Hallmann *et al.*, 2014; Kennedy *et al.*, 2013). A Europe-wide study found that insecticide and fungicide use have consistent adverse effects on wild species diversity and that insecticides also reduce the potential for biological pest control (Geiger *et al.*, 2010). Indirect effects of pesticides have been identified as one of the leading causes of decline in farmland birds in several European countries (Donald *et al.*, 2001; F. Geiger *et al.*, 2010). This decline is reflected in the falling trends for farmland bird index in several Organisation for Economic Co-operation and Development countries. Direct toxicity of nitrogen gases, ozone and aerosols, increased nitrogen availability, and soil-dependent acidification in terrestrial systems lead to reduced plant diversity in wild (Bobbink *et al.*, 2010; Valliere *et al.*, 2017). Industrial–based soil contaminants are of growing concern because of the increased ownership of motor vehicles, mining, and industries. Vehicular exhaust pollutants comprising polyaromatic hydrocarbons and tetraethyl lead (now in decline due to conversion to unleaded fuel) are deposited along the motorways and are increasing quantities of toxic metals deposited on the ground (Davies & Osano, 2005; Olade, 1987). A literature synthesis from Latin America recently (Marzio *et al.* 2019) found relatively high levels of metal contamination, primarily emanating from industrial activity, intensive agriculture, and urban contamination, with serious implications for wild species such as sharks.

It is worth mentioning that hunting with lead ammunition is now the main source of human-induced lead emissions to the soil in the Europe (Tukker *et al.*, 2006), with potential implications for soil fauna. For instance, wild-growing mushrooms, exceptionally prized given the myriad of human-health benefits, are significantly affected by heavy metals (Dowlati. *et al.* 2021). It is well documented that mushrooms' fruiting bodies can bioaccumulate heavy metals (Garcia *et al.* 1998; Barua *et al.* 2019) in concentrations far higher than what is found in agricultural crop plants, vegetables, and fruit (Zhu *et al.*, 2011). For example, in Yunnan Province, one of the leading production areas of wild edible mushrooms in China, the wild edible mushrooms are endangered by various pollutants, especially heavy metals, due to rapid urbanization and industrialization (Luo, 2013). The concentration of arsenic, cadmium and lead in mushrooms are potentially hazardous. These elements in edible mushrooms may enter the food chain and potentially harm human health. It can be seen from a study conducted by Liu *et al.* (2015) that arsenic and lead concentrations in all of the soil samples were below the safe limits and the cadmium concentrations exceeded the safe limit, indicating that the soil in the study area where the edible mushrooms grew had been significantly contaminated by cadmium. The cause of the contamination might be the industries in the southern region of China (Fang *et al.*, 2014). There is sufficient evidence for the impact of pollution on wild growing mushrooms worldwide.

In addition to soil, water and air pollution, the other types of pollution with a profound impact on wild species and wild species include noise pollution, light pollution and radioactive pollution. For instance, chronic and acute marine noise pollution produced by several human activities – such as maritime traffic, pile driving, and air guns cause detectable effects on intraspecific communication, vital processes, physiology, behavioral patterns, health status and survival of marine species, including some keystone predators and habitat-forming species (Di Franco *et al.*, 2020). These individual-based effects may cascade to the ecosystem-wide impacts. Moreover, artificial light at night and noise have been found to interact and produce complex and novel effects on model songbird species, thereby pointing to multisensory pollution being a considerable threat to wild species and stress the importance of including both these anthropogenic stressors in future assessments of the ecological effects of urbanization and human activity (Dominoni *et al.*, 2020). There is sufficient evidence to show that the pulsed telephony microwave radiation can produce adverse effects to wild species by way of affecting nervous, cardiovascular, immune and reproductive systems (Balmori, 2009). Therefore, utmost care must be exercised in installing such towers and technology in and around the protected areas that inhabit invaluable threatened wild species.

4.2.1.7 Environmental hazards

4.2.1.7.1 Overview

This section reviews environmental hazards, specifically geological or geophysical hazards that originate from internal earth processes (earthquakes, volcanic activities, landslides, tsunamis), and biological hazards. Hydrometeorological hazards, which are of atmospheric, hydrological or oceanographic origin (tropical cyclones, floods, drought, heatwaves, heavy rainfall, storms, and cold spells), are dealt with in section 4.2.1.2. Environmental hazards have had significant impacts on ecosystems and species. These hazard events arise from (for the case of zoonotic diseases), or their effects are exacerbated by (for the case of natural hazards), increased human interactions with their environment. Especially in the case of the coronavirus (COVID-19) pandemic, hazards from zoonotic diseases prompt us to re-examine the relationship between people and wild species.

Volcanic activities have had a significant impact on the world's ecosystem. Although volcanic soil is vibrant and helps maintain agriculture in many parts of the world, volcanic eruptions can be catastrophic, spewing lava and ashes, posing a severe risk to people and their livelihoods. Thus, volcanic activities can be considered natural sources of pollution. Ashes ejected from volcanoes can cause much nuisance to farmers, burying agricultural lands and destroying crops. The ashes can also negatively impact human health and animals, contaminating infrastructures and disrupting aviation and land transport (Small & Naumann, 2001).

The numerous active volcanic mountains in Africa are exemplified by the frequent rage of the Virunga Mountains. Their plumes are displaced over a long distance and cause changes to the quality of rainwater, including acidity (pH up to 2), increased concentrations of Fluoride (up to 2,400 mg/L), Chloride (up to 1,750 mg/L) and Sulphide (up to 10,000 mg/L). These events have detrimental effects on the equatorial rainforest and likely impose possible strain on the dwindling populations of gorillas *(Gorilla beringei)* (Delfosse, 2005; Plumptre *et al.*, 2007; Vaselli *et al.*, 2008). Specifically, the gorillas,whose c ensual population stood at a finite 360 in 2003, face dual (anthropogenic and natural) challenges such as fragile and explosive political strife and raging volcanic activities of the Virunga Mountains (Gray *et al.*, 2010; Kalpers *et al.*, 2003; Vaselli *et al.*, 2008).

4.2.1.7.2 Pandemic and sustainable use of wild species

The Corona disease 2019 (COVID-19) pandemic has caused millions of deaths and suffering, brought challenges to public health, food systems, education and employment, and disrupted economy and human activities at an unprecedented scale (FAO, 2020a; ILO *et al.*, 2020). A review of approximately 500 emerging infectious diseases, including pandemics, found that almost all pandemics and the majority of the emerging infectious diseases are caused by wild species-origin pathogens (60% are dominated by zoonoses, of which 71.8% originated in wildlife), showing a linkage between pandemics and biodiversity (Jones *et al.* 2008; IPBES 2020). The emergence of zoonoses is correlated with wild species (mammalian) diversity, human population density, and anthropogenic environmental destruction (Allen *et al.* 2017; Jones *et al.* 2008; Gibb *et al.* 2020). Studies have suggested that the emergence of the disease pandemics such as Zika (2015–2016), H1N1 (2009) and SARS (2002–2004) is the results of ecosystem alteration due to land-use change, deforestation, agricultural expansion and intensification, wild species trade, consumption and other drivers that disrupts natural interactions among wild species and their microbes, increases contact among wild species, livestock, people, and their pathogens (IPBES, 2020; Nuñez *et al.*, 2020). Land-use changes, deforestation/forest fragmentation/ habitat fragmentation, agricultural development/irrigation, and urbanization/suburbanization mainly cause increased pathogen transmission through alteration of the vector, host, and pathogen niche, changes in host and vector community composition, changes in behavior or movement of vectors and/or hosts, altered spatial distribution of hosts and/or vectors (Gottdenker *et al.*, 2014). A recent analysis of 6801 ecological assemblages and 376 host species worldwide showed that the richness and abundance of human-shared pathogens are higher in the sites under substantial human use compared with undisturbed habitats (Gibb *et al.*, 2020).

There are several ways zoonoses spillover—a process that enables a pathogen from a vertebrate animal to establish infection in a human— from wild species to humans (Magouras *et al.*, 2020; Plowright *et al.*, 2017). First direct contact of humans with wild animals. The spillover of pathogens from wild species to humans can occur directly through activities and hobbies of humans such as hunting, farming exotic animals, companionship and butchering wild species. For example, wild meat consumption is linked with the emergence and outbreak of the Ebola virus in the countries of central and west Africa (Coltart *et al.*, 2017; Holmes *et al.*, 2016). The origin of HID/AIDS caused by HID-1 and HIV-2 viruses are linked with repeated exposure to wildlife (Sharp & Hahn, 2010). Another way of increasing direct contact of wild species with humans is caused by selling and butchering live animals in wet markets (Orenstein, 2020). For example, waterfowl, especially Anseriformes (ducks, geese and swans) and Charadriiformes (gulls, terns and sandpipers), are thought to be the natural reservoir of Influenza type viruses (Webster *et al.* 1992; Olsen *et al.* 2006) and transmission of the virus from these avian species to humans might occur in bird markets (Lycett *et al.*, 2019). A sizeable amount of transactions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora -listed species could carry potentially zoonotic risks (UNEP-WCMC & JNCC, 2021). Similarly, the SARS virus outbreak (2002–2003) potentially originated from masked palm civets *(Paguma larvata)* sold in wild species markets in China (Wang *et al.* 2006; Xu *et al.* 2004). Similarly, avian influenza is linked with increased illegal pet trade (Kilpatrick *et al.*, 2006). Wet markets have been characterized and are stereotyped as having poor hygiene and inhuman treatment of wild animals; these in term are thought to cause immunosuppression and the spread of pathogens (i.e., carried by animals) (Fischer & Romero, 2019; Magouras *et al.*, 2020; Martin, 2009; Nakajima *et al.*, 2021). Intensive wild species farming also causes the spillover of diseases. Avian influenza circulated from Ostrich farms in Africa (Abolnik *et al.*, 2016), the recent detection of COVID-19 in mink in the Netherlands (Oreshkova *et al.*, 2020), and an outbreak of rabies in the ranched population of kudu (Scott *et al.* 2013). Nevertheless, the exact timing, place of origin and source of infection of COVID-19 is still not fully known (Frutos *et al.*, 2021; Pekar *et al.*, 2021; Wang *et al.*, 2020). Furthermore, livestock and companion animals are also linked with spillover and amplification of emergent infectious diseases such as Nipah virus (Daszak *et al.*, 2013), Hendra virus (Plowright *et al.*, 2017) and avian influenzas (Fournié *et al.*, 2013).

Second, changes in land use such as environmental degradation, deforestation, and land conversion for agricultural land change are also associated with the disease emergence (Gibb *et al.*, 2020; IPBES, 2019a). Land use change is considered the cause of over 30% of emerging infectious diseases, including the emergence of novel zoonoses globally (IPBES, 2020; Loh *et al.*, 2015). Human-dominated landscapes harbor a higher level of species richness and abundance of wild species hosts of human pathogens (Gibb *et al.*, 2020). Land use change increases human populations into landscapes where indigenous peoples and local communities have often lived since historical times at relatively low density creating new opportunities for contact between humans and livestock with wild species, thus increasing the risk of disease transmission (Böhm *et al.*, 2013; Murray & Daszak, 2013; Rwego *et al.*, 2008). Land use change is linked with the outbreaks of Ebola (Rulli *et al.*, 2017), and Machupo virus (Aguilar, 2009). Additionally, land use change is directly connected with the increased transmission of vector-borne diseases such as Dengue fever (Vanwambeke *et al.*, 2007), malaria (Fornace *et al.*, 2019; MacDonald & Mordecai, 2019), yellow fever (Walsh, Molyneux, and Birley 1993).

Third, the anthropogenic introduction of invasive alien species is linked with disease emergence in new locations and transmission to new hosts (Cunningham *et al.*, 2017; Walker *et al.*, 2008). One of the examples of introductions and escapes of amphibians for the international pet trade causing wild species disease is chytridiomycosis that has caused amphibian declines and extinction (Cunningham *et al.* 2015; Beard and O'Neill 2005).

Fourth, climate change enhanced the spillover risk (IPBES, 2020); therefore, anthropogenic climate change that causes human and animal movements is also considered a driver of emergent infectious disease. Climate change allows microbes to make contact with new hosts to potentially invade new niches (Pecl *et al.*, 2017). Climate change also facilitates the rapid expansion of the host range and microbial species' capacity to colonize new hosts (Hoberg and Brooks 2015; Brooks, Hoberg, and Boeger 2019). The recent spread of bluetongue disease in Europe is caused by the climate-induced migration of biting midge vector (Purse *et al.*, 2008). Similarly, the northern migration of vector-borne diseases such as tick-borne encephalitis is also facilitated by climate change (Hvidsten *et al.*, 2020; Semenza, 2019).

Overall, the drivers of sustainable use of wild species, such as unsustainable and extractive use of wild species, including wild species trade, land use change, climate change, and invasive species, not only have consequences on the sustainable use of wild species but also are connected to the emergence, amplification and spread of disease-causing pathogens. These drivers facilitate the spillover of novel or known pathogens from wild hosts to humans, causing severe impacts on human life, economy, and society. Additionally, domestic animals are hosts of several pathogens, including Tuberculosis, Brucellosis (Rahman *et al.*, 2020). The expansion of the domestic animal trade has led to deforestation and land use conversion. Therefore, curbing those drivers, such as preventing deforestation and regulating wild species trade, including the sale and consumption of wild animals that can host dangerous pathogens, may reduce the risk of future pandemics (Dobson *et al.*, 2020). The protected areas with intact natural habitats and limited disturbances may play a role in buffering against novel disease outbreaks and spillover of diseases from wild species to people by maintaining ecosystem integrity (Di Marco *et al.*, 2020; Terraube & Fernández-Llamazares, 2020). Furthermore, the restoration of biodiversity is a crucial frontier in the management of zoonotic disease risk (Keesing & Ostfeld, 2021).

4.2.1.7.3 Terrestrial animal harvesting

There is evidence that intensified contact between people and wild species arising from the encroachment of human activities into forest ecosystems and increased demand for meat and medicine from wild species lead to transmission of zoonotic diseases, which constitute about 70% of known emerging diseases (Volpato *et al.*, 2020). In Malaysia, a combination of deforestation, drought, and wildfires has led to alterations in the population movements and densities of flying foxes, large fruit bats known to be the reservoir for the zoonosis Nipah virus (Chua *et al.*, 1999). Although elite gastronomic consumption is behind wild species consumption in Asia, food insecurity and poverty increase wild meat hunting in Africa (Volpato *et al.*, 2020), evidence for clear linkages are lacking. There is a gap in the literature on the link between environmental hazards and hunting. While studies in Sub-Saharian Africa demonstrate such links, for example, poor fish harvest resulted in an increased number of bushmeat hunters in Ghana (Brashares *et al.*, 2004), agricultural productivity was a driver of incidences of human Ebola virus infections in Sub-Saharan African countries over the 1976–2013 (Price, 2015), and the link between the West African Ebola virus epidemic with decreased consumption of bushmeat (Ordaz-Németh *et al.*, 2017), which can be inferred as reduced hunting of wild species for wild meat. While it can thus be interpreted that an increasing number of zoonotic diseases can result in a reduction in wild meat consumption, which would then lead to increased pressure on other wild species, such as through fishing, the evidence is unresolved.

4.2.1.7.4 Trends in environmental drivers

Environmental drivers, directly and indirectly, change the distribution and abundance of species and damage service provision of ecosystems and wild resources. Climate change, for example, causes shifts in the distribution and abundance of species; more than 80% of the species that show changes are shifting in the direction expected based on known physiological constraints of species (Root *et al.*, 2003). Climate change will also lead to the extinction of many species in key regions (Thomas *et al.*, 2004). The frequency and intensity of extreme events, such as heatwaves, droughts, heavy rainfall, storms and, coastal flooding, marine heatwaves are expected to increase with climate change (Mitchell *et al.*, 2006). These extreme events cause damage to the ecosystems and habitats of wild species. Invasive species are also driving changes in ecological systems altering communities and ecosystems; however, the evidence supporting a general and primary role for invasive species in extinctions remains limited (Gurevitch & Padilla, 2004). Land degradation, particularly land-use-related pressure, has reduced local species richness by an average of 13.6% and the total abundance of plants and animals by 10.7% compared with what they would have been in the absence of human effects (Newbold *et* *al.*, 2015). Pollution of land, air and water has a significant impact on biodiversity. One notable example of the pollution causing local extinction is the 'dead zone' in the Gulf of Mexico (i.e., mass mortality of coral reefs). Dead zones are the areas of water bodies where the survival of aquatic life is impossible due to low oxygen levels. Deforestation and forest disturbances, particularly in tropical regions, contribute to biodiversity loss, with the most significant adverse effects on species of high conservation and function value (Barlow *et al.*, 2016). Sub-Saharan Africa has a youth population growth rate that is the highest of any region at nearly 20% (United Nations, 2019).

4.2.2 Political drivers

4.2.2.1 Overview

Decisions about the use of wild species define and are determined by the diverse systems of governance that exist at local to global scales. Formal and informal rules vary around the globe and by different species; much more evidence can be found about the structures and processes of formal governance (e.g., statutory international agreements) and their strengths and weakness in managing wild species use. The customary laws and rules developed by indigenous peoples and local communities are less well documented by comparison. The informal or customary rules governing wild species' use and trade are also poorly documented.

Most wild species are defined as public goods or as common property; fewer wild species are defined as private property or found in privately owned spaces. Most governance arrangements dealing with wild species focus on terrestrial megafauna, forests, and freshwater fisheries, with fewer regulations related to marine species. Plants and other non-timber forest products have largely been overlooked, and their harvest and use are poorly regulated (Laird *et al.*, 2010). Regulation of non-extractive use is an emergent area of governance but is poorly developed around the globe.

In regions where wild species have historically declined or extirpated, there are generally much stronger formal regulations to protect what remains; many of these regulations are highly restrictive of any use. In other regions, considered to have a larger number of wild species and spaces, there tend to be few rules related to use, or they are weakly enforced. A critical concern is regions where wild species use appears unsustainable (by various indicators), but there is a paucity of formal and informal rules for management.

Informal institutions (e.g., customary laws) are also crucial in shaping use; they exist even where formal rules do not; indigenous peoples and local communities, for example, who have strong relationships to place and histories of use of wild species have well-developed rule systems (i.e., rules-in-use). There is growing evidence that these kinds of institutions may be more effective at mediating or managing for sustainable use. Where governance systems are highly pluralistic (inclusive of different values of stakeholders) and are flexible and adaptive to ecological and social conditions, wild species use is managed to ensure both social and environmental sustainability. Many international agreements and institutions influence the rule systems within and between different nation states, mainly where there are transboundary use issues (Liu *et al.* 2020). These rule systems are viewed as increasingly important as the world becomes more interdependent due to travel and communication technology and globalized economies (Marauhn, 2013; Paavola, 2005). This section aims to assess how different political drivers influence the sustainable use of wild species, their synergies and interactions.

4.2.2.1.1 Methodology

A systematic literature review was carried out in respect of critical areas of literature using terms such as political drivers, land tenure, governance, political rights, gender, indigenous peoples and each of the regions, and practices (e.g., hunting, fishing). Authors found over 5000 sources. A review of these sources identified major themes and interpretations of patterns in political drivers. Experts developed the sections with 20 + years of experience related to aspects of biodiversity conservation and in the social sciences. Where there were gaps in regions, practices, etc., case studies were developed to illustrate an essential dimension of the political driver and its impacts on practices and uses.

4.2.2.1.2 Gaps

- There is greater published evidence about formal systems of governance when compared to informal systems and customary law, including that of indigenous peoples.
- There are gaps in the literature related to the governance of gathering and non-extractive uses (including viewing) when compared to the practices of hunting, fishing and logging.
- Regional gaps exist in literature published in English concerning governance for many parts of central Asia, Russia and some parts of Latin America, particularly in relation to informal institutions and governance systems of indigenous peoples and local communities.

4.2.2.1.3 Definitions

Governance is fundamentally about the distribution of power among different members of society; it encapsulates the interactions among structures, processes, rules and traditions that determine how people in societies make decisions and share power, exercise responsibility, ensure accountability, and how stakeholders have a say in the management of natural resources (Lebel *et al.*, 2006; Raik & Decker, 2007). It includes formal laws and structures but has other types of collective action, rulemaking, institutions, and general social coordination (Dietz *et al.*, 2003). Governance research also addresses impacts on sustainable use (Kenward *et al.*, 2011).

In this assessment, the experts focus on environmental governance or the rules, practices, policies, institutions, and mechanisms that shape how humans interact with the environment and influence environmental outcomes (Lemos & Agrawal, 2006). It includes those mechanisms, and tools that allow actors (public and private sector, non-governmental organizations, local communities) at different scales (local-global) to manage conflicts, seek points of consensus and take accountable actions and decisions (Lemos & Agrawal, 2006).

Although these governance arrangements can be viewed in isolation from one another, a system view of institutions is needed to account for how different actors, laws, regulations, and mechanisms of governance function together (**Figure 4.5)**. Pluralistic governance arrangements – a mix, hybrid, or bricolage of formal and informal meetings – tend to coexist at the same time (Jentoft & Bavinck, 2014; North, 1991). Different actors (e.g., governments) can be simultaneously involved in multiple, and sometimes conflicting, positions of governance at other times (Berkes, 2005).

Institutions, structures and processes of environmental governance are among the most important drivers of the use of wild species. They are equally critical mediators of how other drivers (e.g., climate change) influence use. Institutions are commonly defined as the 'rules of the game,' norms, values and procedures which shape human interactions with nature (Brechin *et al.*, 2003; McCay & Jentoft, 1996). They can give rise to compliance or resistance. An important question guiding the analysis of the evidence presented in this section is what are the characteristics of good governance regarding the use of wild species? In other words, what governance arrangements protect or contribute to sustainable use?

Institutions that operate from the local to a global level and comprise formal arrangements (e.g., laws, regulations, treaties) are also referred to as statutory or

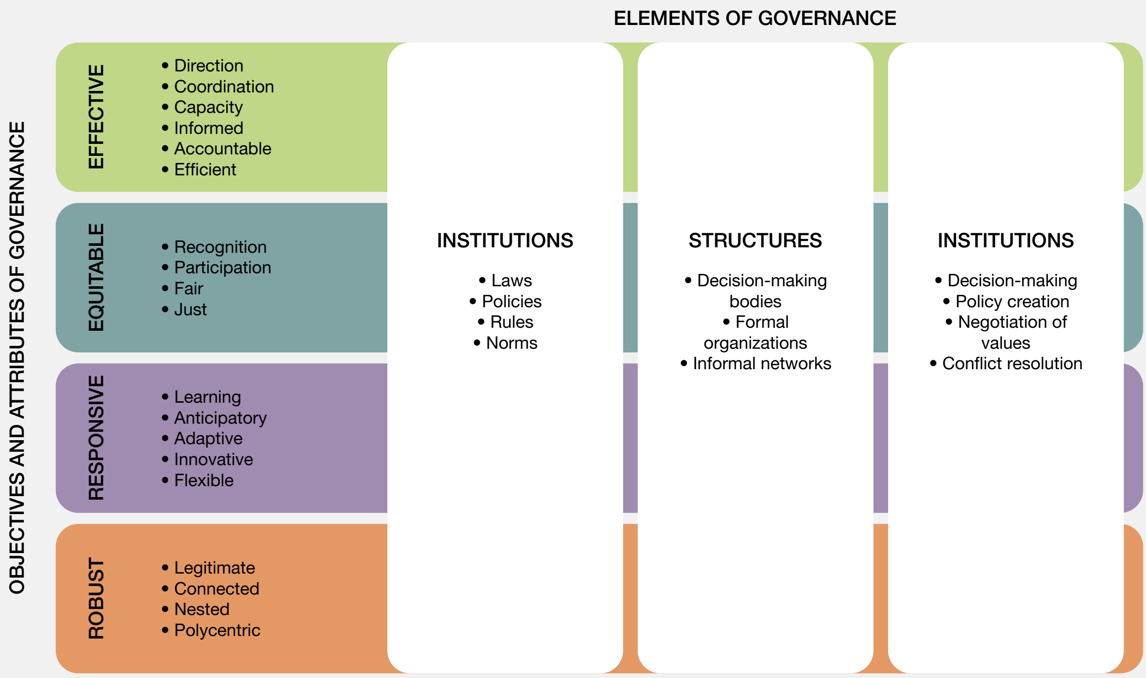


Figure 4 5 **A practical framework for understanding the objectives, attributes, and elements of environmental governance.**

Source: Bennett and Satterfield (2018) under license CC BY-4.0.

de jure governance arrangements. In contrast, informal arrangements (e.g., social norms, taboos, sanctions) with informal institutions are referred to as customary or *de facto* governance arrangements (North, 1991). Institutions can be seen as different (in)formal regimes and coalitions for collective action and inter-agent coordination, ranging from public-private cooperation and contracting schemes to organizational networking and policy arrangements (Geels, 2004; Teisman & Klein, 2000).

Policies are defined as those deliberate and specific principles that guide decisions or express a specific intent; like laws, they are implemented through specific policy instruments, procedures and mechanisms, the outcomes of which are measured against the original intent. Environmental policy focuses on problems arising from human impact on the environment (Schelly & Banerjee, 2018). For this chapter, processes refer to the various kinds of negotiated relationships and interactions between actor groups and how they lead to solving a problem or conflict of sustainable use. A variety of synthesis work related to environmental governance points to various success factors or design principles **Box 4.1**. (Armitage *et al.*, 2011; Bennett & Satterfield, 2018; Lemos & Agrawal, 2006).

Much about governance arrangements, and their success in addressing questions of sustainable use, hinges on property rights associated with the species and its ecosystem, including its definition as public, private, club, or commons. Most wild species globally are framed as commons, others as a public good, with fewer defined as club goods or private property. While a *de facto* position of governments is to enclose wild species that exist as a common and govern use like other kinds of public or private goods, this is not feasible. Different types of institutions (pluralism) are needed for different kinds of resources and in various types of property rights contexts (Ostrom 2009).

4.2.2.2 Formal, statutory governance arrangements

Key messages:

- A growing number of formal laws and policies supporting sustainable use have been developed among nation-states and at regional scales that facilitate sustainable use. Most of these laws relate to large fauna and timber, with more limited laws and policies related to smaller fauna and flora.
- Formal governance systems do not commonly account for indigenous peoples' and local communities' values of biodiversity but tend to support privatization and commercialization.
- Many policies governing wild species use are weak (lacking clarity in institutional responsibility). Many also lack legitimacy and are difficult to enforce due to a lack of engagement and consultation with stakeholders (mainly rural communities). Lack of coordination among different policies (which can sometimes conflict) compounds the challenges of legitimacy and enforcement.
- Pluralistic approaches that account for the diverse values and uses of wild species can be more effective in supporting and nurturing norms and practices of sustainable use.
- In cases where multiple institutions have been unsystematically developed (in an adhoc fashion), some ambiguities and conflicts complicate understanding and compliance with the "rules" of sustainable use.
- Pluralistic approaches that draw upon international and national policy frameworks and laws, and integrate customary law and local practices, are the most

Box 4 1 **Success factors for governance systems in managing the use of wild species.**

- Is there a good fit between the scale of the rule system and the scale of the use issue? Is there coordination within and between different systems of rules (across geographic scales) and between formal and informal rule systems (e.g., customary law of indigenous peoples and local communities)?
- Can rule systems respond to variability in patterns of wild species use? Are the rule systems adaptive and flexible (not rigid)?
- Do the rule systems include mechanisms of ongoing learning (i.e., monitoring)?
- Are the rule systems based on science and other kinds of knowledges of stakeholders and indigenous peoples and local communities dependent upon wild species?
- Are the rules seen as legitimate and enforceable?
- Are there diverse stakeholders engaging in rulemaking?
- Are the rule systems considered just (able to address inequities in the benefits of use and manage conflicts between different users)?

effective for supporting and promoting the sustainable use of wild species. This requires ensuring that conflicts and overlapping mandates are avoided and coordination and complementarity encouraged.

- Institutions that embrace science and indigenous and local knowledge in how they are designed and implemented are more effective in that they match ecological and socio-economic conditions; ongoing monitoring and evaluation of the effectiveness of institutions and their sensitivity to variabilities and changes in ecosystems and society also produce more sustainable outcomes.

- However, laws regulating wild species are often of poor quality, lack clarity in institutional responsibilities, do not result in participatory processes, engagement and consultation with stakeholders, particularly rural communities, are not coordinated with other measures, and are not implemented. This limits their effectiveness.

4.2.2.2.1 International agreements and conventions

Since at least the late 1800s and increasing regularity in the past half century, countries have negotiated hundreds of international legal agreements to address environmental problems they cannot resolve alone" (Mitchell, 2003). Some of these agreements pertain to the sustainable use of wild species. International agreements are defined here as legally binding arrangements among two or more states (e.g., treaties, conventions, accords, or modifications of such structures) (Aust, 2013).

The Convention on Biological Diversity is among the most relevant to this assessment, as its core objective is to facilitate sustainable use: "… the conservation of biodiversity, the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilization of genetic resources…" (CBD, 2020). According to the Convention, member states must "as far as possible and as appropriate, adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity" (CBD 2020, Article 11).

The Convention on Biological Diversity implementation has been enlivened by creating targets, guidelines and principles to conserve biodiversity. The Aichi Targets aim to "reduce the direct pressures on biodiversity and promote sustainable use"; a key factor and mechanism in consideration is poverty reduction (CBD, 2020). These targets, however, have not been easy to reach for many member states, as indicated by the IPBES Global Assessment (IPBES, 2019a). This may be due to ambiguity in, and excessive complexity of, the targets and a lack of appropriate and quantifiable measures for tracking progress, as well as a lack of political will to make the necessary changes in the management and policy (Butchart *et al.*, 2019).

Strategies to achieve these targets developed by some nation-states include a range of formal and top-down approaches aimed at planning, education and monitoring. The targets that are anticipated to be met or exceeded include Target 11 (Protected Areas). "Recent analysis shows that if national commitments are implemented as proposed, global protected area coverage will be on track to meet or exceed the 17% and 10% coverage targets for terrestrial and marine protected areas" (Bacon *et al.*, 2019).

Part of the challenge in meeting Aichi Targets has been the limited availability of meaningful indicators and mechanisms for tracking progress. To date, none of the Aichi Targets have been met; the most significant progress has been made on Aichi Targets 1, 11, 16, 17, 19 (CBD, 2020).

Various efforts have been made to assess nation-state progress towards these targets. Although wealth (measured by the gross domestic product) may be a factor, "quality of governance" explains much of the variation in public and state investment in biodiversity conservation (Baynham-Herd *et al.*, 2018) **(Figure 4.6)**. Other analysis has revealed that greater engagement in developing national plans for achieving biodiversity (Target 17) does not correlate with greater gross domestic product (Whitehorn *et al.*, 2019).

The Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity (CBD, 2004) challenges states to examine formal legal instruments for achieving these targets and customary law and traditions when drafting new legislation and regulations and creating cooperative and supportive linkages between all levels of governance. Throughout, the principles address drivers and causes of unsustainable use, including deficient policy frameworks, lack of respect for the rights and stewardship of local communities (Principle 2), market distortions (Principle 3), the need for integrated and interdisciplinary research and participatory approaches (Principles 6 and 9), and the need for more effective education and public awareness programs on sustainable use (principle 14). The Convention on Biological Diversity process, in turn, spurs national governments to draft legislation to implement commitments under the Convention on Biological Diversity and creates a forum for dialogue and global decision-making relating to biodiversity conservation and the sustainable use of its components. It is recognized that both top-down (e.g., statutory laws) and bottom-up approaches (i.e., informal and customary institutions) are needed and should work together to achieve the targets of sustainable use as in the Convention on Biological Diversity.

Although highly problematic and efforts to meet associated targets are opaque in many jurisdictions, the Convention

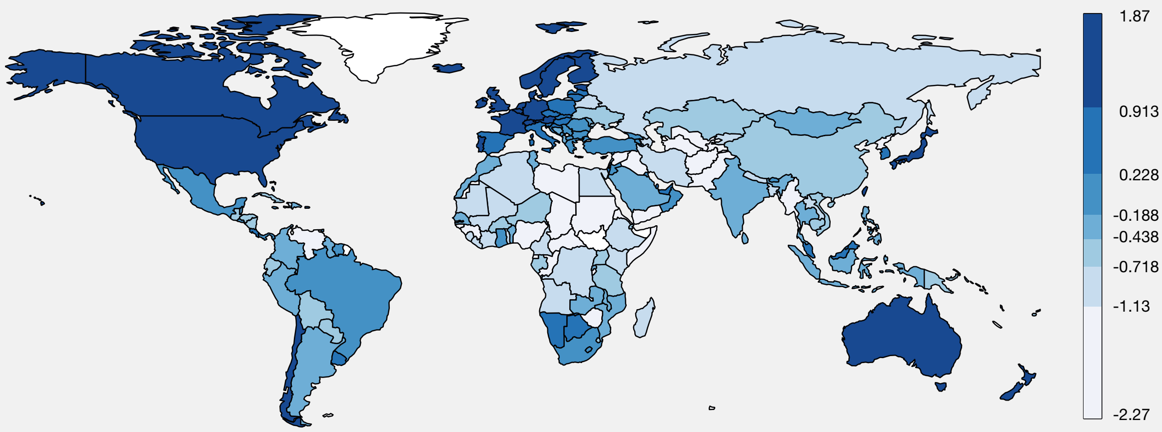


Figure 4 6 **Global distribution of the World Bank's worldwide governance indicators.**

This map is directly copied from its original source (Baynham-Herd et al., 2018) and was not modified by the assessment authors. The map is copyrighted under license CC BY 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

Box 4 2 **New Zealand National Targets to Enhance Implementation of the Convention on Biological Diversity: "Whanau, Hapu and Iwi are Better Able to Practices their Responsibilities as Kaitiaki" (Related to Aichi Target 1, 18).**

Sources: Department of Conservation (2019).

Māori have a strong interconnection with their natural environment governed by the cultural ethic of kaitiakitanga (guardianship). This ethic confers obligations on whānau (family), hapū (sub-tribe) and iwi (tribe) (collectively tangataTangata whenua) to steward biodiversity as articulated as taonga (treasures), including species of indigenous flora and fauna, wai māori (freshwater), wāhi tapu or wāhi taonga (treasured or sacred sites), and whenua (land). The Treaty of Waitangi settlement process has been one part of this assessment, with settlements achieved with 86 groups to date. New Zealand Government engagement with Māori through the relationships supported by these settlements has shown that tangata whenua have worked proactively to lead locally based and culturally monitored conservation projects and indigenous biodiversity protection. For example, Waikato- Tainui fisheries bylaws, effective from 2014, will continue to support sustainable fishing practices and native eel migration while recognizing traditional management practices. The Manaaki Tuna Project (supported by the Waikato River Clean-up Trust) is a completed multi-year project to gather and preserve Waikato-Tainui histories associated with the Waikato River. Tracking the implementation is being done through several quantitative and qualitative indicators (e.g., with the intellectual property being held by tangata.

on Biodiversity remains a critical tool for signaling the importance of biodiversity conservation and sustainable use of wild species.

The Convention on the Conservation of Migratory Species of Wild Animals (CMS) provides a global platform for the conservation and sustainable use of migratory animals and their habitats. The Convention brings together the States through which migratory animals pass, the Range States, and lays the legal foundation for internationally coordinated conservation measures throughout a migratory range. The aim of the Convention on the Conservation of Migratory Species of Wild Animals is the long-term conservation of migratory species that cross international jurisdictional boundaries in the course of their migration. It has been negotiated with the primary objective to endure the coordinated management of migratory species shared by multiple states. While the convention does not focus on harvest per se, it includes provisions that influence the possibility of species used by Parties, e.g., about taking of species listed in its Appendix I. The Convention also acts as a framework convention, under which tailored multilateral agreements on individual species or groups of related species can be negotiated at regional or global levels. The Convention includes animals of the following classes: Mammalia, Aves, Reptilia, Actynoptergii, Chondrichthyes and Insecta.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which came into effect in 1975, was developed to ensure international cooperation for protecting certain species of wild fauna and flora against overexploitation through international trade. CITES has 183 contracting Parties (www.cites.org accessed 30 April 2021) and it regulates international trade in approximately 38,700 species, 85% of which are plants. Species are listed in one of three appendices with approximately 3% of species (~1,100) included in Appendix I, 97% of species (~37,400) are included in Appendix II, and ~240 species are listed in Appendix III. The appendices have different legal implications and give different protection status as follows:

- Appendix I includes those species threatened with extinction which are or may be affected by trade. Trade in specimens of these species is subject to particularly stringent regulation and can only be authorized in exceptional circumstances. Commercial trade in wild sourced specimens is prohibited.

- Appendix II includes those species, which may become threatened with extinction unless trade in specimens of such species is regulated to avoid utilization incompatible with their survival. It may also include closely related species that must be regulated to make enforcement easier, sometimes referred to as 'look alike' species. Commercial trade in these species is allowed if it is not detrimental to the survival of the species.

- Appendix III includes species that any Party identifies as needing regulation within its jurisdiction to prevent or restrict exploitation and which require the co-operation of importing Parties to regulate trade.

CITES aims to protect wild species from over-exploitation associated with international trade and avoid utilization incompatible with their survival (Hutton & Dickson, 2000). Although CITES is not *per se* a treaty to promote the sustainable use of wildlife (OECD, 1997), the CITES vision 2008–2020 aimed to "Conserve biodiversity and contribute to its sustainable use by ensuring that no species of wild fauna or flora becomes or remains subject to unsustainable exploitation through international trade" (Wijnstekers, 2018). Similarly, the vision for CITES post-2020 is that "by 2030, all international trade in wild fauna and flora is legal and sustainable, consistent with the long-term conservation of species, and thereby contributing to halting biodiversity loss, to ensuring its sustainable use, and to achieving the 2030 Agenda for Sustainable Development" (CITES CoP 18.3, 2019). The effective implementation of CITES would therefore be expected to act as a driver for more sustainable levels of use and trade as well as the adoption of practices and processes that ensure greater levels of sustainability. This should be true for all species listed in CITES Appendices but could also be a more general driver for ensuring that the use of wild species is sustainable by raising awareness of the extent and impacts of trade in wild species, the provision of tools and resources, promotion of institutions to ensure sustainable use, and adoption of more sustainable practices by affected industries. The purpose of this section is to assess the evidence for CITES acting as a driver of more sustainable levels of use of wild species. Discussion of CITES as a policy tool and options for better governance of trade in wild species is provided in Chapter 6.

The assessment included evidence in the period from 1985–2021. CITES came into effect in 1975, so the period being assessed allows ten years from inception for the resolutions and decisions of CITES to take effect. The assessment relied extensively on information curated by CITES (www.cites.org), which includes all formal documentation, information documents, reports and links. To assess independent sources of evidence, an initial search was undertaken using the Web of Science in the period 1985–2021 for "Convention on International Trade in Endangered Species" OR "CITES. This yielded 416 publications. For additional analysis on non-detrimental findings, the search comprised terms "non-detriment* finding" OR "NDF" AND "CITES," and the search was conducted in Google Scholar and Web of Science. Additional sources of evidence were obtained from the reference lists of these publications and CITES information documents and resources accessed from the website (www.cites.org).

Convention on International Trade in Endangered Species of Wild Fauna and Flora as a driver for more sustainable practices

CITES adopted a series of indicators to measure progress with the vision 2008–2020 (CITES Strategic Vision 2008–2020, Notification 2015/032 Annex 2). Several of these indicators are appropriate for the assessment of CITES as a driver, particularly those that measure progress with laws, institutions and tools to ensure that trade in wild species is sustainable and those that measure outcomes for the species regulated under CITES.

In terms of improving laws, institutions and tools, CITES require all contracting Parties to put in place appropriate legislation and institutions to implement the Convention, including separate Management and Scientific Authorities. One of the primary roles of Scientific Authorities is to assess risks associated with trade and determine that trade is not "detrimental to the survival of that species" (Article III, 2 (a), 3 (a), 5(a); Article IV, 2 (a), 6 (a)) and "maintains that species throughout its range at a level consistent with its role in the ecosystems in which it occurs" (Article IV, paragraph 3). These are consistent with the ecological dimensions of sustainable use identified in Chapter 2. As a result, the increase in Parties to CITES from 85 to 183 should have resulted in the establishment of institutions and governance systems to ensure the use of wild species is more sustainable. Parties to CITES vary in the extent to which they have appropriate legislation and institutions, reported in 2019 as 32 (17%) with legislation that does not support the implementation of CITES, 43 (23%) with legislation that only partially supports the implementation and 101 with legislation and institutions required to fully implement CITES (CITES CoP 18 Doc. 26 (Rev 1) 2019). This means that the systems to ensure more sustainable use have been strengthened as a result of CITES, at least in the 55% of Parties who are fully compliant with CITES and to a lesser extent in the 23% that are partially compliant. The remaining levels of non-compliance weaken the role of CITES as a driver of the more sustainable and legal use of wild species.

A further question is whether non-detrimental findings in all these countries have been implemented in a way that promotes more sustainable practices or levels of harvest and trade. CITES Resolution Conf 16.7 rev. CoP 17 emphasizes that non-detrimental findings should be based on the best available science, and guidelines for non-detrimental findings have been periodically refined through workshops and working groups to support this objective (Smith *et al.*, 2011). General guidelines for non-detrimental findings (Rosser & Haywood, 2002) have included guidance and templates to assess the impacts of harvest and trade based on biological attributes of the species together with information on population status, management and controls, protection, and levels of trade. Further guidance has been developed at least for trees (Wolf *et al.*, 2018), perennial plants (Wolf *et al.*, 2016), sharks (Mundy-Taylor *et al.*, 2014), aquatic invertebrates, and snakes (Natusch *et al.*, 2015) and case studies have been compiled for more than 60 taxa comprising all the major plant and animal groups regulated under CITES (www.cites.org/eng/prog/ndf/index.php). The literature review in Google Scholar identified 327 publications referring to non-detrimental findings, of which 238 dealt with taxon specific information and a further 99 dealt more generally with non-detrimental findings. The templates and tools, therefore, exist to support the implementation of non-detrimental findings for the ~ 37 420 species regulated under Appendix II of CITES.

The levels of uptake and application of non-detrimental findings standards are harder to assess. Two of the indicators for the implementation of the CITES Strategic Vision 2008–2020 were (i) the number of Parties that have adopted standard procedures for non-detrimental findings, and (ii) the number of surveys of CITES listed species undertaken by exporting States to support non-detrimental findings (CITES 2015). These metrics can provide critical insights into how non-detrimental findings are being implemented. However, although all Parties have to undertake non-detrimental findings and are supposed to report against the agreed indicators, there is no global summary record of progress with these indicators (CITES Secretariat, March 2021). A report compiled for the European Commission (Musing & Shiraishi, 2019) noted that 20 member States had undertaken surveys of the population status of at least some CITES listed taxa, five had undertaken studies of trends and impacts of trade on Appendix II species, and three had published the non-detrimental findings undertaken for CITES taxa. These limited data are insufficient to allow any assessment of the standards being applied to non-detrimental findings nor whether the application of non-detrimental findings has had positive outcomes for the affected species.

One indicator from the CITES Vision 2008–2020 that does measure the potential impact of non-detrimental findings as a driver of more sustainable levels of use, is "the number of Appendix-II species for which trade is determined to be non-detrimental to the survival of the species as a result of implementing recommendations from the Review of Significant Trade." The Review of Significant Trade in specimens of Appendix II species (CITES Resolution Conf 12.8 (Rev CoP18), was designed to identify Appendix-II listed species that may be subject to unsustainable levels of international trade, i.e., where non detrimental findings may be failing to achieve their objective. The process involves monitoring recorded levels of trade in Appendix II species over five years and identifying species for further analysis based on various risk factors, specifically their threat status, high volumes in trade, a sharp increase in trade or increasing levels of trade. These species are then subjected to additional review and input from Range States to determine whether trade is sustainable and conforms to Article IV of the Convention. If trade in these species and from specific countries is deemed to not comply with Article IV, this can result in recommendations to strengthen the capacity of states to ensure sustainable use or to sanctions such as trade suspensions until the trade is compliant. The number of country-species combinations subject to recommended actions due to significant trade reviews varies between years. Between 1975 and 2000, there were 138 recommendations arising from the review of significant trade (RS process (IUCN, 2000), and, in 2020, suspensions were in force for trade in 41 species from 19 countries as a result of the review of significant trade.

In some cases, species have been subjected to repeat reviews due to concerns about unsustainable trade such as the grey parrot, *Psittacus erithacus*, which was included in the review of significant trade in 1988, 1992, 2006 and 2014 (VKM, 2020). Given that there are 37 420 species on CITES Appendix II, which would all be eligible for review if there were concerns about levels of trade, the implication is that trade in the vast majority of taxa is regarded as sustainable within the limits of what is assessed and monitored by CITES. However, a recent review on trade of seahorses (Foster and Vincent 2021) noted that implementation of the review of significant trade was failing to prevent trade that was not compliant with Article IV and was therefore failing in its primary mandate to ensure sustainable trade. They concluded that CITES needs to commit to more effective enforcement to improve the effectiveness of the review of significant trade, and this highlights the need for independent scientific assessments of the outcomes of CITES actions.

A further self-defining indicator of the success failure of non-detrimental findings as a driver of more sustainable use would be the uplisting of species or populations from Appendix II to Appendix I (IUCN, 2021). Between 1976 and 2020, approximately 460 species, subspecies or populations/stocks were uplisted from Appendix II to Appendix I (counted here as the taxon specified in the proposal at the time of uplisting) (data from CITES Secretariat based on records compiled by UNEP-WCMC). The uplisting implies that efforts to bring trade in wild specimens to sustainable levels under an Appendix II listing were deemed inadequate. An example is the grey parrot, with a trend from repeat reviews and trade suspensions (noted above), finally leading to uplisting to Appendix I in 2016. In contrast, species of pangolin *(Manis* spp.*)* were uplisted in 2016 in response to rapid increases in trade volumes and did not follow problems identified with non-detrimental findings. Overall, the number of uplistings from Appendix II to Appendix I remains low relative to the many species listed in Appendix II. The number of uplistings has also declined over time, with 180 taxa uplisted from 1976 to 1994 compared to only 52 from 1997 to 2019. This implies that there might have been uncertainty about the appropriate Appendix in which to list species and that the processes established to ensure sustainable use of Appendix II species were starting to have an impact. It is also worth noting that taxa uplisted from Appendix II to Appendix I are not a random subset of those listed in Appendix II -cacti make up 52% of all plants uplisted, with a further 34% comprising succulent plants; tortoises and turtles make up 61% of all reptiles uplisted and Psittaciformes (including macaws, parrots, cockatoos) comprise 67% of uplisted birds. Uplistings of mammals have been less dominated by particular taxa, with marine mammals, bats, cats (Felidae) and primates all comprising between 13% and 19% of uplisted taxa. The predominance of certain taxa in uplistings indicates particular challenges with sustainable use of these taxa.

Less formalized processes for monitoring the standards of non-detrimental findings include interactions between the Scientific Authorities of importing and exporting countries where the Scientific Authority of an importing country can request evidence relating to non-detrimental findings from an exporting country or undertake their own assessment. There is no centralized record of such requests, so it is impossible to assess the number of species or trade events where such requests have been made. However, a good example is the European Commission Scientific Review Group (https://ec.europa.eu/environment/cites/srg_en.htm) which reviews evidence of sustainability for imports of wild species and compliance with the conservation requirements of Council Regulation (EC) No 338/97. These determinations may require exporting countries to provide additional evidence to show sustainable use. Again, there have been only a relatively small number of adverse findings given the volumes of species in trade, indicating that non detrimental findings are mostly regarded as being of an adequate standard to ensure sustainable levels of use.

The search for literature regarding CITES and non-detrimental findings yielded only seven publications from Web of Science and 327 from Google Scholar, partly reflecting a greater representation of publications in non-peer-reviewed literature. This is partly to be expected, given that non-detrimental findings are designed for regulatory purposes and are not necessarily intended for publication in scientific journals. Nevertheless, the literature search yielded only a small number of publications testing the outcomes of non-detrimental findings, and this represents a data gap given the importance of non-detrimental findings for promoting more sustainable use and achieving the objectives of CITES.

Convention on International Trade in Endangered Species of Wild Fauna and Flora as a driver for sustainable and legal trade

As noted in previous assessments and reviews (Challender *et al.*, 2015; IUCN, 2000), it is difficult to identify specific indicators to determine how CITES has contributed to sustainable use of wild species. Many indicators identified in previous studies measure inputs, (e.g., the number of Parties with increased capacity), or outputs (e.g., Parties that have implemented relevant resolutions and decisions) (CITES, 2015, notification 2015/032). These indicators are more about the operations and processes. To measure the impact of CITES on the sustainable use of wild species, other indicators related to the harvest and trade of species listed as threatened or endangered would be needed (Challender *et al.*, 2015; Felbab-Brown, 2017; Foster & Vincent, 2021; IUCN, 2000).

One possible outcome of CITES listing and processes could be a reduction in the overall trade in wild species. The intention of listing species on CITES Appendix I is to halt commercial trade in wild-sourced specimens, so a reduction in trade in wild-sourced specimens would be the expected outcome for these species. The intention of listing a species in Appendices II and III is to ensure that trade from wild sources does not threaten the survival of the species in the wild. This does not necessarily equate to a reduction in use or trade. Nevertheless, CITES could act as a driver for reduced trade due to the greater regulation of trade from wild sources and increased scrutiny of the evidence that trade is sustainable.

A comprehensive analysis of CITES trade over 40 years showed that overall volumes of international trade in listed species increased from ca. 9 million 'whole organism equivalents' (WOE) per year between 1985 and 1995 to 100 million 'whole organism equivalents' per year between 2004 and 2014 (Harfoot *et al.*, 2018). Although this suggests an increase in trade, the data refer to CITES trade records and need to take into account the dynamic nature of these data (Robinson & Sinovas, 2018). Specifically, the increasing trend in trade does not take into account the addition of new Parties to CITES nor the listing of new species. These factors can contribute to increased records of trade without any actual change in trade volumes (Robinson and Sinovas 2018). For example, the number of CITES Parties increased from 85 to 180 between 1985 and 2014, with 107 and 175 Parties at the midpoint of each review period, respectively (www.cites.org). This represents an increase of between 63% and 111%, so the rise in reported volumes of trade might be explained by an increase in reporting from other Parties rather than an actual increase in trade.

Similarly, changes in the number of taxa listed in CITES also affect any assessment of changes in trade volumes. They are also more challenging to interpret due to the listing of higher-level taxa (genera, families) where the number of species is not specified. Even if the overall number of species in trade has not changed by the same order of magnitude as the change in trade volumes, the listing of highly traded taxa, such as sharks, can lead to a substantial increase in the whole organism equivalents' being reported. On the whole, it is difficult to determine whether the overall increase in 'whole organism equivalents' from 1985 to 2014 represents an actual increase in the trade volume for CITES listed species.

Evidence from specific taxa provides a more nuanced perspective on whether CITES is a driver for reduced use of wild species. Studies have shown a reduction in recorded trade in specific CITES listed taxa for some species, in some regions, and for specific periods. Reduced volumes of trade have been recorded for the following taxa: birds globally since 2005 (Harfoot *et al.*, 2018); birds in Southeast Asia (Harfoot *et al.*, 2018; Shepherd, Leupen, *et al.*, 2020) and Australia (Vall-llosera & Cassey, 2017); live reptiles from 2001 to 2012 (Robinson *et al.*, 2015); snakes (especially pythons) from 2002–2017 (Hierink *et al.*, 2020); tortoises and freshwater turtles from Asia (Luiselli *et al.*, 2016); some mammal species, although the trends are less clear (Harfoot *et al.*, 2018; Nijman, 2010); bear trade in the Czech Republic (Shepherd, Kufnerova, *et al.*, 2020); and African rosewood *(Pterocarpus erinaceus)* following listing on CITES Appendix II (Dumenu, 2019a).

Trends in trade are not always unidirectional. They often reflect changes in markets for wild species products and can include unintended consequences of CITES decisions. The causal factors for these shifts can be highly contested and are typically counterfactual, such as whether once-off sales of ivory in 2008 triggered an increase in illegal trade (Orenstein, 2013; Underwood *et al.*, 2013). The recorded reduction in levels of trade across various groups may be attributable to CITES and associated national legislation (Harfoot *et al.*, 2018; Shepherd, Leupen, *et al.*, 2020). However, reduced trade can also result from other actions such as bans on the import of birds as a measure to contain the spread of avian influenza (Challender *et al.*, 2015; Harfoot *et al.*, 2018; Vall-llosera & Cassey, 2017). There are many factors affecting levels of harvest and trade (Challender *et al.*, 2015; Sas-Rolfes *et al.*, 2019) and, as noted by Underwood *et al.* (2013) "to understand the impact of these and other CITES decisions, it is necessary to identify hypotheses linking them with trade dynamics. Because CITES decisions are implemented in a constantly changing, complex socio-economic environment, a full causal analysis is required to consider all other potential trade drivers and their interactions along the trade chain. Without this comprehensive analysis, the impact of an individual driver may be confounded with the effects of other drivers". Nevertheless, the decline in trade across a range of CITES listed taxa supports the conclusion that these outcomes have been driven at least in part by CITES decisions and associated national regulations.

A second trend that could be strongly influenced by CITES is a change away from trade in wild-sourced specimens. There has been a significant shift over the past 40 years from wild harvested specimens to animals that are claimed as captive bred and plants that are artificially propagated. This shift is especially evident for mammals, birds, reptiles, invertebrates and plants (Harfoot *et al.*, 2018; Hierink *et al.*, 2020; Hinsley *et al.*, 2018; Li & Jiang, 2014; Nijman, 2010; Robinson *et al.*, 2015; Setlikova & Berec, 2020; Vall-Llosera & Su, 2019). It should be noted that consistency across these publications is mainly because they all use the same CITES Trade Database, which is the official source of CITES data. However, some independent data sources also reflect a large proportion of trade from captive sources (Marshall *et al.*, 2020). It is not always possible to attribute these shifts away from wild-sourced specimens to a listing on CITES Appendices because captive breeding and artificial propagation can also be driven by other factors such as the need for more consistent supply, better quality, or control of the supply chain (Harfoot *et al.* 2018; Kasterine and Lichtenstein 2018). An upward trend in the number of species being captive bred and the number of breeding facilities was recorded from 1960 (IUCN, 2000), and thus precedes CITES. Still, the trend has continued since 1975, with more species affected and a greater number of facilities. The number of facilities registered with CITES for captive breeding of Appendix I animals increased from 59 in 16 countries in 1997 to over 400 in 34 countries in 2021 (www.cites.org). The number of species registered for captive breeding has also increased from 16 to 34. For these species, there is a definite link to CITES because commercial trade from wild sources is prohibited.

The shift from wild sourced to captive, or artificially propagated sources, is expected to reduce unsustainable harvest levels from wild populations. The counterfactual evidence indicates that current trade volumes for many species would not be sustainable without specimens sourced from captive or artificially propagated sources. The data presented by Harfoot *et al.* (2018) shows a consistent decline in the rate of wild-sourced specimens, especially for reptiles and plants, and to a lesser extent for birds, invertebrates and mammals. More specific evidence for taxa such as crocodiles shows positive outcomes for wild species when trade is directed towards specimens from captive populations (Jenkins *et al.*, 2004). However, captive breeding and artificial propagation do not always have positive outcomes. The potential benefits can be undermined by the possible laundering of wild-sourced specimens into trade under the guise of captive breeding (Lyons & Natusch, 2011; Martin, 2018; Nijman *et al.*, 2018). In some taxa, there has also been continued unsustainable trade in wild-sourced specimens despite captive-bred or artificially propagated alternatives either due to demand for specimens with wild provenance or characteristics, e.g., orchids (Hinsley *et al.*, 2018) or because it is still relatively easy to source specimens from the wild, e.g., parrots (Ribeiro *et al.*, 2019) or because of weak enforcement. There is no synthetic review of the evidence, so it is not possible to assess the extent to which this undermines the intended benefits. An unintended outcome of shifts to captive breeding and artificial propagation is that it concentrates trade among the few actors who have the technology and capital to engage in these practices. This may exclude local communities with negative consequences for social equity, as well as sustainable livelihoods and conservation programs linked to wild populations in developing countries (Coconier & Lichtenstein, 2014; Cooney & Jepson, 2006; Roe, 2006; Roe *et al.*, 2009).

A clear indicator for CITES acting as a driver of legal and more sustainable levels of harvest and trade would be an improvement in the conservation status of those species subjected to unsustainable international trade. One way to measure this is by using the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, where resource use is listed as a threat. For birds and mammals on the IUCN Red List, and listed in CITES Appendices, 84% of those listed in Appendix I and 76% of those on Appendix II had decreasing population trends (IUCN Red List 2021). The population trend data should be complemented by the Red List Index (Butchart *et al.*, 2007), which provides a more composite index for tracking changes in the conservation status of groups of species. A Red List Index analysis specifically for species listed on CITES is not yet available. Nevertheless, other assessments of utilized species provide some insights into the impact of measures to address unsustainability levels of harvest and trade.

The Red List Index for all fully assessed species where international trade has been documented (www.iucnredlist.org/api/v4/rlindex/image/988730) shows an ongoing decline in status from 1996 to 2020 without any evidence of an upward inflection that would indicate successful interventions. The rate of decline in the Red List Index for species in international trade is steeper than for all terrestrial species combined but comparable to the rate of decline for marine species. A more detailed assessment of the impact of conservation measures on the status of the world's vertebrates, using Red List Index for all data-sufficient species (Hoffmann *et al.*, 2010), concluded that efforts to address exploitation (hunting) had limited positive impacts on the conservation status of affected mammal species between 1996 and 2008 (62 species deteriorated, six improved) but better results for birds from 1988 to 2008 (31 deteriorated, nine improvements). Separate analyses for birds (Butchart, 2008) and parrots (Olah *et al.*, 2016) also show ongoing declines in the Red List Index for species in trade.

There are several caveats to using the available Red List and Red List Index data to assess the impact of CITES. The first is that Red List Index data refer to all utilized species and not only those listed in CITES. The second is that few, if any, species are only traded internationally, and many species listed in CITES are also traded domestically and not under regulation through CITES, e.g., bears (*Ursus* sp.) in Japan (Mano & Ishii, 2008), songbirds in Indonesia (Nijman *et al.*, 2018), orchids in Vietnam (Bullough *et al.*, 2021) and pangolin in Africa (Mambeya *et al.*, 2018). Third, in most cases, utilization is not the only driver leading to decline, and it is often not possible to separate the effects of conservation measures aimed at use and trade. Analyses of birds (Butchart, 2008) and parrots (Olah *et al.*, 2016) show that species in trade have continued to decline, but the more significant impacts of habitat loss make it difficult to determine the actual trend linked only to use and trade. A further example is reef-forming corals, where substantial decline in the Red List Index due to a coral bleaching event in 1998 obscured most other factors affecting the status of corals, including localized impacts associated with unsustainable use (Carpenter *et al.*, 2008). Given these caveats, the general conclusion is that these higher-level analyses show limited evidence for positive changes to the conservation status of species affected by trade.

A review of the effectiveness of CITES (IUCN, 2000) noted the success of reducing unsustainable trade in furs from spotted cats and non-human primates. These were regarded as successful because they acted in conjunction with other interventions, such as media campaigns to end the use of furs. The report noted far less successful outcomes for rhino and many plant species. Additional literature on CITES listed taxa includes camelids (Kasterine & Lichtenstein, 2018), eels (Nijman, 2015), manta rays (Booth *et al.*, 2020), orchids (Hinsley *et al.*, 2018; Phelps & Webb, 2015), parrots (Martin, 2018), reptiles (Robinson *et al.*, 2015), sea horses (Foster *et al.*, 2016; Kuo & Vincent, 2018), snakes (Hierink *et al.*, 2020), sturgeon (caviar) (Doukakis *et al.*, 2012), as well as population studies for species where trade impacts should have declined – CITES for example, cycads (Okubamichael *et al.*, 2016), and elephants (Chase *et al.*, 2016). These studies present mixed outcomes associated with CITES, with some taxa showing strong recovery related to CITES such as vicuna (Kasterine & Lichtenstein, 2018) and crocodiles (Jenkins *et al.*, 2004), others showing positive trends (e.g., manta ray and sea horses) (Booth *et al.*, 2020; Kuo & Vincent, 2018). Others show ongoing declines despite being listed in CITES, such as African elephant (Chase *et al.*, 2016) and African cycads (Okubamichael *et al.*, 2016).

An important question regarding the role of CITES as a driver of legal and sustainable use is the extent to which unsustainable legal trade is replaced by unsustainable illegal trade without actually reducing the impact on the target species. Trade is typically regarded as illegal when it violates procedures and laws (Felbab-Brown, 2017) so listing a species in Appendix I of CITES makes commercial trade in wild-collected specimens illegal. Trade in species listed in Appendix II would also be unlawful if it does not comply with CITES conditions. There is evidence across many taxa for ongoing and often significant illegal trade in wild-collected specimens (UNODC, 2020); specifically for rhinoceros (Chapman & White, 2021; Emslie *et al.*, 2016; le Roex & Ferreira, 2020), pangolin (Dumenu, 2019b; S. Heinrich *et al.*, 2016; Kukrety *et al.*, 2013; Nijman & Shepherd, 2021), reptiles (Auliya, Altherr, *et al.*, 2016; Luiselli *et al.*, 2016), big cats (IUCN, 2014; Morcatty *et al.*, 2020; UNODC, 2020), cycads (Okubamichael *et al.*, 2016), orchids (Phelps & Webb, 2015), birds (Hinsley *et al.*, 2018), sea horses (Foster *et al.*, 2016; Kuo & Vincent, 2018), corals (Petrossian *et al.*, 2020), sharks and rays (Friedman *et al.*, 2018) and elephant ivory (Burn *et al.*, 2011; Huang *et al.*, 2021; Underwood *et al.*, 2013a). Almost all species with high commercial value and where there is continuing demand appear to be subject to ongoing illegal trade.

Illegal trade is sometimes regarded as an issue of national-level implementation of CITES and not a problem of the Convention itself. However, since CITES can only be implemented through the actions of contracting Parties, the intention to achieve legal and sustainable trade depends on the capacity of Parties to develop and enforce supporting legislation. To prevent illegal trade, CITES requires Parties to exercise administrative control over trade for an increasing number of species, and it has been argued that many developing countries are unable to achieve the expected level of control (Chitov, 2019). This is compounded by a lack of appropriate institutions, corrupt officials, and the involvement of transnational crime networks (Dinerstein *et al.*, 2007; McCusker, 2006; Rosen & Smith, 2010).

It is not possible in the scope of this chapter, to assess the capacity of Parties to implement CITES, but the evidence from other forms of illicit trade indicates that it requires considerable capacity and resources to counter illegal activities spanning the supply, transshipment and demand components of trade (Felbab-Brown, 2017). There is consistent evidence that unsustainable and illegal trade in wild species is a complex socio-ecological problem (Challender *et al.*, 2015; Phelps *et al.*, 2016; Roberts & Hinsley, 2020; Symes *et al.*, 2018; 't Sas-Rolfes *et al.*, 2019; TRAFFIC, 2008) and that the effectiveness of any measures to address illegal trade is highly contingent on local context (Felbab-Brown, 2017; Symes *et al.*, 2018). The illicit economy for trade in wild species is poorly understood (Symes *et al.*, 2018) and often poorly policed, except for a few charismatic species such as rhino and elephant ivory.

Unintended outcomes of Convention on International Trade in Endangered Species of Wild Fauna and Flora

In addition to the evidence assessed above, two unintended consequences of CITES listing are briefly assessed.

Leakage and displacement: Listing a species can reduce trade in that species to sustainable levels but displace the trade to other similar species (i.e., which may be more abundant) or to other jurisdictions where there are less stringent controls. Displacement and leakage has been observed in several cases. For example, trade in eels (Nijman, 2015), where bans in Europe resulted in increased harvest and trade from Indonesia. Restrictions in trade in tiger products is one factor which has led to increased harvesting and trade in other species such as leopard, jaguar and lion (Morcatty *et al.*, 2020; UNODC, 2020). Bans on trade in manta rays have increased harvest in areas with lower levels of enforcement (Friedman *et al.*, 2018). A decline in trade in tortoises and freshwater turtles from Asia has been correlated with increased trade from the Nearctic region (Luiselli *et al.*, 2016). The shift to other threatened species or less regulated regions requires an adaptive response to changing trade dynamics.

Increased demand: CITES decisions and the process used to list species have been identified as possible drivers of demand and trade. Proposals to list species on the Appendices are available at least 150 days before any decisions are taken and the listing process can take considerably longer if proposals are not accepted when they are first put forward. There is some evidence for increased trade linked to the listing process, in which harvesters and traders acquire or offload stocks before listing and before restrictions come into place. This has been highlighted for earless monitor lizards, *Lanthanotus borneensis* (Janssen & Krishnasamy, 2018) and lion bone (Williams *et al.*, 2017). The phenomenon of increased trade linked to impending restrictions has also been recorded for national-level regulations that are independent of CITES, e.g., a partial ban on the harvest of African cherry *(Prunus africana)*, imposed by the government of Cameroon in 1991, resulted in the opportunistic and destructive harvest of twice the annual average amount of bark (Cunningham and Mbenkum, 1993). The limited evidence indicates that these are short-term spikes associated with the listing process, although they may negatively impact the affected species (Rivalan *et al.*, 2007a).

A more contentious question is whether CITES listing decisions may drive increased demand and illegal trade. One argument is that when a species is moved from Appendix I to Appendix II, allowing legal trade, this stimulates demand (e.g., Orenstein, 2013), this demand may not always be met through lawful means, and this encourages illegal trade and laundering of illegally sourced specimens into legal trade networks. The counterargument is that CITES restrictions on the supply side of trade limit the availability of legally sourced specimens but fail to satisfy existing demand, resulting in illicit trade. The literature search provided limited evidence relating to this question. The studies focused primarily on issues such as the legalization of trade in rhino horn (Biggs *et al.*, 2013; Crookes & Blignaut, 2015; Eikelboom *et al.*, 2020) and bans on trade in elephant ivory (Conrad, 2012; Kurohata, 2020) (Orenstein 2013), but also includes analyses of laundering of wild-sourced specimens through captive breeding operations (Lyons & Natusch, 2011) and legal quotas (Daut *et al.*, 2015). The evidence relating to key factors in these counterarguments, such as price elasticity, consumer behavior, and the dynamics of legal and illegal trade networks, is limited and often contradictory. For example, studies of the ivory trade in Japan showed that initial bans resulted in increased prices but did not reduce demand. In contrast, later interventions to raise awareness of the impact on elephant populations resulted in decreased demand (Kurohata, 2020). Studies of trade in wild meat (McNamara *et al.*, 2016), succulent plants (Margulies, 2020) and more general trade in wild species (Symes *et al.*, 2018) show how the drivers of trade are not straightforward and differ between species and regions. The evidence is insufficient to provide any clear findings and remains unresolved. Given the importance of this issue for the governance of the use of wild species, this is an area where further research is urgently required.

In summary, CITES has been an essential instrument for driving global action to ensure more sustainable use of species threatened by international trade and to strengthen institutions and tools to achieve this. It has been less successful when measured against outcomes for many species affected by unsustainable use levels. CITES decisions may not consistently achieve the desired outcomes because significant aspects of trade may occur outside of its scope of control. International trade is also not the only driver affecting many species. CITES decisions also does not address the underlying drivers of unsustainable and illegal trade both from the supply and demand side of trade.

Theoretical analyses of use systems have concluded that sustainable outcomes are more likely when the social and biological components are understood and included in the decision-making process (Ostrom, 2009). Commentators on CITES listings have argued for the need to strengthen input from communities whose livelihoods are affected by CITES decisions (Cooney *et al.*, 2021). These issues are being considered albeit in the context that listing proposals should focus on the biological status of the affected species as the primary factor in decisions to amend the Appendices. Nevertheless, there is a growing body of evidence relating to social aspects of trade in wild species, comprising economics, behavior change, the structure of legal and illicit markets, the role of communities in promoting sustainable use, and social drivers which could be used to ensure more durable outcomes for CITES decisions and reduce unsustainable and illegal trade.

4.2.2.2.2 Trans-boundary conventions/ agreements

A variety of regional-level institutions facilitate and support sustainable use that predates or are not explicitly tied to the Convention on Biological Diversity **(Table 4.1)**. For example, the Agreement on the Conservation of Polar Bears was signed Mon ay 26, 1976, to protect the species through a coordinated approach by the five polar bear range states (Union of Soviet Socialist Republics (now Russia), Norway, Greenland (Denmark), the United States of America, Canada). This agreement, coupled with rights, customary laws and knowledge systems, has supported sustainable use; as evidenced by scientific reports, the majority of polar bear sub-populations well studied in Canada, for example, are stable or increasing (Government of Canada, 2019). Although there is growing concern that melting sea ice in the north will lead to declining bear numbers, the global population of polar bears, estimated between 22,000 and 31,000 animals, with more evidence from science and Inuit knowledge that the population is growing or stable, rather than declining. (Government of Canada, 2019; World Wildlife Fund, 2016). The Government of Canada lists only the Hudson Bay and southern Beaufort subpopulations as “likely declined” (Government of Canada, 2019); however, traditional knowledge of Inuit and Inuvialuit peoples in these regions is not consistent with these conclusions (Inuvialuit Joint Secretariat, 2015).

Table 4 1 **International agreements, conventions and treaties related to wild species.**

Year	Institutions, conventions, major non-governmental/governmental organisations
1916	Migratory Birds Treaty
1922	International Committee for the Protection of Birds established in London, 1st green non-governmental organization
1923	Meeting in Paris of the first international non-governmental congress for the protection of nature
1929	Establishment of the International Office for the Protection of Nature, later absorbed by the International Union for Conservation of Nature
1933	London Convention for the protection of flora, fauna and scenic beauty in Africa
1940	United States of America Fish and Wildlife Service
1942	London Convention for the Protection of Nature in the Western Hemisphere
1946	International Convention for the regulation of Whaling
1948	Establishment of the International Union for the Protection of Nature that later became International Union for Conservation of Nature
1950	International Convention on the Protection of Birds ratified by 10 countries
1958	Convention on Fishing and Conservation of the High Seas Resources, ratified by 57 countries
1961	Creation of the World Wild Fund; Creation of African Wildlife Foundation, an American non-governmental organization dedicated to African Protected Areas
1968	African Convention on the Conservation of Nature and Natural Resources, Alger
1971	Ramsar Convention on Wetlands of International Importance
1972	Creation of United Nations Environment Programme (UNEP)
1972	Paris Convention on World Cultural and Natural Heritage (UNESCO)
1972	Stockholm Declaration, states natural resources including fauna and flora should be safeguarded for the benefit of future generations.
1973	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
1973	Agreement on the Conservation of Polar Bears
1979	Convention on the Protection of Migratory Species of Wild Animals (CMS)
1979	Convention on the Conservation of European Wildlife and Natural Habitats
1979	Convention for the Conservation and Management of the Vicuña
1979	European Union Birds Directive
1980	World Conservation Strategy: Natural Resource Conservation for Sustainable Development (International Union for Conservation of Nature – IUCN / United Nations Environment Programme -UNEP/ World Wildlife Fund -WWF), highlighted the importance of “sustainable use” of living natural resources as part of an overall conservation strategy.
1982	Adoption of the World Charter of Nature, prefiguration of an international law on the environment, United Nations
1982	United Nations Convention on the Law of the Sea (Montego Bay)
1983	International Undertaking on Plant Genetic Resources, Common Heritage of Humanity, Food and Agriculture Organization (FAO)
1984	International Tropical Timber Organization
1987	Our Common Future, Brundtland Report, United Nations
1989	International Labour Organization’s Convention N°. 169
1991	Global Biodiversity Strategy, International Union for Conservation of Nature (IUCN), United Nations Environment Programme (UNEP), Food and Agriculture Organization (FAO), United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Resources Institute (WRI).
1992	Convention on Biological Diversity (CBD)
1994	Agreement on Trade-Related Intellectual Property Rights (TRIPS), World Trade Organization (WTO)
1994	United Nations Convention to Combat Desertification
1995	Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries
1995	United Nations Fish Stocks Agreement (conservation and management of straddling and highly migratory fish stocks)
1999	Agreement on the Conservation of African-Eurasian Migratory Waterbirds
2000	Intergovernmental Forum on Forests (IFF)
2000	Adoption of the millennium goals (Goal 7: Ensure sustainable development)
2001	International Treaty on Plant Genetic Resources for Food and Agriculture, Food and Agriculture Organization (FAO)

Year	Institutions, conventions, major non-governmental/governmental organisations
2002	Rio + 10 or Johannesburg Conference "Fight Against Poverty"
2002	Global Environment Facility (GEF)
2004	Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity
2005	Millennium Ecosystem Assessment (notion of ecological service)
2007	United Nations Declaration on the Rights of Indigenous Peoples
2010	Aichi Biodiversity Targets (20), Convention on Biological Diversity (CBD), Strategic Plan 2011–20
2012	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
2014	Nagoya Protocol on Access and Benefit-sharing
2015	2030 Agenda for Sustainable Development, adopted by all United Nations Member States
2016	Food and Agriculture Organization Agreement on Port State Measures (to combat illegal, unreported and unregulated fishing)

Box 4 3 The challenge of contestations and conflicts in the Convention on International Trade in Endangered Species of Wild Fauna and Flora over value differences.

Some iconic species listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora appendices attract a high level of controversial discussion and absorb large amounts of the agenda in its fora. A key challenge is the different values held towards the use and management of wildlife. A complicating element is the presence of influential non-governmental organizations, as representatives of civil society, which have become increasingly numerous and vocal in the Convention on International Trade in Endangered Species of Wild Fauna and Flora debates in recent decades, which hold their values on the moral acceptability of trade and use of certain species (Biggs *et al.*, 2017; Challender & MacMillan, 2019; Duffy, 2013). These non-governmental organizations provide a voice for civil society, are a source of scientific and practical information to parties and may assist selected lower-income countries at the Convention on International Trade in Endangered Species of Wild Fauna and Flora meetings. There is, however, concern among some academics and regional government bodies s over the extent to which increased non-governmental organizations' presence has negatively impacted the extent to which the Convention on International Trade in Endangered Species of Wild Fauna and Flora can make evidence-based decisions and formulate policies on sustainable use (Bauer *et al.*, 2018; Biggs *et al.*, 2017; Challender & MacMillan, 2019; Cooney *et al.*, 2021, CITES 2019). There is also concern over the extent to which this presence may undermine the ability of smaller countries to represent the interests of their citizens effectively due to the levels of resources large non-governmental organizations that may hold contrary value-based positions on wildlife trade that could be either pro- or anti-use (Challender *et al.*, 2019; Duffy, 2013, CITES 2019). In addition, drawing from successful conflict management processes in other domains, it has been proposed that decision-making processes that combine different cultural value orientations towards plants, animals, and their sustainable use, be incorporated with scientific evidence (Biggs *et al.*, 2017).

Box 4 4 Inuit (Inuvialuit) Knowledge (IQ) and the Success of the Agreement on Polar Bear Conservation.

The 1973 Agreement on the Conservation of Polar Bears provided a framework for research and sharing of data at national and circumpolar scales (e.g., article vii) while at the same time respecting the authority of each nation to manage its own polar bear resources (Freeman 1996). In Canada, that authority took shape in two committees. The present-day Canadian Polar Bear Administrative Committee and the associated Polar Bear Technical Committee were created in the 1970s to bring together the various voices in polar bear science and management from federal, territorial, and provincial agencies. The Technical Committee facilitates management decisions by reviewing research results and making management recommendations directly to the constituent jurisdictions. These committees predate the settlement of the Inuvialuit Final Agreement signed in 1984. That agreement recognized the inherent right and authority of the Inuvialuit to manage polar bears among other lands and resources in their region. Over the years, some efforts have been made to ensure that Inuvialuit and Inuit knowledge informs the Polar Bear Technical Committee (and Polar Bear Advisory Committee). However, many scholars suggest 'science' mixed with public sentiment has become the dominant discourse and basis for decision-making (Clark *et al.*, 2009; Tam *et al.*, 2021; Tyrrell & Clark, 2014).

While inequities in voice between Inuit Knowledge holders and scientists have led to impacts on Inuit economies, well-being and co-management (Foote & Wenzel, 2009; B. Parlee & Inuvialuit Game Council, 2020), this system of governance remained relatively stable between 1970 and the mid-1990s,

Box 4 4

save for periodic efforts of interest groups to curtail Inuvialuit and Inuit harvesting rights. When the Inuvialuit settled a land claim agreement with the Canadian federal government in 1984, it significantly changed their role in the national and territorial resource management decision-making processes. The Inuvialuit Final Agreement recognizes and affirms, as other comprehensive land claims in Canada do for other indigenous peoples, the inherent rights of the Inuvialuit for self-government and power in decisions about lands and resources in their homeland. As a result of this agreement, various co-management processes and councils were established that mandated the participation of Inuvialuit in decisions regarding lands and resources in the region, including polar bears. Among these is the Inuvialuit Game Council.

In 1988, the Council and Inupiat from the Alaskan North Slope Borough signed the Inuvialuit – Inupiat Polar Bear Management Agreement in the Southern Beaufort Sea region, underpinning decision-making about quotes of bear harvest in the region. As in other areas of the north, hunting is recognized as part of the way of life but is not antithetical to conservation (Freeman *et al.*, 2005). Embedded within the oral histories and observational accounts are insights into polar bear ecology. Inuvialuit hunters track bears on the ice by looking for specific details about their size, sex, behavior, direction and condition. Over time and through interpreting and sharing with other elders and land users, Inuvialuit knowledge comprises longitudinal data about body condition, population variability, distribution, reproduction, mating behavior, and hunting practices, as well as broader patterns of ecological change, including weather patterns, seal abundance and distribution, sea ice conditions, and human-bear interactions. When interviewed in 2010, most Inuvialuit hunters observed few changes in the abundance of bears, including the number of cubs (e.g., Inuvialuit Joint Secretariat, 2015:182–184). Whereas sea ice conditions were observed to be deteriorating in some areas, making it more difficult and dangerous for hunters to pursue bears, the Inuvialuit from most communities observed that the bears themselves are healthy based on numerous indicators, including body fat and reproductive success. According to some elders, the abundance and location of suitable seal habitat has been changing, but this does not seem to affect the condition or number of bears. Elders attribute this to hunting becoming more and due to thinning ice in some regions and the increased abundance of harp seal, a primary source of food in the region. This knowledge, combined with the outcomes of scientific research, form the basis of decisions by the regional Inuvialuit government (i.e., Inuvialuit Game Council) to make decisions about the harvest of the populations of the south-Beaufort region. As a result, harvest quotas have tended to vary yearly as the distribution of bears has changed. "Reported harvest levels for bears in the southern Beaufort area have been below quotas set for "allowable harvest" (modelled by scientists and Inuit/Inuvialuit) or below what is considered sustainable at a population level in an otherwise healthy population (4.5%) (Regehr *et al.*, 2017)."

This harvest has continued in recent years, despite outside pressure, due to the confidence and belief of Inuvialuit peoples in the rigour and validity of their own evidence, knowledge and experience.

Box 4 5 **The Convention for the Conservation and Management of Vicuñas – and the lack of a Convention for Guanacos.**

The Convention for the Conservation and Management of the Vicuña (1979) was signed by Argentina, Bolivia, Chile, Peru and Ecuador and is an example of a regional institutional arrangement that succeeded in the management of a common pool resource over a vast area to protect a wild South American camelid that lives in the High Andes (Lichtenstein, 2010). In Article I of the Vicuña Convention, and in the signatory states' subsequent submissions to the Convention on International Trade in Endangered Species of Wild Fauna and Flora meetings, Andean people that had been bearing the burden of vicuña conservation were named as the main beneficiaries of future vicuña use. However, translating this article into national legislation and ensuring exclusive benefits to local people has proved difficult (Lichtenstein, 2010). Due to its fleece which has one of the finest fibres in the world, it has long been hunted, ultimately resulting in the species almost being driven to extinction in the middle of the 20th century. The species recovery was a result of concerted international conservation efforts through the Vicuña Convention, the entry into force of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the prohibitions imposed by the Fish and Wildlife Service of country (Lichtenstein, 2010; McNeill *et al.*, 2009).

In contrast to the approach with Vicuña, another wild South American camelid species that lives in Andean countries – Guanaco – is also listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix II. Still, there is no multilateral-regional agreement between the range of countries regarding its sustainable use and conservation. The lack of common goals towards the conservation and sustainable use of the species results in its range countries (Argentina, Chile, Peru, Bolivia, Paraguay) having very different management schemes that range from protection to culling. There is no sharing of information about best practices, and no coordinated national measures as in the case of vicuña. Guanaco populations are critically engendered in Bolivia and Paraguay and severely threatened in Peru (Baldi *et al.*, 2016).

The Agreement on Conservation of Polar Bears sets out terms for sharing knowledge and monitoring populations, creating the foundation for local-regional decisions about Inuit harvest quotas. There have been key examples of such knowledge documented by Inuit that strongly suggest bear populations are healthy, contrary to models and assumptions that sea ice melt is having an adverse impact (Clark *et al.*, 2009).

There are more examples of regional conventions and agreements related to large fauna and hunting practices, including agreements related to marine and freshwater fisheries. Most notably, regional fisheries management organizations cover almost all oceanic areas. Their members (generally national delegations) have established rules regarding the collection and sharing of data, accepted methods for assessing the state of fish stocks, and negotiations to allocate shares of allowed catch among members. Examples include the Inter-America Tropical Tuna Commission and Northwest Atlantic Fisheries Organization (DFO-Department of Fisheries and Oceans Canada, 2019).

Despite their comprehensive spatial coverage and formal cooperation processes, regional fisheries management organizations focus almost exclusively on tuna and other high-value species and have been criticized for overlooking possible impacts on bycatch species; there are also concerns they supposed science-based catch recommendations due to political factors and allowing for unbalanced negotiation power in quota allocation and participation of new or non-members in discussions (Haas *et al.*, 2020).

Another convention is the International Whaling Commission, established initially to support the sustainable harvest of whales by member nations. Over time, open membership and vote-based rules led to the International Whaling Commission functioning as a *de facto* conservation convention, resulting in the eventual exit of some founding members wishing to continue whaling and ongoing debates regarding impacts on indigenous whaling practices (Punt & Donovan, 2007).

Aside from these global or very large-area examples, there are examples of bilateral or multilateral conventions to manage fisheries stocks—including cod and herring in Northern Europe, salmon and halibut in the US and Canada, and even preemptive agreements for Arctic fisheries. There is growing interest in further establishing such conventions between smaller countries, particularly as climate change increases the number of transboundary fish stocks. One recent example is the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (Balton, 2019).

A significant challenge with regional agreements related to fisheries is the problem of open access in ecosystems for which no binding global institutions exist. Fishing fleets are also increasingly mobile and tend to "operate like roving bandits because global markets often fail to generate the self-interest that arises from attachment to place" (Berkes *et al.*, 2006). This high degree of mobility coupled with the adaptability of fishing fleets to respond to shifts in markets is also part of the governance challenge. "Developing the institutions to deal with commons issues is problematic and slow; new markets can develop so rapidly that the speed of resource exploitation often overwhelms the ability of local institutions to respond" (Berkes *et al.*, 2006). Most industrial fishing occurs in these areas, which lack governance (Kroodsma *et al.*, 2018; Palacios-Abrantes *et al.*, 2018). It is this transboundary nature of fisheries, coupled with a lack of strong institutions in many areas of the globe and for large numbers of fish species, that has led to problems of unsustainable use or overharvesting (Berkes *et al.*, 2006; Kroodsma *et al.*, 2018; Palacios-Abrantes *et al.*, 2018; Tickler *et al.*, 2018) (see **Figure 4.7**).

In addition to agreements explicitly related to fisheries, there are a variety of transboundary arrangements for freshwater ecosystems that have developed to address transboundary issues of water use as well as management of aquatic habitats (e.g., across the Canada-United States of America border, in the Mekong river basin) (Fox & Sneddon, 2007; Hildebrand *et al.*, 2002). Their role in addressing questions of biodiversity loss and sustainable use is less well-developed.

Small-scale freshwater fisheries contribute significantly to the food security of those living in transboundary systems, including the Amazon, Congo and Mekong. However, their species use is threatened by a focus on these river systems as a source of development, including hydroelectric power (Winemiller *et al.*, 2016). The absence of transboundary institutions that deal with questions of sustainable use at basin-wide scales is a major barrier to protecting indigenous peoples and local communities and the freshwater fisheries on which they depend (Chen *et al.* 2008; Begossi *et al.* 2019). "Institutions that permit and finance hydropower development should require basin-scale analyses that account for cumulative impacts and climate change. Proposed dam sites should be evaluated within the context of sustaining a portfolio of ecosystem services and biodiversity conservation" (Winemiller *et al.*, 2016).

Addressing broad questions of development in river basins requires institutions to "move beyond the current inward focus on project approvals in projects, toward an outward focus on the cumulative effects of all disturbances in a watershed" (Sheelanere *et al.*, 2013). Balancing such large and basin broad perspectives should not be at the expense of recognizing the complexity and diversity of the values and uses of biodiversity of indigenous peoples and local communities, whose fishing practices have long been sustainable (Baird *et al.*, 2021).

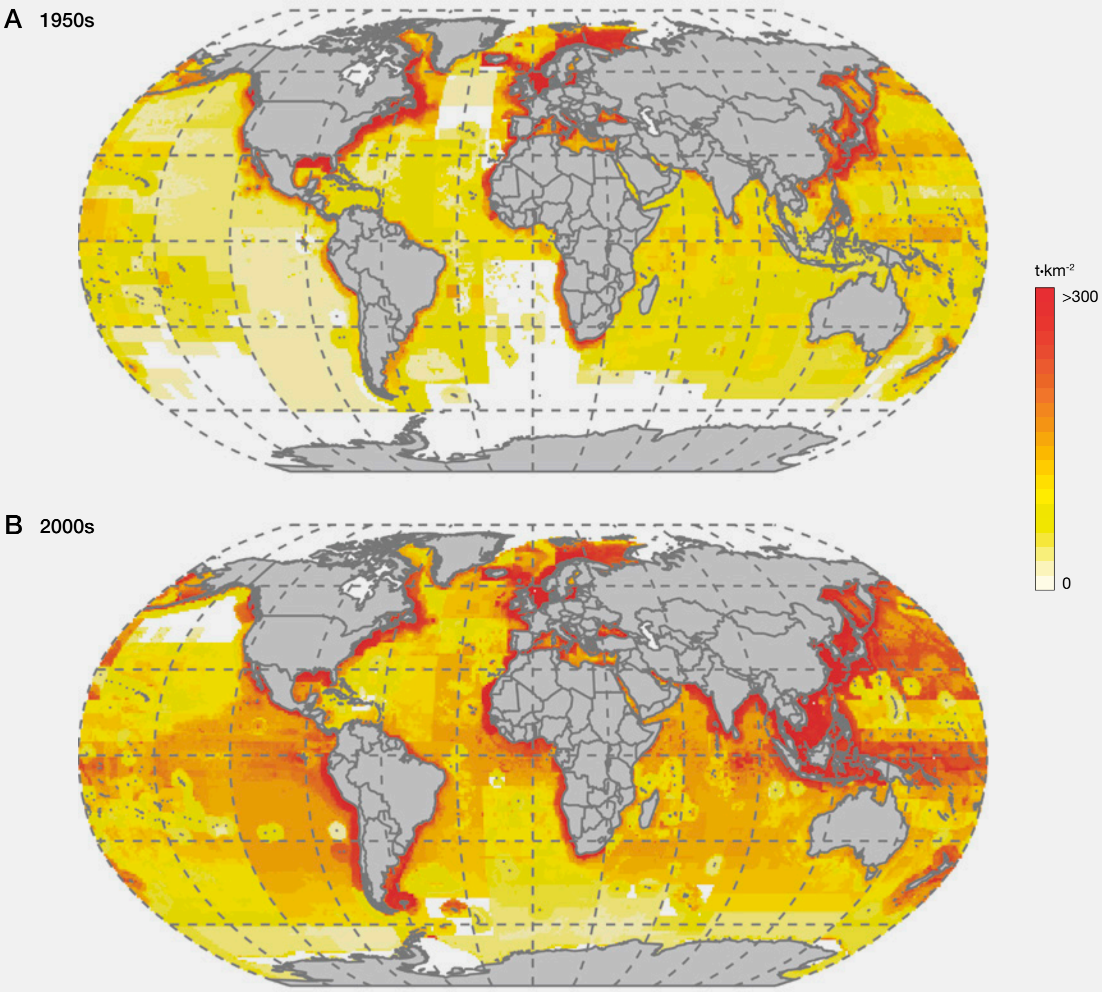


Figure 4 7 Map presents mean industrial fisheries catch in metric tons per square kilometer by-catch location during the (A) the 1950s and (B) 2000s.

This map is directly copied from its original source Tickler et al. (2018) and was not modified by the assessment authors. The map is copyrighted under license CC BY-NC 4.0. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

Box 4 6 Hydro-electric Development in the Lower Mekong and its Impacts on Sustainable Use.

The Mekong river is a large transboundary river originating from the Tibetan Plateau, spanning 4909 km and ending in the South China Sea (Chen *et al.*, 2020; Soukhaphon *et al.*, 2021). Its substantial geographic area, vast biodiversity, and connection to local communities make the Mekong one of the most important freshwater aquatic systems in the world (D'Souza & Parlee, 2020; Soukhaphon *et al.*, 2021). Although purported as a source of clean energy, the rapid development of ongoing and proposed hydroelectric dams is adversely impacting local fishing communities and is a major driver of change in fishing practices (Chen *et al.*, 2020; D'Souza & Parlee, 2020; Ziegler *et al.*, 2013). Hydroelectric development complicates traditional practices, and, as a result, local people have had to cope with significant stress related to loss of livelihood and inability to engage in traditional practices (Baird *et al.*, 2020; D'Souza & Parlee, 2020; Soukhaphon *et al.*, 2021). Currently, over 65 million people live near or along the Mekong river, and thus, the cumulative impacts of hydropower affect communities for decades after their completion (Soukhaphon *et al.*, 2021).

Box 4 6

While hydropower dams exist throughout the Mekong basin, there is a significant number in the Lower Mekong Basin. Since the 1990s, 64 dams have been constructed in the Mekong basin, 46 of which are in the Lower Mekong Basin (Green and Baird 2020; Yoshida *et al.* 2020). Additionally, 123 dams are projected to be built in the Lower Mekong Basin in the future (Yoshida *et al.*, 2020). One of the most controversial dams in this area is the Pak Mun Dam, a "run-of-the-river" hydroelectric dam that is situated at the confluence of the Mun and Mekong rivers in Northeastern Thailand, (Baird *et al.* 2021; Amornsakchai, 2000; Soukhaphon, Baird, and Hogan 2021). Since 1989, the Pak Mun Dam has caused contention and conflict between local communities and the Electrical Generating Authority of Thailand (Amornsakchai, 2000). Its location causes major impacts on upstream and downstream communities, including those beyond Thailand, in Lao, Cambodia, and Vietnam (Soukhaphon *et al.*, 2021). For communities that utilize the river, this dam and its resulting embankment have caused both environmental and socioeconomic issues such as decreases in fish migration, flooding, increase in water level, increased reliance on store-bought food, loss of traditional community practices, and more (Baird *et al.*, 2020; Foran and Manorom, 2009; Roberts, 2016; Soukhaphon *et al.*, 2021). These negative and severe impacts mean that fishing is no longer a sustainable practice, and to cope, communities have had to diversify their livelihoods over the past thirty years.

Diversifying fishing practices include more innovations to fishing gear, including some local community members who use recycled material to create fish and shrimp traps (D'Souza & Parlee, 2020). Additionally, some community member takes advantage of fiberglass boatmaking programs initiated by their Tessabaan (Municipal Government) (D'Souza & Parlee, 2020). The Tessabaan also offers programs that teach people how to raise Tilapia in personal fishponds (D'Souza & Parlee, 2020). These personal fishponds provide a way for community members to feed their families while also generating income by selling fish (D'Souza & Parlee, 2020). Selling fish persists and is often preferable, but sharing fish is decreasing, as people cannot afford to share the little catch they have (D'Souza & Parlee, 2020). For upstream communities, such as those along the Sebok River, there may be even less sharing of fishing gear as people wish to preserve their store-bought gear (D'Souza & Parlee, 2020).D'Souza & Parlee, (2020) outline common diversification of both upstream and downstream, including preferring to sell their fish over sharing or eating, more reliance on store-bought fish, and wanting more fish stocking from the government. A major shift in perception of fishing livelihood has also occurred, as community members prefer to diversify outside of fishing, including the common practice of farming, mobile markets, and rural-to-urban migration (D'Souza & Parlee, 2020). Broader drivers of change have led to more focus on education and children supporting their grandparents by sending money back to their villages (D'Souza & Parlee, 2020). Local people must often engage in multiple diversifications to cope with stressors related to the Pak Mun Dam.

However, although community members can and have coped with the longitudinal impacts of the Pak Mun Dam, they wish to return to their previous lives. Since the implementation of the Pak Mun Dam, its decommission has been widely recommended by community members, scholars, and non-profits (Baird *et al.* 2020). The opening of the floodgates year-round, or for an extended period during the rainy season, is mentioned frequently as a way to help restore the environment to its original state, including bringing back the fish populations (Baird *et al.*, 2020; D'Souza & Parlee, 2020; Foran and Manorom, 2009). It is clear that local community members are adversely affected and struggle with the long-term impacts of the Pak Mun Dam on their fishing livelihoods. As more hydroelectric development is projected to take place in the region, including the highly contested but not yet constructed Sambor dam, more research on hydroelectric development as a driver of change for communities in the region is needed.

Box 4 7 Treaty on the Conservation and Sustainable Management of Forest Ecosystems in Central Africa and establish the Central African Forests Commission (2005).

The 1999 Yaoundé Declaration recognized the protection of the Congo Basin's ecosystems as an integral component of development processes. It reaffirmed commitments to work cooperatively to promote the sustainable use of the Congo ecosystem in accordance with their social, economic, and environmental agendas. The Declaration led to the formalization of commitments to protect the Congo Basin's ecosystems in a 2005 Treaty that legally recognizes the Central African Forests Commission as the decision-making body on forests. Representatives from all the governments have met regularly to discuss an agenda and develop a Convergence Plan (2003–2010) that identifies priorities under the themes of harmonization of forest policy and taxation, inventory of flora and fauna, ecosystem management, conservation of biodiversity, sustainable use of natural resources, capacity building and community participation, research, innovative financing mechanisms, and the convergence and harmonization of regulations including those concerning wild species use and management. While regional level agreements have been slow to filter down to the national level, the alignment focus has been important in raising awareness and simulating data collection (via, for example, the Central African Forest Observatory and annual State of the Congo Basin Forest reports) at the national level, including on un-regulated wild species for which little data exists to inform policymakers.

The Mekong River Commission, for example, was founded in 1995 as a successor to the Mekong Committee (1957);. However, historically, there was a stronger focus on economic development, and the Mekong River Commission includes a greater scope on sustainability. States involved include Thailand, Laos, Cambodia and Vietnam. The Commission has multiple focal points, including sustainable development. However, the continued development of the Lower Mekong for hydropower and the absence of China from the membership of the Commission (where the headwaters of the Mekong Basin are located) have been highlighted weaknesses. As a result, the fishing livelihoods of many basin residents (particularly those directly affected by upstream/downstream and tributary effects of hydropower) have been compromised (Baird *et al.*, 2020; Pearse-Smith, 2012; Soukhaphon *et al.*, 2021). A more integrated approach to watershed management is needed that deals with the dynamics of transboundary use and cross-scale problems such as hydroelectric development (Hensengerth, 2009; Hirsch *et al.*, 2006; Suhardiman *et al.*, 2012).

Conventions and treaties related to the management of forest ecosystems and regulation of use are more common in some areas than others.

A critical issue in the usefulness of global agreements is how they are implemented and enforced within national borders.

4.2.2.2.3 National Laws and Policies

Although sustainable use of wild species is a global issue, the nation-state has long been considered the answer to most governance problems, including those related to biodiversity conservation (Sampford, 2002). Laws and policies impacting wild species include both those directly regulating species and products and those indirectly doing so. Direct regulations (e.g., quotas, permitting, quality, safety and efficacy standards, trade restrictions, taxation) tend to exist when species are in commercial trade and governments seek to generate revenue or protect endangered species (Laird *et al.*, 2010; Lele *et al.*, 2010; Pierce & Burgener, 2010). Laws and policies that indirectly impact wild species often have an equal or greater impact on these species (Cronkleton & Pacheco, 2010; Dewees & Scherr, 1996; Novellino, 2010), and include agriculture, land tenure, taxation, labor, and broader natural resource laws (Laird *et al.*, 2010). In most countries, permitting, harvest quotas, taxation, and restrictions on domestic and international trade are used by national governments to regulate the direct use of wild species. Some of the most common and well-established formal institutions at the national scale are related to the hunting and harvesting of large game.

The degree to which laws are applied and enforced is also highly complicated and can vary by political priorities and institutional capacity (i.e., resources to hire fish

Box 4 8 **Marine ecosystems and sustainable use in Indonesia – towards an ecosystem approach to fisheries management.**

Indonesia is the world's second-largest producer of wild-capture fish; small-scale fishers harvest 60%. There are more than 2.62 million fishers in the marine and inland capture sector in Indonesia, and the country is one of the most fish-dependent countries in the world. The Indonesian government has been working with international organizations to establish marine protected areas to protect marine species, including coral reefs. Tourism impacts on coral reefs are among those non-extractive uses, increasing in scale and impact. What kinds of institutions and government tourism impact coral reefs in Indonesia? Fisheries management Law N°. 31/ 2004 and Law N°. 45/2009 regulates all matters concerning fisheries in Indonesia, including all aspects of fishing activities, use, management and enforcement. These include: (i) specifying a fishing method or gear; (ii) determining the maximum sustainable yield or total allowable catch for domestic and foreign fishing; (iii) specifying fishing and aquaculture activities; (iv) preventing activities such as pollution and destructive fishing of the resource and its ecosystems; and (v) rehabilitation of the resources and its habitat. Article 60 of Law N°. 1/2014, amending Law N°. 27/2007 also recognizes traditional communities' rights to cultural (traditional) fisheries harvesting practices. So, although there are no specific laws for Ecosystem Approach to Fisheries, this suite of laws is consistent with the Ecosystem Approach to Fisheries which attempts to balance social and ecological values and needs (Muawanah *et al.*, 2018).

Many national laws, for example, limit the threat of over-harvest of species on public lands; they are premised on protecting the public interest in accessing game as subsistence, recreational, and commercial value. For example, in many Central African countries, current legal and policy frameworks concentrate on a small number of generally traded, high-value wild species such as timber, "bushmeat" (i.e., wild species used for food with a focus on protected animal species), and a generally small proportion of traded, sometimes endangered plant species (Laird *et al.*, 2010). Lower value species are generally not included in these frameworks (Sola *et al.*, 2019). They have species important for food, medicine and construction (Ingram & Schure, 2010; Lescuyer *et al.*, 2016). These systems of sustainable harvest contribute significantly to community well-being in most countries and for most species. Laws within nation states can operate harmoniously to support desired outcomes but are more often *ad hoc* and contradictory. The latter has been argued to be the case in Brazil, for example, which has been described as a "patchwork" of rules that are

Box 4 8

often weakly defined and enforced (Drummond & Barros-Platiau, 2006).

These have been effective due to the flexible way in which these regulations are adapted to local and regional variabilities in ecosystems and species population, distribution, and health. In Arctic ecosystems in Canada, regional co-management boards are responsible for research and monitoring caribou, muskoxen, bear, and other populations and regularly update harvest limits to ensure sustainable use. This is also true in respect of Titi or Sooty Shearwater birds *(Puffinus griseus)* in New Zealand (Lyver *et al.*, 2008; Moller *et al.*, 2009) and moose harvesting in Sweden and Norway (Lavsund *et al.*, 2003). An important limitation of the effectiveness of national scale regulation of harvest and use of wild species is the degree to which these regulations are a fit with other kinds of institutional arrangements that are based on data from science and indigenous and local knowledge. Regulations and other types of institutional arrangements that are adaptive and flexible are particularly important in the case of wild species that are highly dynamic in distribution, migration, and population or highly sensitive to environmental conditions (e.g., climate change) (Berkes 2018; Berkes *et al.*, 2000). For example, in the case of waterbirds, management (or a lack of appropriate management) in one part of the flyway, be it harvest, or site management related, may have consequences for the status of a population throughout its range. An integrated approach and coordinated management are crucial (the waterbird harvest specialist group, Wetlands International, 2015). Weak harvest regulations and the absence of customary laws related to sustainable harvesting are particularly concerning where there is a high degree of variability or environmental stochasticity and where there is the absence of ongoing monitoring of population dynamics; in such cases, even the most adaptive of regulations may be insufficient to prevent species decline.

Box 4 9 **Bat conservation in the Philippines and New Zealand.**

Bats play an essential role in ecosystems around the world. In particular, fruit bats have known pollinators and seed dispersers, meaning that population declines have vast economic and ecological consequences. The Philippine bare-backed fruit bat, *Dobsonia chapmani*, is a species of endangered bat native to the islands of Cebu and Negros and was believed to be extinct in the early 1970s, only to be rediscovered in 2001 (Raymundo & Caballes, 2016). The combination of "hunting, deforestation, guano mining, and a general lack of environmental awareness" is believed to have contributed to the steep decline in bare-backed fruit bat populations (Raymundo & Caballes, 2016). Through their research on the bat hunters in the Philippines, Raymundo & Caballes (2016) found that majority of the local bat hunting was for subsistence. The two most common perceived drivers of bat population decline among hunters were large-scale hunting (and increasing numbers of hunters) and habitat destruction (from logging, agriculture, and forest burning for charcoal), with migration to favourable habitats and proximity to a reopened copper mine as less common drivers outlined. The main explanation for reliance on wild food, including bats, among local populations was found to be socioeconomic constraints. According to Raymundo & Caballes (2016), the Wildlife Resources Conservation and Protection Acts of 2001 in the Philippines has successfully deterred some wild species hunting among individuals. However, it is vague enough that multinational companies can still destroy habitats with little consequence, partly due to the shortage of government personnel trained in enforcing conservation laws. In New Zealand, there have been successful management strategies in conserving long-tailed bats, *Chalinolobus tuberculatus*, which were previously in decline (Nelson *et al.*, 2019). The primary drivers of the decline in bat species in New Zealand have been habitat loss and predation by invasive species. Conservation efforts included predator control of mustelids and rodents, which has protected native bats from invasive species. These conservation methods have, however, only been effective in safeguarding colonies and enabling their recovery where bat populations have not been threatened by habitat modification. In the Ellington Valley, a "strong collaboration between local conservation managers, field staff and scientists (that) involved the local community" has been vital in protecting bat populations. Communities in some New Zealand regions are encouraged to engage with bat conservation through different local, government-led projects (Nelson *et al.*, 2019, p. 290). As highlight,Field Nelson *et al.* (2019) highlight that long-tail bat populations require ongoing, active management to be sustainable. Active management may not be successful in areas with habitats that have been destructed. Only by addressing the socio-economic pressures that local populations in Cebu and Negros will effective hunting regulation and protection areas are possible (Raymundo & Caballes, 2016). Providing support for developing food security may help to reduce local reliance on bat populations for subsistence. Although the drivers of population decline in New Zealand do not include over-hunting, the significance of engagement of actors from multiple levels, including local community members, field scientists, and conservation managers, in the effectiveness of conservation strategies of long-tail bats may prove to apply to the Philippine bare-back fruit bat. Although relocating bat populations has proven to be an ineffective conservation strategy (because of bats' honing skills), the protection of further habitat destruction through the development of terrestrial protected areas may also serve to enable additional conservation strategies. Although there may be economic pressures to continue allowing multi-national corporations to use land in unsustainable ways, strengthening land-use restrictions may help limit further habitat destruction.

Box 4 10 **Weaving commercial and subsistence harvest of moose *(Alces alces)* in Scandinavia.**

Scandinavian moose are among the most productive and heavily harvested populations in the world (Lavsund *et al.*, 2003; Wikenros *et al.*, 2020). From a total annual harvest of fewer than 10,000 animals in the early 1900s, harvest levels increased rapidly in the 1970s (Cederlund & Bergström, 1996; Lavsund *et al.*, 2003). The tremendous population growth of moose in Scandinavia can be explained by several factors, including changing forestry practices, abandonment of marginal agricultural land, absence of predators, and changing moose harvesting practices(Browder, 1992; Lavsund *et al.*, 2003; Ruusila & Kojola, 2010; Thulin *et al.*, 2015). The most critical drivers are state and local management policies and regulations designed to maintain viable populations (Sjölander-Lindqvista & Sandströmb, 2019). Generally, these policies are rooted in the importance of moose as a game species and source of livelihood (Bjärstig *et al.*, 2014; Sandström *et al.*, 2013; Wikenros *et al.*, 2020). The introduction of age- and sex-specific harvesting policies in the 1970s is assumed to be the most important factor in the present productivity of moose populations (Lavsund *et al.*, 2003). As a result of selecting calves, yearlings, and adult males, the proportion of productive females, mean age of females, and recruitment rate increased (Lavsund *et al.*, 2003). However, as moose population densities increased, so did impacts on commercial forests and transportation (e.g., moose-related traffic accidents) (Selby *et al.*, 2005). In Sweden, for example, the economic impact of moose browsing damage on forestry can exceed the economic and recreational values of moose hunting (Bjärstig *et al.*, 2014). Consequently, damage to economically important forests and moose-vehicle collisions play a central role in moose management (Lavsund *et al.*, 2003; Linnell *et al.*, 2020; Sandström *et al.*, 2013). One of the main moose management goals in Scandinavia is finding balance between a sustainable population for hunting and minimizing damage to forestry and public transportation (i.e., vehicle collisions) (Lavsund *et al.*, 2003; Selby *et al.*, 2005; Storaas *et al.*, 2001). Local authorities and stakeholders play a significant role in management efforts. In Sweden, landowners and hunters have been delegated management responsibilities since the first Hunting Act in 1938 (Balčiauskas *et al.*, 2020; M. Johansson *et al.*, 2020). In Norway, there is an increased emphasis on local population management plans developed by the landowner. While in Finland, moose hunting is managed by a central organization for hunters that is organized locally into game management districts and local-level associations (Selby *et al.*, 2005). Harvesting quotas are set based on data collected by hunters as well as vehicle collisions and damage to forestry (Danielsen, 2001). In Norway, for example, population indices based on local monitoring efforts are used as a tool in local moose management (Lavsund *et al.*, 2003). While local management is a generally acceptable approach, it has not resolved a conflict among hunting and forestry stakeholders (Lavsund *et al.*, 2003; Sandström *et al.*, 2013). Competing interests and values continue to challenge the ability of stakeholders to establish trust and find mutually acceptable management solutions (Johansson *et al.*, 2020; Linnell *et al.*, 2020). For example, in Sweden, forestry and hunting groups disagree on how to limit browsing damage to commercially essential tree species while at the same time maintaining sustainable harvest levels (Sandström *et al.*, 2013; Wikenros *et al.*, 2020). To resolve conflicts, the Swedish government introduced a local ecosystem management system to coordinate moose harvesting at an ecosystem-level (Sandström *et al.*, 2013). Management efforts, such as the recent ecosystem-based approach in Sweden, have contributed to a dramatic recovery of moose populations. However, the ongoing sustainability of moose populations may be challenged by several factors, including rapidly expanded carnivore populations (Wikenros *et al.*, 2020), climate change effects on distribution ranges of moose (Johansson *et al.*, 2020) as well as the geographic expansion of chronic wasting disease (Sutherland *et al.*, 2018).

Box 4 11 **Mobilization of local communities to create Brazilian extractive and sustainable development reserves, conservation units for sustainable use of natural resources.**

The movements triggered in the Amazon in the mid-1980s to create protected areas by the Brazilian State should, first, be considered social movements and not exclusively as environmental movements. They intended to react to the immediate threats suffered by the populations involved and their territories and social spaces, on which their cultural identity and economic survival depended (Browder, 1992). In the first National Meeting of Rubber Tappers, which took place in Brasília in August 1985 and when the National Rubber Tappers Council was created, it was the first time that extractive workers met to discuss land conflicts and forest conservation. The creation of extractive reserves was also a demand made at that meeting. The leaders participating in the meeting demanded that the rights to use these protected areas be transferred to local associations and granted in accordance with traditional land use standards, without the classic occupation models being copied (Allegretti, 1990), because contrary to the agrarian reform settlement projects, extractive reserves were already populated by traditional communities, who were familiar with local conditions and ecosystems. Among the main objectives of creating these areas, they claimed the creation of legal guarantees for extracting forest products and promoting a better quality of life for local populations (Butler, 1992). Thus, from the indigenous areas that already existed at the time, the National Rubber Tappers Council borrowed the idea of an area protected by the State, where local populations could practice their traditional culture and economic activities. However, extractivism should first be officially recognized as the main

Box 4 11

activity of these conventional populations, to be differentiated from other rural activities, such as the settlers of the settlements of the National Institute of Colonization and Agrarian Reform, which were predominantly agricultural activities. In extractive reserves, the units of exploitation of extractive families, known as placements *(colocações)*, are not formed according to traditional geographical references. The natural resources of the land, and not the land per se, define the boundaries between placements (Allegretti, 1990). In the case of extractive reserves, the terms "reserve" and "extractive" carry very particular connotations. The conventional use of the adjective "extractive" in the context of extractive workers in the Brazilian Amazon refers to a specific economic activity that depends on the maintenance of forest areas in the long run. Regarding the term "reserve," this designates an area with limits for human use, protected by the State, where the right of use is granted free and collectively to the populations in question (Allegretti, 1990). Since 2002 Brazil has had a National System of Conservation Units, which divides conservation units into two types: Integral Protection and Sustainable Use (Brazilian Ministry Environment, 2004). Extractive Reserves and Sustainable Development Reserves fall into this second category. The first Sustainable Development Reserve implemented in Brazil was the Sustainable Development Reserve of Mamirauá, in the state of Amazonas. Its history is relatively different from the creation of the extractive reserves since it was initially created as an Ecological Station after demand to allow the protection of some specific natural attributes, especially for the protection of the uacari-white primate *(Cacajao calvus calvus)*, which at that time was already on the list of species officially threatened with extinction in Brazil, as well as the International Union for Conservation of Nature (Queiroz, 2005).

and game officers). Where there is a strong synergy between centralized institutions and local and regional level knowledge and management systems (as with co-management), enforcement can be less costly (i.e., as there is a greater degree of self-regulation), limits social conflict and can lead to improved sustainable use outcomes. In some cases, national, level institutions can favour some kinds of sustainable use and disadvantage others. For example, in North America, a critical concern is how states and provinces privilege recreational, sports and commercial hunting over indigenous and subsistence harvesting of game (See section on indigenous institutions).

Laws related to the sustainable use of wild species, like other kinds of environmental laws, are usefully conceptualized along a sliding scale of 'hard' and 'soft' referring to the degree of enforceability. "Some hard laws contain soft requirements (e.g., to 'consider' or 'assess') while some soft law instruments contain hard law norms (e.g., legal principles)" (Dernbach & Mintz, 2011, p.539). It is widely held that a combination of hard and soft laws, including customary laws and social norms, when knitted together in a clear system, are the most effective at addressing problems in sustainability (Dernbach & Mintz, 2011). Soft law has the advantage of being flexible in allowing different stakeholders to respond and address issues in their own fashion, creating opportunities for more sustainable outcomes than narrow and rigidly enforced rules. However, too much flexibility may provide no incentive or assurance of compliance. One example of a potent combination of hard and soft laws related to protecting sustainable use occurs in the North Atlantic; the International North Sea Conferences focused on addressing pollution in the North Sea, which was indirectly impacting the sustainability of fishing and other kinds of harvesting and use of this ecosystem. The North Sea Conferences agreement was attributed with the strengthening and speeding up of the creation of harder laws within the European Union (Skjærseth *et al.*, 2006). The continued sustainable use of polar bears in the Northwest Territories, Nunavut, and Greenland, is also grounded in the interconnection between solid regulations and laws protecting the rights of Inuit, working together with the customary laws of Inuit, which are based on generations of Inuit knowledge (Clark *et al.*, 2009; Schmidt & Dowsley, 2010; Tyrrell, 2006). Soft law includes consideration and implementation of the precautionary principle set out in the Rio Declaration (1992).

Statutory laws and policies governing the sustainable use of wild species are highly variable in their quality and comprehensiveness and their implementation, effectiveness, and enforcement, particularly in the global South and many countries with still high levels of natural biodiversity. There is a lack of clarity in institutional responsibilities and a low extent of consultation with and engagement of diverse stakeholders, particularly among ethnic or minority groups and the traditional land and resource custodians with varying levels of recognition, rights and responsibilities.

While on paper, the quality and comprehensiveness of legal and regulatory frameworks appear strong, there is variation in the strength (i.e., teeth) of various laws and policies as applied and enforced (Ingram *et al.* 2017; Abbott, Tsinda and Mugisha 2018; Tieguhong *et al.* 2015). A range of soft and harder policy tools can be most effective at encouraging sustainable use, including the development and implementation of international agreements and protocols within national borders (Harrop & Pritchard, 2011; Skjærseth *et al.*, 2006).

Available harvest data coupled with oral histories and academic research provided ample evidence of sustainable use of Bathurst and other herds by indigenous peoples

Box 4 12 **Precautionary principle – Barren Ground Caribou and mining in Northern Canada.**

During 1990–2015, barren-ground caribou in northern Canada declined by over 70% as part of a cycle of natural herd population cycles (Vors & Boyce, 2009). In the case of the Bathurst herd in the Northwest Territories, Canada. The population declined more than 98% from 475 000 animals to less than 8000; the management board highlighted the possible extirpation of the herd. Numerous factors were considered to be a driver of population decline of this herd; the most controversial being habitat degradation associated with mining activity and over-harvest by recreational hunters and indigenous peoples. Many indigenous governments interpreted the mining boom in the Bathurst range and disturbance of more than 30 million hectares of summer and fall range as the core driver of the decline. However, the management focus was on harvest regulations. This privilege of mineral resource development, whilst efforts were made to criminalize subsistence hunting, was perceived as a major injustice by many indigenous peoples.

over the hundreds of years. In addition to adaptive and flexible harvesting practices (i.e., the decreasing harvest of caribou during periods of decline) and harvest substitution (i.e., harvest for other species such as fish, moose and muskoxen). The availability of other wild species, which have provided strong support for continued cultural continuity, economy and food security, has enabled Indigenous populations to ride periodic declines or variability in barren-ground caribou. The tracking of key indicators of population decline (e.g., body condition, reproductive success, habitat conditions) as well as catch-per-unit effort type information is regularly documented and shared by harvesters with one another. Well-developed sets of rules or norms of how to respect the caribou during times of decline form the foundation of decisions about where, when and how many caribou to harvest during population declines. This case study on the Bathurst caribou reveals the value of indigenous knowledge as a management foundation. Moreover, strong social networks and norms of reciprocity have also offset inequities in those most affected by population declines (i.e., food sharing within and between communities) and also ensured sustainable use. Some of the fundamental elements within Dene knowledge systems that contribute to the sustainable use of caribou include the following listed in **Table 4.2**).

The regulation of hunting within national borders also combines hard and soft tools (Peters *et al.*, 2020). It is suggested that changes in practice, law, and policy are urgently needed to promote sustainable trade and livelihoods (Tieguhong *et al.*, 2015; Yobo & Ito, 2016). Institutional responsibilities generally fall under ministries of forest and wild species. Interactions with agencies responsible for trade, enterprises, and particularly agriculture – given that the extent a species is wild or cultivated is often (Wiersum 2014), generally insufficient to ensure either sustainable resource use or livelihoods of people dependent upon the use and trade in these species (Awono *et al.*, 2016).

Table 4 2 **Key elements within Dene knowledge systems that contribute to sustainable caribou use.**

Practices from indigenous knowledge	Contribution to sustainable use of Barren Ground caribou
Adaptive caribou harvesting—decreased harvesting during periods of decline (and corresponding increase in harvest of other species and/or substitution for market foods) (Nuttall 2005; Wray and Parlee 2013; McMillan and Parlee 2013; Jacobsen *et al.*, 2016; Smith 1978; Winterhalder 1983)	Decreased hunting pressure on declining resources; diversification of traditional diets and/or increased dependence on market foods of lesser nutritional value
Increase in organization and communication at larger scales (Kendrick 2003; Doubleday 2007; Berkes 2009)	More complex institutional arrangements; opportunities for cross-scale decision-making
Increased in enforcement of informal property rights (for example, traditional hunting territory) and rules for caribou harvest (Padilla and Kofinas 2014; Berkes 1989)	Self-organized enforcement of rules to protect caribou
Strengthening and/or expansion of food sharing networks within and outside the caribou range (Jeans *et al.* 2017; Winterhalder 1983; Collings 1998)	Increase in knowledge generation and transmission (including with younger generations) within and between communities
Cultural rediscovery, social learning, and innovation to address food shortages (Berkes, Colding, and Folke 2000; Duhaime *et al.* 2008)	Increase in the breadth of potential solutions to food shortages
Cultural and spiritual learning	New spiritual learning; changes in the socio-cultural and spiritual relationship of people and caribou

In some countries there has been consultation with, and engagement of, diverse stakeholders around regulatory changes on wild species trade, for example via community forestry and plants, algae and fungi legal frameworks in Gabon, Cameroon, and Democratic Republic of the Congo (Awono *et al.*, 2016; Ingram *et al.*, 2017; Kimengsi *et al.*, 2019; Laird *et al.*, 2010; Lescuyer *et al.*, 2019; Yobo & Ito, 2016).

Examples of formal, or statutory, institutional arrangements that can drive sustainable use of wild species include: environmental laws on endangered species and designation of protected areas (national parks, provincial/state parks, or international designations such as Biosphere Reserve, RAMSAR site or Geographic Indication); rules and regulations that manage fishing, hunting, logging, or harvesting of plants or other species through licenses, permits, quotas and others means; and tenure or ownership rights of land or seas where wild species lives, and rights to resources contained therein. Internationally, legally binding institutions include conventions or treaties.

4.2.2.2.4 Co-management and cooperative arrangements

Co-management and cooperative management arrangements are well developed in many areas of the world including Canada, New Zealand, Europe and parts of Asia where they have proven highly effective at engaging local users of resources in the design and implementation of formal governance (Berkes 2009) (**Tables 4.3** and **4.4**). These arrangements are particularly well-developed with respect to regulating harvest of fish and wild species as well as forest resources and protected areas. Co-management has been helpful in the management of small scale fisheries (Borrini-Feyerabend *et al.*, 2004; Cárcamo *et al.*, 2014, Jones *et al.*, 2017). Although top-down fisheries management systems are critical in some cases, fisheries managers in many parts of the world have recognized for decades that most fisheries cannot be managed without the cooperation of local fishers, and in situations of significant resource competition (i.e., many users with diverse interests and values), co-management is critical to trust building and ensuring compliance with laws and regulations (Pomeroy & Williams, 1994). This is true in

Table 4 3 **Co-management institutions and transboundary problems.**

Species	Lesson related to managing for sustainable use
Pacific salmon	Salmon populations are under stress in northwestern Canada and the United States of America due to such factors as habitat loss and degradation (from climate change and resource development) and commercial fishing. “Management is complicated by the geographical scale of salmon production, encompassing terrestrial and aquatic habitats, extending from inland watersheds to ocean basins, and encountering different property and governance regimes” (Ebbin 2002). Commercial habitat use and fishing interests have long dominated management to the detriment of indigenous peoples and local knowledge, and the sustainability of fish stocks. Various kinds of shared decision-making models have emerged that redistribute some power to local fishers through legal agreements (e.g., Nisga’a Final Agreement) requiring the engagement of Indigenous Peoples and knowledge in the management have emerged in the last two decades and other kinds of Tribal and Indigenous-led conservation efforts (e.g., Columbia River Inter-Tribal Fish Commission, Nuu-chah-nulth Tribal Council) have improved management outcomes. However, many inequities and socio-economic and political barriers to sustainable use continue to exist that are detrimental to salmon and salmon-based economies and cultures (Atlas *et al.*, 2021; Ebbin, 2002; Pinkerton, 1994).
Rangifer (porcupine caribou management board)	One of the oldest and most successful transboundary co-management institutions is the Porcupine Caribou Co-Management Board shares power between management authorities of multiple Indigenous governments, Alaska, and the Yukonthe Yukonst Territories and federal governments of Canada. The Porcupine Caribou Co-Management Board is an advisory board established under the Porcupine Caribou Management Agreement (1985) to communicate information about the herd and provide recommendations to agencies responsible for managing the herd. The success of the management can be measured by the sustainability of the population which has remained relatively stable in recent years when compared to other caribou herds in the circumpolar north. Sustainability is also measurable by the ability of indigenous peoples in the region to continue to sustainably harvest caribou to meet subsistence needs. The strength of land claim institutions that protect Inuvialuit and Gwich’in rights to harvest, respect of indigenous knowledge and customary laws for harvesting, coupled with effective lobbying to protect caribou habitat from resource development are among the factors contributing to this success (Kendrick, 2003, 2003; Kofinas, 2005; Kruse *et al.*, 1998; Moller *et al.*, 2004; Nadasdy, 2003; Parlee *et al.*, 2018; Peacock *et al.*, 2020; Peacock. & Turner, 2000; Thomas & Schaefer, 1991; Usher, 1993).
Central American Ccral reef and inshore fisheries	The diverse fisheries of Central America and the Caribbean region largely overexploited, particularly those of the nearshore and coral reefs. Development without effective conservation and management measures has led to this problem. Most countries have weak legislation and no active or effective fisheries management plans. Centralized, top-down management has largely been to blame in this region, coupled with limited self-policing of local fishers. The political culture (i.e., weak institutions and poor enforcement of laws) of the region coupled with socio-economic conditions have been factors that have limited power-sharing and effective management towards sustainable use. In Costa Rica as in many other jurisdictions, “centralized regulation of fishing inputs (e.g., gear and seasonal restrictions) has largely failed to address overcapacity and, in some cases, has intensified competition and uncertainty among fishers” (Garcia and Heninen 2016: 759). The Marine Area of Responsible Fishing (Área Marina de Pesca Responsible, or AMPR), suggests the opportunities that can come for sustainable use through the involvement of local fishers’ organizations (Fargier *et al.*, 2014).

Table 4 3

Species	Lesson related to managing for sustainable use
Forest ecosystems (e.g., Mesoamerican biological corridor)	Co-management institutions can be an effective way to mediate transboundary resource management problems including competition between users as well as ensuring fit between ecological scales and political scales of decision-making. A bio-regional lens has been used in establishing protected areas and developing forest co-management institutions in some regions such as central America (i.e., Mesoamerican Biological Corridor) (Barquet, 2015).
Transboundary Pprtected areas (e.g., Great Limpopo Transfrontier park)	Transboundary of frontier governance arrangement in southern Africa have created opportunities for new kinds of governance of lands, species and protected areas. The South Africa Development Community signed a Treaty in 1992 aimed at managing complex natural resource management problems and creating economic opportunities (e.g., cross-border trade). It is recognized that many peoples in the region are dependent on species that span or are dynamic across borders. The potential for shared decision-making over these natural resources is seen as an important pathway towards sustainable use of natural resources as well as sustainable economic development more broadly. Despite the Treaty being more than twenty years old, conflicts persist due in large part to economic uncertainties and stresses on local communities and governments (Katerere *et al.*, 2001). Other kinds of transboundary agreements and initiatives such as the *Great Limpopo Transfrontier Park* have also had mixed success; rather than decentralizing power to local people, large NGOs and donors may have centralized power elsewhere and limited the rights and interests of local organizations and communities (Duffy, 2006).

Table 4 4 **Success Factors in Co-management.**

Source: Armitage *et al.*, (2009) © The Ecological Society of America under license number 5154840749156.

Condition of success	Explanation
Well-defined resource system	Systems characterized by relatively immobile (as opposed to highly migratory and/or transboundary) resource stocks are likely to generate fewer institutional challenges and conflicts, while creating an enabling environment for learning.
Small-scale resource use contexts	Small-scale systems (eg management of a specific rangeland or local fishery) will reduce the number of competing interests, institutional complexities, and layers of organization. Larger-scale resource contexts (transboundary stocks, large watersheds) will exacerbate challenges.
Clear and identifiable set of social entities with shared interests	In situations where stakeholders have limited or no connection to “place”, building linkages and trust will be problematic. In such situations, efforts by local/regional organizations to achieve better outcomes may be undermined by non-local economic and political forces.
Reasonably clear property rights to resources of concern (eg., fisheries, forest)	Where rights or bundles of rights to resource use are reasonably clear (whether common property or individual), enhanced security of access and incentives may better facilitate governance innovation and learning over the long term. Such rights need to be associated with corresponding responsibilities (eg., for conservation practices, participation in resource management).
Access to adaptable portfolio of management measures	Participants in an adaptive co-management process must have flexibility to test and apply a diversity of management measures or tools to achieve desired outcomes. These measures may include licensing and quota setting, regulations, technological adjustments (eg gear size), education schemes, and so on. In other words, economic, regulatory, and collaborative tools should all be available.
Commitment to support a long-term institution-building process	Success is more likely where stakeholders accept the long-term nature of the process, and recognize that a blueprint approach to institutions or management strategies is probably not advantageous. Commitments of this type can provide a degree of relative stability in the context of numerous changes and stresses from within and outside the system.
Provision of training, capacity building, and resources for local-, regional-, and national-level stakeholders	Few stakeholder groups will possess all the necessary resources in an adaptive co-management context. At the local level, resources that facilitate collaboration and effective sharing of decision-making power are required. Regional- and national-level entities must also be provided with the necessary resources.
Key leaders or individuals prepared to champion the process	Key individuals are needed to maintain a focus on collaboration and the creation of opportunities for reflection and learning. Ideally, these individuals will have a long-term connection to “place” and the resource, or, within a bureaucracy, to policy and its implementation. Such individuals will be viewed as effective mediators in resolving conflict.
Openness of participants to share and draw upon a plurality of knowledge systems and sources	Both expert and non-expert knowledge can play productive and essential roles in problem identifica-tion, framing, and analysis.The tendency in most resource management contexts is to emphasize differences in knowledge systems. However, there are substantial contributions to social–ecological understanding, trust building, and learning, where the complementarities between formal, expert knowledge and non-expert knowledge are recognized.
National and regional policy environment explicitly supportive of collaborative management efforts	"Explicit support for collaborative processes and multi-stakeholder engagement will enhance success. This support can be articulated through federal or state/provincial legislation or land claim agreements, and the willingness to distribute functions across organizational levels. Additionally, consistent support across policy sectors will enhance the likelihood of success, and encourage clear objectives, provision of resources, and the devolution of real power to local actors and user groups."

Box 4 13 **Karuak and co-management of the forests in California and Oregon.**

The Karuk people are the indigenous peoples of the Klamath River valley which is biodiverse region near the border between California and Oregon; their territory spans over 1.38 million acres. Many members of the nation depend on the forest for the subsistence foods from the forest and its waterways. Among the cultural practices and uses of the forest was cultural burning in support of managing forest fire risks and shaping the landscape in ways that nurtured the growth of particular kinds of resources and wild species habitats. The Karuk Tribe is now federally recognized by the U.S. government but was not historically recognized with land rights as a result their capacity to live and harvest resources from their homeland has been tenuous. A pilot project of co-management involving the Karuk Tribe and the United States of America Forest Service was established in the Klamath Basin of Northern California, with the intention of building greater equity in decisions being made about the use of resources of the forest. The project was successful due to simultaneous efforts of the United States of America Forest Service to reconsider colonial histories and institutions that excluded the Karuk people and the willingness of Karuk government to engage in institution building that blended Karuk laws and those of the state of Oregon and California in ways that are consistent with cultural values and uses. Challenges continue due to the rigidities of formal government and colonial systems which persist in forest management decision-making (Diver, 2016; Marks-Block *et al.*, 2019).

cases where resources are remote or scattered in areas where enforcement is difficult as "under these conditions, delegation of fisheries management and allocation of decisions to local fishers (at the) community level may be more effective than the management efforts that distant, understaffed and underfunded national government agencies can provide" (Pomeroy & Williams, 1994). Over the last 30 years the principles or factors that most critically contribute to the effectiveness of co-management of fisheries have been further developed. A critical factor in many regions of the world is recognition of the customary laws of local and indigenous peoples who have long-term relationships to fisheries resources and a vested interest in ensuring the sustainability of the resource. These customary laws are based on generations of indigenous and local knowledge and are continuously informed by systems of social learning (e.g., monitoring), are among the most vital kinds of co-management institutions, and tend to be most effective at ensuring sustainable use (Armitage *et al.*, 2009; Berkes, 2009).

Over the last forty-five years, co-management arrangements have been emerging in various regions and for diverse species and habitats around the world. Conservation areas or protected areas have proven to be managed in ways that ensure sustainable use where co-management systems have been designed. Inclusive approaches to governance are evidenced as effective in many nation-states and with respect of numerous wild species including those of wild species, fisheries, timber and other forest resources. The engagement of citizens in governance can take many forms and range in rigor and depth along various kinds of continuums (e.g., Arnstein's Ladder of Participation) (Arnstein, 1969). Co-management is considered key in addressing many different types of sustainable use problems due to the integration of diverse stakeholders into the rule-making process, monitoring, and enforcement (Berkes *et al.*, 1991).

4.2.2.2.5 Indigenous rights

Indigenous peoples and rights are defined and recognized variously in many parts of the globe. A typical pattern has been the history of colonization and its impacts on indigenous cultural-spiritual relationships, access and use of natural resources including wild species. A discussion of indigenous rights is a critical question to this assessment because many aspects of unsustainable use of wild species (i.e., compromised health, extirpation, etc.), have direct impacts on the health and well-being of indigenous peoples (Godoy *et al.*, 2005; Posey, 1996; United Nations, 2019; Westra, 2012). This is because many indigenous peoples rely heavily on hunting, trapping, fishing, gathering of berries and medicinal plants, and visiting of sacred sites are critical to food security (Kuhnlein, 2015), cultural continuity, and health and well-being (Biddle & Swee, 2012; Burgess *et al.*, 2009; Stephens *et al.*, 2006). Indigenous peoples also have well established knowledge practices and belief systems that have contributed to the sustainable use of wild species for generations; thus, the support and recognition of indigenous rights are a significant pathway toward wild species conservation (Gadgil 1993).

In 1982, United Nations Special Rapporteur of the Sub-commission on the Prevention of Discrimination and Protection of Minorities released a global report on systemic discrimination (United Nations, 1982). Following this, over 30 years of consultation and negotiations between nation-states and indigenous peoples led to the creation of the United Nations Declaration on the Rights of Indigenous Peoples (United Nations, 2007). The United Nations Declaration on the Rights of Indigenous Peoples sets out clear principles in respect of indigenous rights related to land and resource use. These rights are recognized as highly consistent with other principles of the United Nations including the Sustainable Development Goals.

Table 4 5 **Examples of indigenous customary laws and related norms that support sustainable use of wild species.**

(1) Kosoe *et al.*, (2020); Ntiamoa-Baidu, (1991); (2) Sudo, (1984) (3) (4) de Mattos Vieira *et al.*, (2015) (12) Waller & Reo (2018) (13) Deur, (2009) (14) Turner & Turner (2008) (15) McKemey *et al.*, (2021) (16) Samakov & Berkes (2017), (18) (M. Gadgil (1987) (19) Parlee *et al.* (2006); (20) Gangadhar *et al.* (2018) (21) Hickey & Johannes (2002) (22) Chowdhury *et al.* (2014); Laugrand & Oosten (2010); (23) (Meyer-Rochow, 2009); (24) Kendrick *et al.* (2005); (25) Begossi & de Souza Braga (1992); (26) Pezzuti *et al.* (2010) (27) Nijhawan & Mihu (2020); Ross *et al.* (1978); (28) Golden & Comaroff (2015); (29) (Anbacha & Kjosavik, 2018; Argumedo & Pimbert, 2010; Arnold *et al.*, 2021; Berkes *et al.*, 2000; Carothers *et al.*, 2021; Colding *et al.*, 2003; DeGeorges & Reilly, 2009; Fowler, 2003; Francis, 2019; Gonzales, 2013; Kimmerer, 2011; McMillen *et al.*, 2017; Mulrennan, 2014; Phalan *et al.*, 2011; Sowerwine *et al.*, 2019; Thomas, 2015; Watkin Lui *et al.*, 2016; Welch, 2014).

	Fishing	Terrestrial animal harvesting	Gathering	Non-Extractive
Landscape and habitat taboos	Taboos limit access to sensitive habitats as in (1) coastal lagoons in Ghana and (2) coral reefs in Micronesia.	Rotating goose hunting to limit hunting disturbance (3) Cree in northern Canada and the Piagaçu-Purus Reserve in Brazil (4).	(5) Sacred forests that protect valued habitats (e.g., Malawi). (6)	Taboos against travel in areas of glaciers as in northwestern Canada (7) (8)
Rituals and ceremonies that support habitat protection and regeneration	Making offerings or 'paying' the water as with the (9) Dene of northern Canada; and "first salmon ceremony" harvest rituals that limited early access to salmon spawning areas.	Respect of key migration corridors and water crossings and calving grounds of barren-ground caribou as with the Gwich'in of northern Canada and Alaska (11) Culling of deer population (harvest for food to limit over browsing and promote biodiversity richness (12).	Cultural burning practices that support the regeneration of medicinal plants as with the (13) Klamath. First food ceremonies to recognize spirits of berries and signal access to berry patches as in Northwest Coast Canada (14). Cultural burning in Australia to support social fertility and manage bush fire risk (15)	(16) Cleaning and care of sacred sites to ensure continued spiritual value and healing properties as in Kirghizstan.
Temporal and dynamic taboos and regulations related to harvesting in breeding / reproductive seasons (i.e., closed seasons)	Taboos instituted when stocks are decreasing – promote stock recruitment as in (17) South-East Asia.	Bans hunting certain animals in the four months from July to October exist in many (18) Indian villages.	Care and stewardship of plants such as berries and medicinal plants are visible among the Gwich'in Nation (19)	Taboos against entry of sacred meadows limit impact on sensitive wild species habitats (e.g., high altitude areas of India such as Bhadelguar)
Specific Species-Taboos	Taboos against harvest of sea turtle in (21) Vanuatu reefs.	(22) There are taboos based on indigenous and local knowledge against hunting of rare species or those under stress as with the *Mro* people of Bangladesh. Beliefs and rules about 'not wasting' meat are associated with the respect for Sedna or Senna as in Inuit culture in Nunavut and Siberia.	(23) Food and medicinal taboos against gathering of plants are common to protect against adverse health or dietary outcomes and/or ensure availability of species other specific uses.	(24) Access of particular wild species habitats can be seen in many regions and can be gendered (e.g., women should not visit caribou crossings while menstruating).
Taboos for Species Consumption (as food)	Fish species in the (25) Tocantins River (Amazon) are not eaten due to their value as medicine. Taboos against turtle harvest in the (26) Amazon as food (due to potential for illness).	(27) Taboos against the consumption of meat from hunting exist. For example, taboos against consuming primates.	(28) Food taboos are common and indirectly contribute to conservation of these species (e.g., as in Madagascar)	NA
Rules and incentives related to sharing observations (e.g., reciprocal care)	(29). Food sharing networks and incentives or reciprocity are common in many indigenous cultures and include care for others (e.g., more vulnerable populations) as well as care for the species and habitats. For example, when animals given themselves as gifts to feed the community, expressions of care and respect are shown for the animal and the ecosystem.			

The extent to which these rights are recognized by nation-states varies significantly. In some countries, there is little recognition of these rights nor ratification of the United Nations Declaration on the Rights of Indigenous Peoples principles. Canada, although slow to acknowledge the protocol, has made significant efforts to do so in recent years. In many ways, the United Nations Declaration on the Rights of Indigenous Peoples a fortification of other kinds of rights held by indigenous peoples and protected by the Canadian Constitution (1982), through historic and modern treaties, and Supreme Court case law. Many of these legal instruments protect the rights of indigenous peoples to hunt, fish, trap for subsistence, or sustain a reasonable livelihood based on their traditional lands and resources. These rights are often interpreted by the courts as superseding provincial and federal laws and regulations related to management, such as those associated with the east coast lobster fishery as has been the case in recognition of the Marshall Decision. indigenous peoples in Canada bear a significant burden of ill will by non-indigenous peoples who fear these rights will lead to declines or losses in resources. However, there is no evidence that recognition of indigenous rights results in "over-harvesting" and species decline (whether fish, wild species, timber or other resources) but data shows that the recognition of indigenous rights have led to significant conservation outcomes (Lynch *et al.*, 2016; Popp *et al.*, 2019; Stephenson *et al.*, 2018). However, in some key cases, the subsistence and rights of indigenous peoples have often been undermined by poor management of resources For example, contamination of the Athabasca river fishery due to oil sands mining (Westman and Joly 2019; Kelly *et al.* 2010) collapse of Atlantic and Pacific fish populations due to industrial fishing (Atlas *et al.*, 2021; Lotze & Milewski, 2004; N. Turner *et al.*, 2013), moose population decline in Nova Scotia associated with habitat fragmentation, conversion and loss (Beazley *et al.*, 2006; Popp *et al.*, 2019), extirpation of boreal caribou herds in northern Alberta due to overharvesting of old growth forest (Collard *et al.*, 2020; Johnson *et al.*, 2015; Nagy-Reis *et al.*, 2021).

Similar patterns are visible in many other countries with strong evidence of the impact of biodiversity loss on the health and well-being of indigenous peoples (Hunter *et al.*, 2015; Kuhnlein, 2015). Fishing, forestry, hunting, gathering practices are not only essential component of their traditional diets but of culture and well-being (von der Porten *et al.*, 2019). Hence rights to terrestrial and marine resources and territory are inseparable from broader indigenous rights to self-determination (Cisneros-Montemayor *et al.*, 2016; Larson *et al.*, 2016) as well as a more comprehensive suite of rights protected by the United Nations Declarations on the Rights of Indigenous Peoples and Human Rights more broadly. Efforts led by indigenous organizations to reduce poverty through sustainable use of biodiversity tend to include key elements of indigenous resurgence strategies, involving the reinvigoration and reestablishment of indigenous land tenure, decision-making, rights, and leadership (von der Porten *et al.*, 2019). Amazon forests managed by indigenous communities show lower rates of deforestation and carbon emissions (Blackman & Veit, 2018). Globally, indigenous territories see lower rates of ecosystem health declines compared to other areas (although trends are nonetheless mostly negative) (Díaz *et al.*, 2019). In addition, it is essential to recognize that indigenous worldviews and decisions are unique and should be included and respected in approaches to knowledge co-creation and resource co-management (Hill *et al.*, 2020).

In addition to the adverse impacts of formal institutions on Indigenous rights and sustainable use of wild species, there is clear evidence of how Indigenous knowledges and customary laws have been vital to sustainable use of wild species in many places globally. In addition to ensuring many conservation outcomes, Indigenous systems of stewardship have been protective of food security, health, culture and well-being (Berkes *et al.*, 2000; M. B. Gadgil *et al.*, 1993). For example, in the case of forest ecosystems in Nepal, customary laws associated with the conservation of 'ranivana' (community forests) were established by shamans and priests; over generations, they have proven successful in ensuring the conservation of valued forest species as well as equitable access for benefits to people (e.g., fuelwood, fodder and medicinal plants) (Khatri, 2008). Many more examples exist (see **Table 4.5**). A key challenge for these and other customary law systems is the extent to which they are in conflict with or are not recognized as a system of laws by nation states. Despite evidence of the social and cultural benefits, many kinds of rules are little recognized.

4.2.2.3 Informal institutions, voluntary measures and collective action

Informal institutions are defined as those sets of rules that are used (i.e., rules in use) that effectively form the basis of decisions about access, use, and sharing of resources (Berkes 1998). They can, along with international agreements and state-level institutions, be highly effective at ensuring sustainable use of wild species (Griffiths, 1986; Laird *et al.*, 2010; Shanley *et al.*, 2015). Informal institutions may develop as a softer dimension of, or response to, more formal institutions, but may also function as the sole mechanism for regulating sustainable use.

They are critical in filling gaps in formal, state-level institutions, or where these formal institutions have failed (Ostrom, 2000). Voluntary organizations and efforts at collective action are also very important and can contribute significantly to addressing questions of sustainable use of a variety of species and myriad practices; some of the most effective voluntary organizations are in fisheries management (Blyth *et al.*, 2002; Jentoft & Bavinck, 2014). Collective

Box 4 14 **Politics of forest management in the Himalayas: Nepal and Myanmar.**

The Himalayan temperate forest zone has some of the highest percentage of endemic and threatened species in the world (Brandt *et al.*, 2017). Many of the threatened species in this region depend on forests (Brandt *et al.*, 2017). Five countries, including Nepal and Myanmar, contain >98% of the remaining forests in this region (Brandt *et al.*, 2017). While deforestation is a concern in the Himalayan temperate forest zone Nepal and Myanmar have different results when it comes to forest management (Brandt *et al.*, 2017). In general, Nepal is known for having successful forest management through their progressive community forest management that provides benefits to local communities (Anup *et al.*, 2018; Baral *et al.*, 2018; Brandt *et al.*, 2017; Rai *et al.*, 2017). However, studies examining Myanmar show that the country has weak forest policies riddled with corruption (Brandt *et al.*, 2017; Lim *et al.*, 2017). Rates of deforestation in unprotected areas from 2000 to 2014 were very low in Nepal at 0.6% whereas Myanmar had the highest deforestation rates of the region at 1.7% (Brandt *et al.*, 2017). Additionally, Myanmar had the third largest deforestation by area in the world from 2010 to 2015 (Reddy *et al.*, 2019). In the Himalayan temperate forest zone, Nepal has the best record of successful community management (Brandt *et al.*, 2017). In Nepal, 68% of forests are managed by the government and the remaining 32% are under community management (Brandt *et al.*, 2017). Community forest management in Nepal has helped to enhance forest cover, conserve biodiversity and support local livelihoods (Anup *et al.* 2018). After the civil war in Nepal, the government used conservation, especially forest conservation, as a tool of state building (Dongol & Neumann, 2021). A key to Nepal's success with community forest management is the active involvement of villagers in the protection of their local forests (Anup *et al.*, 2018). Community forest management was used as a tool to reduce conflict between the government and rural communities by giving those communities authority over the local forests (Dongol & Neumann, 2021). Not only are the citizens directly proximate to the forests included but distant users are also involved in forest management (Rai *et al.*, 2017). Community forest management in Nepal provides forest products to distantly located citizens who are unable to physically participate in forest management activities (Rai *et al.*, 2017). Providing forest products to these citizens has contributed to positive support for forest management in proximal and distant communities alike (Rai *et al.*, 2017). Overall, Nepal's community forest management approach to reduce deforestation is a sustainable approach. On the other hand, Myanmar has fallen short with its forest management practices. A huge contributor to the current patterns of deforestation in Myanmar is the long history of military rule and conflict (Brandt *et al.*, 2017). Myanmar's forests are controlled by the national government through a centralized forest ownership approach (Brandt *et al.*, 2017). Timber extraction and agricultural advancement are often given priority over forest protection and sustainable use (Brandt *et al.*, 2017; Lim *et al.*, 2017). As a result, government forests are viewed as the equivalent of an open-access area (Brandt *et al.*, 2017). Government forests in Myanmar have insufficient monitoring and enforcement mechanisms which leads to exploitation of forest products (Brandt *et al.*, 2017). In conclusion, the community forest management system in Nepal has proven a successful method of forest conservation. Community forest management is a practice of forest management that is sustainable and increases biodiversity. This practice in Nepal has had tremendous results in the Himalayan temperate forest zone that is currently susceptible to deforestation. While Nepal has found success, Myanmar has struggled to maintain integrity in their conservation attempts. The political instability in Myanmar has provided a barrier to achieving effective forest management. The approach that Nepal used of building governance structures around conservation policies is an interesting approach and has been an important development for the region's conservation of forests.

actions (e.g., information campaign, protest) are important for social groups who are not represented in formal kinds of governance and have been found effective at addressing issues of unsustainable use. These include actions by rural and subsistence communities, indigenous peoples, women and others. Indigenous and local communities are in the frontlines of resisting "development" schemes (Díaz *et al.*, 2019). As an example, in the Puna area of South America, local communities such as the ones from Salinas Grandes and Laguna Guayatatoyoc engage in collective action against lithium mining in order to protect their pastoralist activities and livelihoods (Pragier, 2019). When compared to more formal institutions, less is known about informal institutions and collective actions; there are gaps in understanding of "the social and political mechanisms involved in large-scale collective action problems and how cooperation in large communities is facilitated or obstructed"(Duit, 2011, p.907). Forms of collective action aimed at addressing issues of unsustainable use often focus on questions of rights of access, benefit, and use.

Informal institutions are rooted in the social and cultural norms of communities and societal groups, and customary law can provide effective regulation of wild product harvesting. In the case of Cameroon, it was found that customary laws addressed who owns resources, who can harvest them, where harvesting will take place, in what quantity, and who benefits and in what ways; all with greater specificity and legitimacy than weak government regulations (Ingram, 2014; Laird *et al.*, 2010).

There are similar examples from almost every corner of the globe and with respect to nearly every practice and use of wild species. Ndoye and Awono (2010) and Ingram, Ndumbe, and Ewane (2012) describe for *Gnetum africanum* how allocation of permits and quotas (which are not based on any inventory of the plants) and standard practices of bribes and corruption at official checkpoints, raises costs, increases losses, and leads to increased resource exploitation. Sunderland *et al.* (2010) and Ingram *et al.* (2017) report on the trade of bush mango *(Irvingia* spp.) and njansang *(Ricinodendron heudelotii)* (Ndumbe *et al.*, 2018) in Central Africa, which is widely traded nationally and regionally and likewise conclude that government institutions are all but absent, with corruption an issue for those that do function. The Sami management of reindeer in Finland and Norway is the result of the interaction between local and national institutions (Marin & Bjørklund, 2015). In Finland, herders work with a range of new formal bureaucratic institutions that have come on top of customary ones. There is a mismatch between the formal and informal institutions and their underlying logics and styles of thinking have resulted in a complex institutional dynamic affecting land and resource tenure (Marin & Bjørklund, 2015). Areki & Cunningham, (2010) report on the sustainability crisis around the wood carving species *Intsia bijuga*, which requires a complementary approach of strengthening weakened customary law and stronger and better-coordinated national regulation.

In some countries, lack of recognition by government of customary systems (including their criminalization) have undermined sustainability (Laird, McLain, and Wynberg 2010; Arnold and Pérez 2001; Wynberg and Laird 2007; Michon 2005; Lele, Pattanaik, and Rai 2010). However, in cases where species are under strong commercial pressure, for example *Prunus africana* across much of Africa (Wiersum *et al.*, 2014), and customary systems of governance have broken down, statutory law is an important and often necessary complement to replace or reinforce customary law (Laird, McLain, and Wynberg 2010).

4.2.2.4 Customary laws and common pool resource institutions

Systems of natural resource management, including those related to wild species use, have changed significantly over the last thirty years in many jurisdictions from centralized, top-down conservation approaches to community-based approaches, which account for social and ecological dimensions of use (Agrawal & Gibson, 2001; Borrini-Feyerabend, 1996; Meinzen-Dick *et al.*, 2002; Russel & Harshbarger, 2003). Part of the success of community-based institutions is attributed to the flexibility and adaptability of rule systems to ups and downs in resource availability and condition. Rules that integrate the well-established cultures and way of life of local peoples are most often successful and may be considered ‘customary’. “Customary rights” refer to community rules and regulations inherited from ancestors that are accepted, interpreted, and enforced by the community, which may or may not be recognized by the State (Awono *et al.*, 2016). Whether recognized by statutory laws or not, rural communities often consider themselves to be the traditional owners of resources within their respective domains (Wily and Liz 2004; Laird, McLain, and Wynberg 2010).

A subset of these rules related to “commons” are relevant to this assessment, given that many wild species are defined as common-pool resources. Such institutions are well developed in many countries around the world and in relation to numerous species. These institutions delineate many aspects of management. Rights to use, harvest and associated trade may be governed through systems of short and long-term leases, loans, gifts, payment (including in-kind) and inheritance, which can differ depending on which societal and ethnic groups dominate access to resources and access to markets. These customary norms typically differ within a country and determine who owns resources and may access them; where and in which quantities harvesting may take place; and who benefits and how.

These common pool resource institutions have proven to be particularly effective at addressing what is defined as the open access problem (i.e., unregulated harvest). Many authors including (Berkes, 1989; McCay & Acheson, 1987; Van Den Berg *et al.*, 2007; Wakjira & Gole, 2007) have evidenced the usefulness of customary and community-based resource management systems in the sustainable management of small-scale fisheries and of plants, algae and fungi. Similarly, there is concrete evidence that participatory, community-based natural resource management approaches are effective in promoting sustainable use of wild species, in Africa (Abensperg-Traun, 2009; Rowcliff *et al.*, 2004) and in Asia (Nasi *et al.* 2008), especially with the involvement of local and indigenous peoples and their traditional knowledge of sustainable use of wild species (Freeman, 1999; Hakimzumwami, 2000). At the same time, there is also evidence of failure of such approaches (Acheson, 2006).

In Cameroon, harvesting wild plants, algae and fungi on land held by a clan or family may take place only with the family’s permission. On communal lands, any member of a community can harvest for subsistence use, but for high value traded products (such as *Prunus africana, Gnetum* spp and *Irvingia* spp), approval is generally required from the chief or village council. Outsiders often need permission to harvest and should provide in-kind or cash compensation before or after harvesting. In some communities, conflicts occurred when such proceeds were not used to benefit the wider community (Ingram *et al.* 2015).

In general, the principle of customary law and common pool resource institutions involving wild species are focused on safeguarding the health of species while at the same time meeting social and economic needs. Not all common pool

Box 4 15 **Medicinal and aromatic plants in Asia.**

Medicinal and aromatic plants have played significant socio-cultural and economic roles in many rural households in the Himalayan region of Asia, for thousands of years (Joshi & Rao, 2011; Karki *et al.*, 2005; Kumar *et al.*, 2015; Kunwar *et al.*, 2015; Lal & Samant, 2019; Olsen & Larsen, 2003). One such meaningful plant is the deciduous shrub Ephedra, which is traditionally used for primary health care in rural households (Joshi & Rao, 2011; Khan *et al.*, 2011; Sher *et al.*, 2016) and has sacred or religious connections (Negi *et al.*, 2018; Sher *et al.*, 2016) dating back to the beginnings of Zoroastrianism (Falk, 1989). Ephedra also provides economically for households through harvest and trade (Karki *et al.*, 2005; Olsen & Larsen, 2003; Sher *et al.*, 2016), which is highly driven by interest from pharmaceutical companies (Lal & Samant, 2019; Negi *et al.*, 2018; Sheng-Ji, 2001; Shinwari & Gilani, 2003; Upadhyay *et al.*, 2019). The Ephedra genus has eleven different species throughout the higher elevations of the Himalayas, one of which is *E. gerardiana*, found in drier temperate and alpine areas (Lal & Samant, 2019). *E. gerardiana* is becoming increasingly vulnerable due to landscape change and over-harvesting in many regions (Roland, 2020) driven by the need for income in many rural subsistence communities. In the Uttarakhand state of India, a high number of medicinal and aromatic plants including *E. gerardiana* are found to be under pressure, resulting from factors which include: loss of indigenous knowledge (Kumar *et al.*, 2015), disinterest from younger generations (Kumar *et al.*, 2015; V. S. Negi *et al.*, 2018) over-harvesting and illegal trade (Joshi & Rao, 2011; Kala, 2005; Phondani *et al.*, 2015), land pressures (Kanwal & Joshi, 2015), lack of policy and conservation enforcement (Joshi & Rao, 2011; Kala, 2005) and climate change (Negi *et al.*, 2018). Primarily because of the economic demand and overharvesting of medicinal and aromatic plants for harvest and economic trade, the need to turn towards partnerships with local farmers to cultivate certain plants is recognized. Pilot projects are underway in the Champawat district (Phondani *et al.*, 2015) and the Byans valley (Negi *et al.*, 2018) to create gardens for medicinal and aromatic plants to be sustainably harvested for household income and primary health care. While this is just a beginning, India is showing benefits of local markets and herbal gardens playing a role in sustainable growing and harvesting methods of medicinal and aromatic plants such as *E. gerardiana* (Joshi & Rao, 2011). In Pakistan's upper Chitral Valley and Astore district, medicinal and aromatic plants are vulnerable due to landscape pressures including deforestation (Khan *et al.*, 2011; Shinwari & Gilani, 2003) and habitat destruction because of over-grazing and soil erosion (Alam *et al.*, 2017; Khan *et al.*, 2011; Ullah & Ur Rehman, 2016). According to Sher *et al.* (2016) and Shinwari & Gilani (2003) residents of this Himalayan region rely extensively on medicinal and aromatic plants for traditional healing and primary health care. Pharmaceutical companies, eager for *E. gerardiana* have increased the harvest demand in an economically challenged region (Ali & Qaiser, 2009; Shinwari & Gilani, 2003). *E. gerardiana* has been over-harvested by collectors eager to create income- whether nomads or local inhabitants (Alam *et al.*, 2017; Khan *et al.*, 2011; Ullah & Ur Rehman, 2016). This is largely a result of global demand and dealers without conservation policies, and limited local knowledge of the need for sustainable harvesting practices (Ali & Qaiser, 2009; Z. Shinwari & Gilani, 2003). In addition to landscape pressures, overharvesting of medicinal and aromatic plants for income purposes puts *E. gerardiana* in a continual vulnerable state. Similar to India, it has been recognized by researchers that in order to decrease pressure the delicate Himalayan ecosystem where medicinal and aromatic plants species have been recorded as extinct (Dhiman & Rautela, 2014; Z. Shinwari & Gilani, 2003) and over-harvesting for income purposes continues; cultivating *E. gerardiana ex situ* by pharmaceutical industry and households will be a way forward to allow for sustainable harvest, sales, and use of this high-demand medicinal and aromatic plants. While *E. gerardiana* has been shown to be one of a few medicinal and aromatic plants that survive well in cultivation (Shinwari & Gilani, 2003), this has yet to be seen in Pakistan at the time of this research.

resource institutions are effective; those that are successful generally adhere to the following eight design principles as defined by Ostrom (1990):

- Boundaries of users and resource are clear.
- Congruence between benefits and costs.
- Users had procedures for making own rules.
- Regular monitoring of users and resource conditions.
- Graduated sanctions.
- Conflict resolution mechanisms.
- Minimal recognition of rights by government.
- Nested enterprises.

Among the biggest threats to the sustainability of common-pool resource institutions is industrialization and globalization (Dietz *et al.*, 2003). The social, cultural, and ecological stresses created through these processes effectively undermine the systems established within local or regional areas, or in respect of particular species, effectively creating a larger scale open-access problem and "tragedy of the commons" (Hardin, 1968).

Some mixes of governance and institutional arrangements can lead to unsustainable use of wild species when they are confusing and overlapping; developed without scientific evidence; without consultation with local communities and indigenous peoples, and broader stakeholder involvement; where multiple institutions exist to oversee or govern the same activities, but their mandates overlap and conflict, and coordination is not encouraged; and when good laws are not implemented. International and national institutional arrangements can fail to achieve intended results when they are not linked with strong institutions at the national levels, and global, national, and local objectives do not align. In many regions, pluralistic approaches that draw upon international and national policy frameworks and laws, and integrate customary law and local practices, are the most effective for supporting and promoting the sustainable use of wild species. Pluralism is most notable between statutory and informal or customary rules, sometimes as a complement to statutory systems of governance in a context of legal pluralism (Griffiths, 1986; Laird *et al.*, 2010). The balance of evidence from the Commons literature for the past few decades is that neither purely local level management nor purely higher-level management work well alone. Instead, there is a need to design and support management institutions both horizontally (across space) and vertically (across levels of organization). Issues need to be considered simultaneously at several scales when there is coupling or interaction between scales (Berkes *et al.*, 2008; Ehara *et al.*, 2018).

4.2.2.5 Trends in governance arrangements

Over time, governance arrangements constantly evolve and adapt (Garcia *et al.*, 2014); stakeholders may try to craft their own arrangements, creating hybrid or completely new arrangements (Cleaver, 2017). Since the 1960s, natural resource management governance arrangements and approaches in many countries have moved from centralized to decentralized management, and from state-controlled to community, private, public and participatory. Participatory management, or co-management, approaches to natural resources grew up at this time in response to greater awareness of social justice issues, and to develop more effective sustainable management approaches that restore resource rights to communities and ensure they benefit from use of their land and resources (Agrawal & Gibson, 2001; Escobar, 1998; Ghermandi *et al.*, 2013; Martín-López & Montes, 2015; Neumann, 2015). In some cases, participatory projects produced real gains for sustainable use and local communities (e.g., Gelose law in Madagascar, wood energy in Niger), and through projects carried out in various ecological and socio-political contexts (e.g., wild species management in Zambia and Zimbabwe with the Admade and Campfire programs, extractive reserves in the Brazilian Amazon) (Babin *et al.*, 2002; Rodary *et al.*, 2003).

In other cases, these projects re-enforced existing inequities and elite capture, and exacerbated tensions between groups. Social contracts can be diverted by a minority of local elites (made up of customary chiefs, elders of lineages, local elected officials, and/or administrative agents), to the detriment of the majority or specific groups (such as women, youths or the landless) in a community, which have no access to decision-making power, nor to the benefits of conservation, nor to natural resources or their markets (Brechin *et al.*, 2003; Ribot *et al.*, 2010; Sze, 2017; Vandergeest & Peluso, 2006; Wiersum *et al.*, 2014).

Until the 1970s central governments tended to view natural resource governance as centralized and top-down. Given the perceived failure of top-down policies, decentralization became the new paradigm during the 1990s following a growing consensus that effective management and governance of environmental challenges required policies and actions that were compatible with the realities and perspectives of local communities that have the most direct contact with the environment yet have the most to lose from environmental degradation (e.g., Dressler (2010).

This was supported by an earlier shift in the field of conservation away from purely protectionist approaches towards greater integration of conservation and sustainable use. Articulated in the 1987 United Nations publication of the Brundtland Report *(Our Common Future: Report of the World Commission on Environment and Development)*, this new approach linked conservation with sustainable development. The *Convention on Biological Diversity* and other agreements emerging from the 1992 UN Conference on Environment and Development further linked conservation, sustainable use, and equity, as did national protected area, conservation, Forestry and other laws drafted to implement the Convention on Biological Diversity (Laird, McLain, and Wynberg 2010).

While environmental governance views were changing, so too were views about the role of indigenous peoples and local communities in conservation and sustainable use. Movements that pressured governments to recognize the land, resource, human, cultural, intellectual and other rights of indigenous peoples and local communities influenced global processes and laws like the International Labor Organisation's Convention No 169, the United Nations Declaration on the Rights of Indigenous Peoples, and work on traditional knowledge in the World Intellectual Property Organisation (Laird *et al.*, 2010; Posey & Dutfield, 1996). Many national governments have moved to recognize the rights of indigenous peoples to control the use of their resources and associated knowledge, but in several countries, this continues to be little more than window dressing and centralized systems continue to control benefits from wild species (Arquiza *et al.*, 2010; Castillo & Alvarez-Castillo, 2009; Novellino, 2010). However, the recognition of existing customary governance and institutions for natural resource management has become more common place (Bromley & Cernea, 1989; Wily & Liz, 2004).

Box 4 16 **Political drivers of sustainable harvest of sturgeon *(Acipenseridae)* in the Caspian Sea.**

The sustainable use of sturgeon of the Acipenseridae family, is a challenge for fishery management regimes throughout the world (Pikitch *et al.*, 2005; Pollock *et al.*, 2015). Sturgeon, or Acipenseridae, a group of semi-armored fish, pose some biological challenges to conservation due to their low reproductive rates, relatively long life spans, and long migrations (Scott & Crossman, 1973). Sturgeon are also the source of black caviar, a scarce and highly priced global commodity, meaning their exploitation is tied to boom-bust economic cycles and resulting in the collapse of many sturgeon populations (Pikitch *et al.*, 2005). The Caspian Sea is the habitat for a variety of sturgeon species, primarily being Beluga *(Huso huso)*, Russian *(Acipenser gueldenstaedtii)*, Persian *(Acipenser persicus)*, and Stellate *(Acipenser stellatus)* (Ruban & Khodorevskaya, 2011). The Caspian Sea represents an important example for international species conservation, with the shores of the sea backing onto multiple countries on the south-western border of Russia. Throughout recent history, sturgeon populations and associated products can be partially explained through the area's political history, specifically the rise and fall of the Soviet Union within the Caspian Sea region (Akhmadiyeva & Abdullaev, 2019). Due to this jurisdictional overlap, and political history, there are multiple socio-political influences that could affect the fishery. In a contemporary frame, a significant driver of unsustainable and declining sturgeon stocks in the Caspian Sea has been the prevalence of illegal fishing activity, with illegal sturgeon harvesting accounting for several times the level of legal harvesting (Aghilinejhad *et al.*, 2017; Ermolin & Svolkinas, 2016; Ye & Valbo-Jørgensen, 2012). While illegal fishing activity has been closely tied to the price and scarcity of sturgeon products (Ruban & Khodorevskaya, 2011), others have shown that social factors also play a significant or parallel role (Aghilinejhad *et al.*, 2017; Akhmadiyeva & Abdullaev, 2019; Ermolin & Svolkinas, 2016; Mirrasooli, 2019). The social perceptions of the legality and enforcement of sturgeon fishing regulation contribute to the actions of legal and illegal fishers, with the actions and behavior of enforcement officials discouraging, and in some cases encouraging, illegal fishing (Ermolin & Svolkinas, 2016). Underlying all of these social factors in the sustainability of sturgeon is the social context in which illegal fishing activities are occurring. The state of local employment, individual investments in fishing equipment, and general rates of poverty, all contribute to the persistence of illegal fishing activity (Aghilinejhad *et al.*, 2017; Ermolin & Svolkinas, 2016; Mirrasooli, 2019). The role of local knowledge and familiarity with sturgeon stocks generally is a significant influencing factor in the occurrence of illegal fishing of sturgeon in the Caspian Sea (Aghilinejhad *et al.*, 2017; Mirrasooli, 2019). Some have considered this factor to be a "lack of awareness" on behalf of the fisher people (Mirrasooli, 2019), while others have conceived this variable as "fishers' knowledge" (Aghilinejhad *et al.*, 2017). Studies of indigenous management in North America concerning sturgeon have shown there is a lack of consideration and mobilization of indigenous knowledge (including fisheries knowledge) in fisheries (and specifically sturgeon) management (Oloriz & Parlee, 2020). Due to the challenges of complex overlapping jurisdiction harvesting regimes and the prevalence of illegal fishing, the state of sturgeon fisheries in the Caspian Sea is concerning. Studies here have begun to investigate the complex ways in which social and political factors influence this illegal fishing activity and highlight the need to approach the sustainable harvest of wild species from a more holistic perspective (Aghilinejhad *et al.*, 2017; Akhmadiyeva & Abdullaev, 2019; Ermolin & Svolkinas, 2016; Mirrasooli, 2019; Pikitch *et al.*, 2005; Pollock *et al.*, 2015; Ruban & Khodorevskaya, 2011; Ye & Valbo-Jørgensen, 2012).

The impact of changes in the governance and institutional framework of conservation on the sustainable use of wild species is difficult to quantify, which should not be surprising given the complex and multidimensional nature of wild species use (Alexiades & Shanley, 2004; Neumann & Hirsch, 2000). Individual cases support these approaches, however broader landscape level conservation gains are more difficult to identify. This is not a problem inherent to conservation and sustainable use that involves local groups and indigenous peoples, but instead reflects the outsized impact of global political, cultural and economic factors. These include international and national governance and institutions that do not adequately regulate sustainability or implement environmental laws, and a large and constantly expanding culture of consumerism in wealthy nations that is overwhelming wild species everywhere.

The growth in protected areas and innovations in protected areas management is another vital trend in governance. Historically, protected areas controlled by governments and reinforced through international agreements (e.g., the Aichi Target of "By 2020, at least 17% of terrestrial and inland water areas, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved…") have been an essential mechanism for conserving the world's biodiversity by increasing protected areas (Nepstad *et al.*, 2006). Over the past two decades protected area governance has diversified, with significant growth in not only government-managed areas but also private and community-based management, and a variety of hybrid, partnership-based models that build multi-layered pluralistic approaches into protected area management (Borrini-Feyerabend *et al.*, 2013). Collaborative governance of protected areas has the potential to yield multiple biodiversity and socio-economic benefits through the formation of alliances and partnerships between stakeholders (governments, the private sector, local communities, and non-governmental organizations), as a means of developing consensus and efficiently deploying available skills and resources (Munthali, 2007). Such arrangements can draw on various knowledge systems to foster trust and develop joint visions, promote experiential and experimental learning, and function as bridging organizations that lower the costs of collaboration and conflict resolution (Armitage, Plummer, Berkes, Arthur, Charles, Davidson-Hunt, Diduck, Doubleday, Johnson, Marschke, *et al.*, 2009; Folke *et al.*, 2005).

Although protected areas historically excluded use by indigenous peoples and local communities, institutional arrangements are changing (Colchester, 2004); some parts of the world now privilege use for subsistence and cultural continuity. This is true in the laws and arrangements associated with most protected areas in Canada, New Zealand and some areas of Australia (Lee, 2016; Muller, 2003; Ross *et al.*, 2009; Smyth, 1995; United Nations, 2007; Zurba *et al.*, 2019). Some protected areas are now defined as indigenous protected and conserved areas (Moola & Roth, 2019; Zurba *et al.*, 2019). This new approach to protected areas management (i.e., that recognizes social, cultural use) has been positive in ensuring sustainable use. Specifically, "protected areas that explicitly integrated local people as stakeholders tended to be more effective at achieving joint biological conservation and socioeconomic development outcomes" (Oldekop *et al.*, 2016).

4.2.2.6 Land tenure and resource rights

Key Messages:

- Land tenure and rights to resources in a given area can involve many separate rights, which taken together are essential components of sustainable use and broader good governance. Tenure arrangements that foster secure rights over land and resource use and trade can incentivize resource conservation, sustainable use, and diverse livelihoods, in part because they allow for longer-term planning.

- Secure rights are not guaranteed by a formal title or certificate. In fact, in some cases, customary systems are more secure than formal systems, though in general, due to encroachment on the tenure rights of indigenous peoples and local communities, some kind of formal recognition is increasingly needed. Still, many other contextual factors besides formal recognition determine level of security.

- For forests, centralized management that disregards robust traditional systems and cultural relationships with forests has failed historically to support conservation and sustainable management.

- In fisheries, centralized management has been shown to be difficult and unresponsive to local conditions, resulting in poor implementation of management measures and a subsequent large amount of illegal, unreported, and unregulated fishing activity in almost every jurisdiction.

- Indigenous territories store large quantities of global terrestrial carbon and see lower rates of ecosystem health declines compared to other areas, but governments have only recognized indigenous peoples' legal rights to a small portion of the lands they occupy. Secure rights and robust customary governance systems are associated with lower deforestation rates.

- Even if men's rights are secure, whether in individual or common property systems, women's rights tend to be less secure. Securing women's access to assets and participation in decision-making is seen as integrally related to sustainable livelihoods and resilience.

- Despite challenges associated with recognizing and securing tenure rights, the growing awareness of the role of tenure in achieving development and environmental goals has created a range of new commitments, initiatives, and policy openings at the country level.

Land and resource tenure, understood here as the rights of an individual or group over the use of natural resources, is an essential component of sustainable use and broader good governance. Tenure determines who is allowed to use which resources, in what way, for how long and under what conditions, as well as who is entitled to transfer rights to others and how. During colonial and post-colonial regimes, tenure rights, granted by the state in the form of legal titles over land and other resources, often displaced and marginalized indigenous peoples and local communities who held land and resources under customary systems. The ongoing legitimacy of the latter has nonetheless been increasingly affirmed, including by the Inter-American Court of Human Rights and the United Nations Declaration on the Rights of Indigenous Peoples (United Nations, 2007). Yet, in practice the usurpation of customary rights is common, as is the harassment, criminalization, and murder of environmental and resource rights defenders (global witness).

Tenure arrangements that grant secure rights over land and resource use can incentivize resource conservation, sustainable use, and diverse livelihoods. Secure resource rights allow for longer-term planning and the use of such rights as collateral for investments (German *et al.*, 2014) and public-private partnerships. This has sometimes been interpreted to mean that rights should be granted to individuals (De Soto, 2011), but decades of research on

Box 4 17 **Snow leopard in the Himalayas – ecotourism.**

With a habitat that ranges throughout the Himalayas and Central Asia, the snow leopard *(panthera uncia)* has a complex relationship with humans. A history of conflict with farmers, as well as decreasing habitat size and climate change, increasingly threaten the already-low population of this large felid. With an estimated population between 4,000 and 7,000 (Riordan *et al.*, 2016) spread across 12 countries, diminishing wild prey has pushed leopards towards more steadily attacking livestock. Consequently, the snow leopard interacts and is mainly threatened by retaliatory herders (Rashid *et al.*, 2020). Contested living in arid highlands with access to grazing grounds continues to be one of the most significant challenges for the conservation of snow leopards (Jackson and Wangchuk, 2001; Vannelli *et al.*, 2019). Throughout the "Roof of the World" region, efforts to maintain population levels have used community-based conservation, and have focused on the education of locals, often in partnership with community-based ecotourism (Hanson *et al.*, 2019; Millican, 2016; Vannelli *et al.*, 2019). For the impact on leopards to change, a cultural shift is needed in which snow leopards are not seen as another source of conflict but as an animal to protect who plays a role in the sustained socio-economic presence of communities. Community-based ecotourism with regards to the snow leopard has the opportunity to address various issues. In creating a niche for tourists, community-based ecotourism provides the opportunity to increase revenues for communities and their conservation efforts (Hanson *et al.*, 2019). As a result, it creates a more positive image of leopards, rendered sustainable by the heightened education surrounding the carnivore. Even though sightings of leopards are rare, programs package outings with activities such as trekking, trophy hunting of ungulates, and homestays (Hanson *et al.*, 2019). In addition to assisting in community initiatives and funding preservation, the income from nature-based tourism has also been used to compensate for lost livestock (Rashid *et al.*, 2020). These initiatives have been taken up in Afghanistan (Simms *et al.*, 2011), India (Kala & Makhuri, 2011;), Jammu and Kashmir (Jackson & Wangchuk, 2001) Nepal (Hanson *et al.*, 2019), and Mongolia (Millican, 2016), among others. However, research is most abundant in India and Nepal, with Nepal being the first country to implement community-based conservation of snow leopards through the Annapurna Conservation Area Project (Jackson & Lama, 2016). Nature-based tourism has been changing the relationship to leopards, decreasing human-wild species conflicts, but it is neither sufficient nor sustainable as a single approach. This strategy should be combined with better anti-predation technologies and training (Simms *et al.*, 2011), tourism that does not rely on wild species (Jackson & Lama, 2016; Jackson & Wangchuk, 2001; Mishra *et al.*, 2003), and compensation unrelated to tourism (Hussain, 2000). Some authors (Mishra *et al.*, 2003) have addressed the possibility of the relocation of already-small settlements outside of preserve areas, with the need for assistance in establishing sustainable livelihoods outside of herding. Until now, community-based ecotourism has been a relatively successful and sustainable effort in snow leopard preservation, but the ecological impacts of extraction may soon become too large to match in a timely manner. A proposed response to the multinational challenges that snow leopard conservation faces is for initiatives to attain a transboundary scale (Maheshwari, 2020; Riordan *et al.*, 2016; Rosen & Zahler, 2016). Not only does the leopard's habitat span a dozen nations, but it also does so along various borders. Thus, focusing on a country-based response may lead to several oversights or pitfalls in strategy. Maheshwari (2020) highlights the possibility for joint governance efforts in preservation, with the possibility of a rippling benefit to the fragile ecosystems inhabited by leopards. In speaking of the political and social drivers of sustainability, cross-boundary models of co-governance are a lever that could bolster conservation while exemplifying a globalized model of community-based conservation (Jackson & Lama, 2016; Rosen & Zahler, 2016; Zahler & Paley, 2016). In doing so, communities across the Roof of the World may become more interconnected and redefine their relationship to large carnivores without sacrificing their local identities.

common property resources has demonstrated both the importance (for livelihoods, resources and human rights) and the effectiveness of common and communal governance systems (Ostrom, 1990; Ostrom & Nagendra, 2006).

Rights to land and resources in a given area can consist of many separate and overlapping rights, and may differ according to gender, age and ethnic group, as well as within communities and societal groups (Ingram *et al.* 2016; Wiersum 1997; Larson *et al.* 2010). Hence assuring security is not necessarily a simple task, as granting exclusive rights for one group may deny it to another that also manages and depends on resources for local livelihoods. There has been increasing attention to the potential for inequitable distribution of benefits and power imbalances in conferring resource rights (Fitzgerald *et al.*, 2020). Conflicts over resource use are prevalent (and in the case of fisheries resources, increasing) (Spijkers *et al.*, 2018), and lack of transparency and legal clarity can enable inequitable outcomes (Fitzpatrick *et al.*, 2008). In this context, addressing tenure rights can become a mechanism not only for incentivizing sustainable use but for supporting just transitions to sustainability (Bennett *et al.*, 2019). Access and rights to resources, extent of local control and coordination with customary land tenure arrangements are vital issues.

As implied above, a large body of evidence shows that tenure rights which incentivize sustainable and equitable use of natural resources should be secure and involve local user communities. From (Larson & Springer (2016), a "systematic review of research on the environmental impacts of different property regimes in forests, fisheries and rangelands found that avoiding open access situations in fisheries and forests and transferring user rights to communities usually led to positive environmental impacts (Ojanen *et al.*, 2015).” The benefits of empowering local communities and recognizing local knowledge in management are not limited to local livelihoods and sustainability of resource sectors. Still, they have further positive impacts on other ecosystem services (for example, better-managed forests with improved production and carbon storage) (Chhatre & Agrawal, 2009).

Devolving tenure from centralized management to local communities can be challenging, despite evidence of the benefits. For forests, centralized management that disregards strong traditional management systems and cultural relationships with forests has been shown to lead to poor outcomes, failing to support conservation or sustainable resource use (Larson & Dahal, 2012; Ribot & Larson, 2012; Sunderlin, 2011).

Public trust institutions such as those in the United States of America are among the emerging shifts in land tenure that create incentives for conservation. They involve spending public and private funds, including donations to ensure lands are set aside for conservation (Hodge & Adams, 2012). While there is much literature on how to create land trusts, evidence about their impact on conservation outcomes and sustainable use of wild species is limited (Merenlender *et al.*, 2004).

In fisheries, centralized management has been shown to be difficult and unresponsive to local conditions, resulting in poor implementation of management measures and a subsequent large amount of illegal, unreported, and unregulated fishing activity in almost every jurisdiction (Zeller & Pauly, 2019). Importantly, incomplete or passive decentralization, whereby centralized management is formally phased out but without the real transfer of meaningful authority to subnational governments (Ribot, 2006), and without legal frameworks and institutional support for local tenure rights, can also create power imbalances and vacuums with negative ecological and social impacts (Méndez-Medina *et al.*, 2020). In the case of forest and wild plant species, when commercial pressures increase significantly, local and customary systems of governance are often overwhelmed and require support from statutory systems (Wynberg & Laird, 2007).

4.2.2.6.1 Gendered land, resource, and trade rights

Gender differences and inequalities are common in resource access and security and in the commercialization of wild products. There is limited information available on gender in trade, and a strong bias in the literature towards African countries (Haverhals *et al.*, 2016), though this is changing (see, for example, Women’s Studies International Forum). Gender differences in participation in trade are mainly the effect of social-cultural factors, including gendered resource access rights. In addition, due to the nature of value chain activities, cultural norms and overlapping customary and formal regulatory arrangements often position men in more favourable positions than women in the value chains of wild-sourced products. Although interventions have primarily focused on enhancing women’s participation and benefits, they rarely consider the relationships between men and women. Hence, raising awareness of gender biases, relations, and potential trade-offs among those involved in value chains and those supporting inclusive and sustainable trade should accompany technological innovations and should occur across all stages of the value chain (Ingram *et al.* 2016).

Women make up a substantial amount of labor participation in wild seafood resources (e.g., up to 50% in seafood production chains) (Harper *et al.*, 2017) and often fill key roles in value chains, including sales, marketing, and business administration. The literature on wild forest and tree product resources generally provides little information on male/female participation in trade. Where quantified, the male to female participation ratio ranged widely from zero to 100%. Information on the rates of participation was specifically lacking for processor (all locations) and trader (in Latin America and Asia) stages in chains. Female dominance is recorded at the harvester, processor, and trader stages; however, there were substantial differences depending on geographic region and product (Haverhals *et al.*, 2016). At the harvester stage, female dominance only holds in Africa. Women are mostly confined to small-scale retail trade, and men run larger businesses. Generally, men and women gain different levels of revenue and profits from commercializing wild products and spend their related incomes differently, with solid differences occurring globally. Typically, but not always, men sell a higher proportion of wild forest and tree products than women (Haverhals *et al.*, 2016).

Despite their contribution and prominence in specific resource sectors, women are often excluded from land and resource tenure rights and wider participation in management discussions; this is true for both legal and customary rights systems.

Resource access and control is a tenure issue, which is thus also important from a gender perspective. (Larson & Springer, 2016) write that “Women and families depend on tenure security for secure livelihoods and resilience” For example, women’s tenure rights have been found to be associated with their increased participation in household decision-making, increases in household income, and increased expenditure on food and education (Giovarelli *et al.*, 2013). However, women’s security is not the same

Box 4 18 **Fishing and gender: women marginalization and empowerment.**

Millions of women worldwide, paid or unpaid, work in the fisheries sector, mainly involved in the tasks that come before and after fish landing. But they also play a significant role in the catch of the small-scale fishery, according to the techniques and, more generally, the fishing system (target species, fishing grounds, fishing gear, value-chain, etc.). The contribution of women in the fishery has long been underestimated in the national and international statistics (World Bank, 2012). From the Food and Agriculture Organization of the United Nations, women represent just 14% of the 59.5 million people engaged in fisheries and aquaculture in 2018. However, their invisible role is increasingly highlighted and conceptualized, notably through a feminist approach (Frangoudes *et al.*, 2019; Frangoudes & Gerrard, 2018). In 2019, the Food and Agriculture Organization of the United Nations, with WorldFish and Duke University, among others, launched a synthesis "Illuminating Hidden Harvests", for quantifying the contributions of small-scale fisheries to the three dimensions of sustainable development (social, economic and environmental), and better assessing the qualitative and quantitative contribution of the women in this sector (FAO, 2020b).

With a few exceptions – sea women of Iceland (Willson, 2016), freediving to fish sea cucumber or sea urchins, such as Vezo women in Madagascar (Astuti, 1995) or Mentawai women in Siberut (Burgos & Younger, 2019), the sea trips, especially of more than one day, whether artisanal or industrial fishing, are carried out by men. Also, in Madagascar (Barnes-Mauthe *et al.*, 2013), fishers are predominately men (97% of fishers and 95% of fisher–gleaners), while gleaners are predominantly women (98% of all gleaners). Women generally only engage in fishing activities near the shores – lagunas, lakes, rivers or sea. They travel on foot or in non-motorized canoes. They fish with traps and holes or by hand or using spears on reef flats, seagrass beds, and mangrove mudflats; they target small species of fish (Tilapiae and Ethmalosis), shrimp, molluscs and crustaceans. On the other hand,, they have dominated the processing and marketing of catches for a long time. In particular, it is the fishermen's wives who have traditionally been entrusted with either all or part of the catch for exploitation and part of the catch is for family consumption and redistribution (*ndawal* in Wolof) (Thiao *et al.*, 2018). Since the 1950s, with the development of sea fishing, particularly in tropical areas, in connection with multiple innovations – technical (motorization of pirogues, distribution of large nets, cold chain), economic (growth of urban markets), institutional (credit and fishing cooperatives) – women often lost this central role at the wharf and were marginalized. Globalization (long-distance maritime migrations, export-based policy, including removal of trade barriers and low-cost transport) further accentuates this process of marginalization (M.-C. Cormier-Salem, 2017b). For example, in Mauritania, Imraguen fishermen now sell mullet fish *(Mugil cephalus)* and in particular the precious eggs to make bottarga to Asian or European export companies; women now have little access to this product and have lost one of the few sources of income in a context of strong constraints in the Banc d'Arguin National Park (Boulay & Cormier-Salem, 2012). The trajectories of women in small-scale fishery are nevertheless varied: in West Africa, it is often women, known as Mama Benz (because they would be used to circulate in shiny Mercedes, external signs of wealth and power) who have the capital to buy the means of production (canoes, engines, large nets, provision for the fishing campaign, etc.) and make fishermen their quasi-employees, not only in their countries of origin, such as Côte d'Ivoire, but also in the countries of migration of these fishermen (Bennett, 2005; Cormier-Salem, 2017b). Even in India, where fishing is a low-value activity, relegated to the poor and untouchable, women are becoming powerful thanks to globalization (Jalais, 2010). For example, in the Sundarbans, women, who do not have access to the products of the mangrove forest, fish for shrimp fry along the banks of the Ganges and Brahmaputra rivers. With the explosion of shrimp farms since the 1980s, they supply the industrial aquaculture sector and have gained economic and, therefore, social and political power. Besides, women are more and more involved in innovative projects to face poverty and achieve social and political recognition, such as marine protected areas co-management, ecocertification schemes and invest new sector such as shell-handicraft (Fröcklin *et al.*, 2018). Despite recent synthesis (Frangoudes and Gerrard 2018; Frangoudes, Gerrard, and Kleiber 2019; FAO 2020b), women in fishing, fisheries labor, and fisheries decision-making still are invisible. The complexity of the intersectional identities and the on-going changes of the women's situations (gender, gender relations and power relations at diverse scales), need further contextualized studies.

as men's, and their tenure rights tend to be weaker than men's in rural areas of developing countries (FAO, 2011). Securing women's participation in decision-making is seen as integrally related to ensuring women's resource rights (United Nations, 2013), as women "have different needs, uses and knowledge in relation to their ecosystems" (Aguilar, 2016). Agrawal *et al.* (2013) found a significant positive correlation between the number of women on community forestry executive committees and forest conservation outcomes. In another study, women's participation in forest-related decision making was found to be highly correlated with less disruptive conflict (Coleman & Mwangi, 2013).

4.2.2.6.2 Growing awareness and improved policies on community tenure rights

Despite challenges associated with recognizing and securing tenure rights, the growing awareness of the role of tenure in achieving development and environmental goals has created a range of new commitments, initiatives, and policy openings at the country level. Several countries are in the process of reforming their legal frameworks for land tenure, such as Cameroon and the Democratic Republic of the Congo. In other countries, such as Kenya and Liberia, new land laws have recently been enacted. Advocacy regarding the impacts of large-scale land acquisitions have prompted private sector commodity investors to adopt commitments to avoid "land grabbing" in their supply chains (e.g., see Oxfam 2016). Initiatives such as the Global Donor Working Group on Land and the European Union program of support to implement the Voluntary Guidelines on Governance of Tenure indicate that some international donors are providing support to tenure-related activities. These opportunities highlight the importance of learning lessons from previous tenure reforms, including key conditions for reforms and practices that can help advance them.

Nepal's community forest user groups provide an important example of how greater tenure security has enabled community-based institutions to build sustainable livelihoods and improved forest management at scale. While forest devolution started in Nepal since the mid-1970s, significant progress in terms of community forestry was observed once the 'Master Plan for the Forest Sector' (1988) adopted a 'user group' approach, which was based on the existing indigenous forest governance arrangements in various parts of the country (Gilmour, 1990). Traditional users were granted usufruct rights over the forest. The Forest Act (1993) and Forest Regulations (1995) offered strong legal backing for community forestry, which has since contributed to community development, institutionalized inclusive and democratic governance at the local level, and developed leadership of women and other marginalized members (Pokharel *et al.*, 2012). Currently there are over 18,000 forest user groups managing over one third of Nepal's forest area.

Ensuring that reforms create enabling conditions for communities to develop resource-based livelihoods, with strong financial and technical support to meet regulatory requirements, has been another critical approach. Guatemala's community forestry concessions are an exceptional example of community management regimes with positive results for both forests and livelihoods. Between 1994 and 2001, the Guatemalan government, with the backing of important international donors, signed 12 25-year community concessions contracts (for areas ranging from 7,000 ha to 85,000 ha) inside the Mayan Biosphere Reserve with local community groups (Monterroso & Barry, 2012; Radachowsky *et al.*, 2012; Taylor, 2010). The previously conflictive forest landscape was transformed, as communities were granted rights to manage and sell both high-value timber and non-timber forest resources in about 400,000 ha. Although the regulations were strict (requiring Forest Stewardship Council certification), it was possible for communities to meet them because of the investment made in the arrangement by multiple actors including key government supporters (Monterroso & Larson, 2013). A comparative study of forests in the region (the Maya Forest of Mexico and Guatemala) found no significant difference in deforestation rates between the community concessions and protected areas (Bray *et al.*, 2008). Income from collective timber and non-timber sales surpasses 44 million United States Dollars and is distributed to members, invested in social infrastructure, and reinvested in community forest enterprises (Monterroso, 2015). The cases from Guatemala and Nepal also demonstrate the ongoing importance of social movements, and specifically the higher-level federations of community organizations, to overcoming implementation challenges (Paudel *et al.*, 2012; Taylor, 2010).

4.2.2.7 Equity and benefit sharing

Key Messages:

- Inequitable distribution of the benefits for the use of wild species undermines sustainability by encouraging over-harvesting, short term gains over long term sustainable management, poaching, and mining of resources by companies.

- Inequities exist between local communities and companies, governments, and others, but they also exist within communities, where elite capture of benefits is familiar with wild species use and trade, particularly when sold outside the community.

- Equitable distribution of benefits from the sustainable use of wild species is a stated goal of many governance and institutional frameworks. However, implementation of these goals is often flawed. This has a direct impact on sustainability, creates incentives to over-harvest species, undermines long term management of species, and can support unsustainable commercial extraction.

- Marginalization and exclusion stem from a range of political, economic and other factors and lead to inequity in resource allocation, distribution of benefits and participation in decision-making and management; such inequities mean that there are limits on who has access to and who benefits from (and who does not), from wild species use.

- People's perception of fairness and justice influences their willingness to comply with regulations that govern sustainable use.

The sustainability of wild species use is significantly impacted by the broader issues of equity that surrounds this use. Below the expert's review aspects of equity in use, including access to and distribution of benefits, extent of engagement and marginalization of stakeholders, and the role of civil society, social movements, and political processes in bringing more significant equity to use of wild species.

4.2.2.7.1 Impact of marginalization and inequality on sustainable use

Marginalization in sustainable use is a complex issue, which requires not only consideration for contemporary inequities but also historical, political, and social contextual factors that create an uneven playing field from initial distributions of access, capabilities, and power (McDermott *et al.*, 2013). It is defined as the significant reduction of capacity and power, and political and economic exclusion, of rural and indigenous people to make or participate in decisions over the sustainable use of plants and animals in areas they depend on, with detrimental impacts on their livelihoods and well-being (adapted from Raleigh *et al.*, (2010). Marginalization and disempowerment can have social equity implications, in that marginalized people may not have access to benefits or rights, they may not have a voice in decision-making process, and their values, knowledge, and culture may not be recognized (Martin *et al.*, 2016).

Marginalization can be driven by a variety of mechanisms, including exclusion from decision-making, elite capture and power concentration, management systems not representative of relevant interests or experiences, and a lack of knowledge or recognized rights (Colfer, 2011). For example, women make up a substantial amount of labor participation in natural resource sectors (for example, up to 50% in seafood production chains) and often fill critical roles in value chains, including sales, marketing, and business administration. However, despite their contribution and prominence in resource sectors, women often are excluded from tenure rights and wider participation in management discussions; this is true for both legal and customary rights systems (Harper *et al.*, 2017).

There has been a (poorly documented) history of evictions from protected areas, where access to and use of natural resources by local people has been restricted (West *et al.*, 2006) (Burgess *et al.*, 2014). Externally imposed or post-colonial laws often underpin these restrictions (e.g., McCarthy & Cramb, 2009), or influential international organizations (e.g., companies, or even large non-governmental organizations) can impose their vision of what nature should look like (Brockington & Igoe, 2006; Brockington & Scholfield, 2010).

Elite capture (or concentration of decision-making power in the hands of a few) and centralization across different levels of government can also entrench inequities and drive marginalization. For instance, studies have documented how local people who engage with government administrations benefit more from forest governance programmes (Wright *et al.* 2016). Involvement of external organizations runs the risk of reinforcing this elite capture and can create dependencies for local communities (Calfucura, 2018). Similarly, the promotion of market-based conservation mechanisms can shift power around natural resources use from local people to more powerful organizations (Martin *et al.*, 2013).

People's perceptions of fairness and justice can influence their willingness to comply with rules and regulations intended to govern the use and management of natural resources (Colfer, 2011). There is extensive evidence from the common pool resources literature that empowering people affected by policy changes to participate in discussions, management, and monitoring of natural resources improves outcomes, both for sustainable use and for more effective and lasting implementation of rules to manage and restrict resource harvest and access (Biggs *et al.* 2019; Ostrom 2009). Fairness, and the nature of decision-making processes rather than participation itself, is considered to be central to both quality and justice in natural resources management (Reed, 2008; Smith & McDonough, 2001). Stakeholder engagement early on has been linked to more effective and longer-lasting solutions to environmental issues and can contribute to a more comprehensive understanding of the social-ecological context by integrating local and scientific knowledge (Reed, 2008). Co-management of protected areas is one governance model employed to recognise rights of indigenous or local people, while building support for sustainable use and natural resource management (Timko & Satterfield, 2008).

4.2.2.8 Impacts of peace and armed conflict on sustainable Use

Key messages:

- Impacts of conflicts on sustainable use are diverse and varied across contexts and through different pathways and indirect ways.
- Post-conflict settings pose significant risks to sustainable use for a variety of reasons.

4.2.2.8.1 Definitions

Conflicts have a detrimental effect on human well-being and socio-economic development (Gates *et al.*, 2012; Lopez & Wodon, 2005; Machel, 2001; Melander, 2005). A variety of definitions of what classifies as armed conflict exist (Gleditsch *et al.*, 2002; Stewart, 2003). For the purposes of this assessment, the experts define conflict as periods of armed violence due to political insecurity, instability, or war. These conflicts often lead to a disruption of economies, government services and the extensive movement of people to flee conflict zones for personal safety and/or better opportunities. These conflicts have a range of impacts, mainly negative, on sustainable use, which are discussed below.

4.2.2.8.2 Direct pathways of impact

Armed conflict affects sustainable use through multiple pathways including where conflict directly affects wild species and via broad socio-political and economic pathways that arise because of the conflict, such as changing institutional dynamics, migration and displacement of peoples, and transformed economies and livelihoods (Gaynor *et al.*, 2016).

Direct adverse effects of conflict on sustainable use include a reduction on economic activity, which can reduce deforestation (Burgess *et al.*, 2016), unsustainable use of forest resources (Butsic *et al.*, 2015; Machlis & Hanson, 2011) including the killing of wild animals and the destruction of habitat (Gaynor *et al.*, 2016). Many forms of weaponry commonly utilised in armed conflict, such as land mines, can inadvertently kill wild species (Eniang *et al.*, 2007). Large-scale habitat alteration may occur when armies destroy habitat for tactical advantages (e.g., defoliation used in the Vietnam war (Orians & Pfeiffer, 1970). Armed groups may also use protected areas as staging grounds, due to their remote location and plentiful natural resources, leading to overexploitation of certain species (Hanson *et al.*, 2009; Machlis & Hanson, 2011). An increase in the availability of guns during and following a conflict may increase the prevalence and sophistication of hunting, further undermining sustainable use (Jacobs & Schloeder, 2001). Soldiers may also kill wild species at high rates for various reasons, including subsistence in the field; and high-value wild species products, such as ivory, are used to finance operations (Beyers *et al.*, 2011; Yamagiwa, 2003).

4.2.2.8.3 Indirect pathways of impact

Indirect effects of conflict on sustainable use include the reduction of international development, investment, and support, which reduces the ability of policymakers, managers and research institutions to fulfil their conservation roles (Biggs *et al.*, 2019; Conteh *et al.*, 2017) Reductions in funding reduce the ability to enforce laws and regulations within protected areas, including stopping wild meat hunting and deforestation (Butsic *et al.*, 2015; Kaimowitz & Fauné, 2020). The disruption of traditional institutions in local communities also creates challenges for post-war conservation activities. One of the most significant changes arising from armed conflict is the forced movement and migration of people, where large groups of people in vulnerable situations form dense camps and extract natural resources such as wild foods and timber for survival (Jambiya *et al.*, 2007). For people remaining in conflict zones, normal livelihood activities are drastically affected, as conflict disrupts industry and trade and creates shortages of goods. Therefore, local people may turn to natural resource use, especially as longer-term investments such as those required by farming and commerce become risky (Lanjouw, 2003).

The most common positive effect of armed conflict on the use of natural resources is the so-called “refuge effect”, where people avoid or move away from an area, creating places where pressure on wild species is lessened (McNeely, 2004). These areas can host flourishing wild species populations (e.g., the Demilitarised zone between North and South Korea (Kim, 1997). Similarly, due to the reduction of international trade across borders during armed conflict, global trade of wild species products may be reduced (Lindsey *et al.* 2011). Another positive effect can arise when forced disarmament of local populations by armed groups may disrupt customary hunting efforts. Yet, these refuges may result in displacement of extraction of resources, as people that move away from conflict zones move into other areas where over-extraction and unsustainable use of natural resources occur (Alvarez, 2020).

4.2.2.8.4 The impacts on sustainable use in post-conflict settings

The end of conflicts can lead to rapid change in the development of agriculture and extractive industries with subsequent impacts on sustainable use (Machlis & Hanson, 2011). Many post-conflict regions possess valuable oil and mineral reserves and timber-rich forests that were off-limits to development because of the conflict. In post-conflict periods, rural return and its associated development can have catastrophic consequences for the natural environment and undermine sustainable use, as evidenced in Liberia (Brottem & Unruh, 2009), Cambodia (Loucks *et al.*, 2009) and Colombia (Negret *et al.*, 2017). Post-cold war case studies from Russia and previous republics of the USSR also provide insight into sustainable use in post-conflict settings. After the Soviet period, the state suddenly reduced and even stopped many essential food resources provided to communities. “These food shortages incentivized the development of an illegal market, especially for expensive products such as meat. Such incentives, with the help of cars, artificial lights and modern firearms, induced a strong increase of illegal hunting in all these newly independent countries” (Svizzero, 2019). This situation was not only the result of the collapse of the centralized government (e.g., formal laws) but was also because during the Soviet period, many kinds of community-based systems of natural resource management and customary laws had been severely eroded. Although, in many areas, new informal and formal institutions are now developing to fill the vacuum of central governance, a lack of coordination has led to conflicts between resource users. For example, in the Kamchatka region of Russia, there are many obstacles to the sustainable and equitable management of salmon fisheries and reindeer herds. These have arisen from tensions between formal regulations and informal entitlements (Gerkey, 2016).

Post-conflict periods can also have positive outcomes if state control is established rapidly after conflict ceases. New opportunities to plan for and regulate sustainable use in previously inaccessible areas can be developed. Where there is foreign or outsider control in post-conflict regions, however, these planning efforts and restructuring and creation of new institutions can be unstable, lack relevance to local contexts and have limited longevity (i.e., green grabbing in Sierra Leone) (Cavanagh, 2018; Fairhead *et al.*, 2012).

Understanding the influence of post-conflict on sustainable use is crucial for informing conservation actions in megadiverse countries (Hanson *et al.*, 2009); however, in many cases, the relationship between armed conflict, post-conflict, and unsustainable use of resources is complex with confounding factors that need to be considered—establishing governmental control where illegal groups are present or where they had influence before the post-conflict periods is essential to avoid unsustainable use of resources. One potential way to improve governmental control of these areas is through working with the local communities to establish development and natural resource needs and objectives (Negret *et al.*, 2019).

4.2.3 Social drivers

Key Messages:

- Social drivers: Various demographic and social factors influence the sustainable (or unsustainable) use of wild species: migration and urbanization, social organization and reproduction, empowerment, effective participation and accountability, poverty and process of marginalization, gender equity and rural development (roads, infrastructure, access to material assets and immaterial goods-market, credit, internet) *(well established)* {4.2.2.7}

- Population growth, demographic change and mobility affect use patterns of wild species. Specifically:

  - Population density and growth are leading to increased demand/consumption of wild species in some regions, particularly in urbanized areas of the global south *(well established)* {4.2.3.2}.

  - Increased mobility is leading to unsustainable use of wild species in critical areas. Such mobility is associated with displacement (i.e., from conflict, environmental degradation) as well as economic opportunity (e.g., transnational labor movements). In addition to increasing pressure on species, there is growing displacement of local uses (e.g., of indigenous peoples and local knowledge) *(well established)* {4.2.3.2}.

  - Mobility across political and ecological borders, may be leading to unsustainable use, particularly where such mobility is accompanied by lack of attachment to the place(s) *(established but incomplete)* {4.2.3.2, 4.2.3.2.2}.

- Urbanization tends to lead to decreased consumption of wild species due to access to the market economy for food *(established but incomplete)* {4.2.3.2.3}.

  - Mobility of peoples across political and ecological borders, may be leading to unsustainable use, particularly where such mobility is accompanied by lack of attachment to the place(s) *(established but incomplete)* {4.2.3.2, 4.2.3.2.2}.

- Social organization and networks affect how the benefits and costs of wild species use are distributed. Societies that are more equitable tend to experience less poverty, conflict and social inequality, which are factors correlated with sustainable use patterns *(well established)* {4.2.3.5}.

  - Social inequity and poverty are a growing trend globally, particularly in the global south. In many regions, where alternatives to basic needs (e.g., shelter, food) and economic and social supports (e.g., education) are limited, there is greater dependence on wild species. However, it is an over-simplification to attribute unsustainable use of wild species to those living facing poverty. *(well established)* {4.2.3.5}

  - Although some evidence points to those living in poverty are culpable for increasing unsustainable use of wild species, the socio-economic and political systems that have created and perpetuate poverty and inequity are the underlying driver *(well established)* {4.2.3.5}.

  - Given that poverty is multidimensional, eradicating it requires a multifaceted approach. Access to food, shelter, education, employment, and health can lift people out of poverty and make them less dependent on wild species *(well established)* {4.2.3.5}.

  - Equitable distribution of benefits from the sustainable use of wild species is a stated goal of many governance and institutional frameworks. However, implementation of these goals is often flawed. This has a direct impact on sustainability, creates incentives to over-harvest species, undermines long term management of species, and can support unsustainable commercial extraction *(well established)* {4.2.3.4, 4.2.3.5}.

  - Use of wild species by women and indigenous peoples are under-recognized and poorly protected and consequently create / aggravate problems of food insecurity and poor health for vulnerable populations (e.g., poor nutrition) and increase dependency on commercially produced food resources *(well established)* {4.2.3.4; 4.2.3.5}.

- Social values and norms influence how wild species are used, and many aspects of their sustainability are interpreted:

  - Social groups who are most dependent on wild species tend to experience more significant concern and anxiety about their health and unsustainable use (i.e., have heightened risk perception *(well established)* {4.2.3.3.6}. These groups thus tend to be critical stakeholders in identifying sustainable use solutions *(well established)* {4.2.3.7}, Among the groups with long term dependencies and support sustainable use are indigenous peoples *(well established)* {4.2.2.2.5}.

  - Many indigenous peoples and local communities who have long term relationships to wild species have well developed relationships, knowledge systems, practices, and rules (i.e., customary laws) which ensure their sustainable use *(well established)* {4.2.3.5}.

  - Social norms create the social context in which wild species use is structured/organized and also interpreted by users. Where practices of hunting, fishing and gathering are fundamental to food provisioning, and support livelihood and social identity, these practices and uses tend to be more sustainable *(established but incomplete)* {4.2.3.3}.

  - The harvest of wild species is recognized as essential to food security, health and well-being in many regions; where there is increasing risk (both reported and perceived) of bioaccumulation of contaminants, presence of disease (including transmissible disease to humans), hunting, fishing and gathering of wild species tend to decrease. However, trust in the actors involved in risk communication is a mediating factor *(well established)* {4.2.3.7}.

- Gender inequity in how the costs/benefits of wild species use are distributed is visible in critical regions of the globe *(well established)* {4.2.3.6}.

4.2.3.1 Overview

There are numerous social drivers that (along with other economic, political and environmental drivers have a significant impact on patterns of use of wild species and the associated practices of use. The definition of social drivers as those social structures (class, ethnicity, gender and location), norms (e.g., unwritten but accepted rules of behavior), relationships and broad systems of social interaction that shape individual and collective uses of wild species (Dugarova & Utting, 2013). This section is focused on specific drivers within the context of social organization (demographics, livelihoods and urbanization, migration), social equity, poverty and exclusion, social movements, health and well-being.

4.2.3.1.1 Methodology

A systematic literature review was carried out in respect of key areas of literature using terms such as social organization, norms, population mobility, gender, indigenous peoples and each of the regions, and practices (e.g., hunting, fishing) as well as for well drivers identified in other assessments as begin related to biodiversity including urbanization, rural development, poverty and inequity. Published academic papers in the social sciences (e.g., sociology, geography, economics, interdisciplinary – environmental studies) were reviewed; they were mainly from English-speaking journals and were published in the last 20 years. Other kinds of publications (e.g., grey literature, conference proceedings, indigenous and local knowledge reports) were also included in the review, mainly where there was an absence of academic publication. Other kinds of reporting of indigenous and local knowledge were also a consideration (e.g., alternative media). A higher value was placed on papers that offered evidence/data about particular kinds of trends, patterns and dynamics in a social system (i.e., less consideration of conceptual/ theoretical and editorial articles). Those publications offered a synthesis of data from multiple locations and over time. Authors found over 2000 sources. Based on a review of these sources, major themes and interpretations of patterns in political drivers were identified. Experts developed the sections with 20 + years of experience related to aspects of biodiversity conservation and in the social sciences. Where there were gaps in regions, practices, etc., and case studies were developed to illustrate an important dimension of the social driver and its impacts on practices and uses.

4.2.3.1.2 Gaps

- Social systems, like many aspects of ecosystems, are highly complex and there are many factors that affect sustainable use that are not well documented.

- There are gaps in literature related to governance of gathering and non-extractive uses (including viewing) when compared to the practices of hunting, fishing and logging.

- Regional gaps exist with respect to social norms, perceptions, and gendered dimensions of sustainable use in most parts of the globe with particular gaps apparent for Latin, America, Asia, particularly in relation to informal institutions and governance systems of indigenous peoples and local communities.

4.2.3.2 Demographics and mobility

4.2.3.2.1 Population growth and demographic change

Demographic shifts are occurring with significant population increases occurring in areas of the globe. These demographic increases are creating increased pressures on wild species. Globally the average population density is 25 people per km^2 but there are unique patterns in different parts of the world which are factors in the relationship of people to, and use of, nature including fisheries, wild species, timber resources and other resources. For example, in some island natures such as Macao, Special Administrative Region of China; Singapore; Hong Kong, Special Administrative Regions of China and Gibraltar, population density is well above the average. The population of Singapore for example, has nearly 8,000 people per km^2 (2,000 times more densely populated than Australia. Bangladesh is the most densely populated with 1,252 per km^2, followed by Lebanon (595 per km^2), South Korea (528 per km^2), the Netherlands (508 per km^2) and Rwanda (495 per km^2). Population in and of itself is not a pre-determination of unsustainability; norms of stewardship, for example, meditate patterns such as over-harvest in many regions. This is evident by the examples of Netherlands and Rwanda. Wild species are a reported rarity in the Netherlands (i.e., all land and species are managed), however, some of the most valued and largest megafauna in the world (e.g., mountain gorilla) are being sustainably managed in Rwanda (Abensperg-Traun, 2009). In addition to density, population growth (including rapid population) growth are a consideration in future sustainable use patterns. Population growth is highest in Sub-Saharan Africa. In other areas of the globe, the rate of population growth is falling (Anríquez & Stloukal, 2008; Saad, 2010).

Age differences also affect use patterns. For example, hunters are generally younger than non-hunters (Loibooki *et al.*, 2002), mainly due to a lack of income–generating opportunities. In areas with high fertility, children may provide labor to gather natural resources (De Sherbinin *et al.*, 2008; Gifford & Nilsson, 2014). However, conservation and norms related to protecting the environment tend to be more prevalent in younger generations. For example, in Nigeria, Togo and Niger younger people ate less bushmeat than older persons, in part be due to a growing 'westernization' of the lifestyles (Luiselli *et al.*, 2019). This is also true in northern Canada.

4.2.3.2.2 Migration and mobility

Key Messages:

- Many peoples around the world (including indigenous peoples and local communities) have developed livelihoods over many generations, that are interconnected with the migratory wild species; knowledge and practices (e.g., hunting, fishing, etc.) developed over many generations have resulted in dynamic but sustainable use patterns. The loss, fragmentation and/or degradation of migratory species habitats is leading are major challenges to sustaining sustainable use.

- Forced migration due to war and conflict as well as environmental refugees is leading to changes in the use of wild species in some key areas of the globe.

- Increasing mobility (due to transformation innovations) and the globalization of markets is associated with a break-down of the social norms related with care and stewardship of place (lack of attachment of place).

- There is an unprecedented multi- directional movement of peoples around the world involving new patterns of transnational migration, identities and communities (Robinson 2007).

- Transcience is associated with a breakdown of social norms and institutions that governed human behavior and increase in individualistic human behavior and choices than are often antithetical to sustainability.

Livelihoods in many parts of the world are highly interconnected with the dynamics of ecosystems including the variabilities of migratory species. For example, in the circumpolar north, indigenous peoples have well developed systems of travel and tracking of wild species such as barren-ground caribou; although there is significant spatial and population variability (Vors & Boyce, 2009), their hunting practices have been sustainable for generations. One of the keys to such success has been the critical importance of learning and adapting to changes in population dynamics and health is the diversity of wild species valued for food security and the flexible livelihood strategies of harvesters who are able to adapt their harvesting practices to other species when caribou populations decline (Berkes *et al.*, 1995; Nuttall, 2005; Winterhalder, 1983). Similar patterns of sustainable use of migratory species are evident in other regions. However, with increasing pressures of climate change and the loss of wild species habitats due to industrialization and land clearing, migratory species and associated livelihoods are under stress. Alternatives, however, are not easily constructed. "Given that many hunting and forest peoples are semi-migratory, their lifestyles do not allow for adequate care of livestock, other than easily transported species such as chickens. Dayaks of Long Segar, Kalimantan, for instance, move from villages to their fields at planting and harvest times so that government efforts to introduce cattle into such societies have been a miserable failure" (Bennett & Robinson, 2000). Protections of migratory species and livelihoods are urgent but also challenging given the rigidity of protected areas and mobility of such wild species and peoples; "traditional conservation strategies involving static tools (e.g., protected areas that have fixed spatial boundaries) may be ineffective for managing species whose ranges are changing" (Bull *et al.*, 2013). Mobile or flexible protected area systems that support migratory species (including a high degree of variability in habitat use), are most successful in ensuring sustainable use (Bull *et al.*, 2013; Hole *et al.*, 2011; Maxwell *et al.*, 2020).

Perhaps one of the most illustrative examples of livelihoods being interrelated with variable species relates to fishing. The rotation of fishing lakes is a well-established example in the case of indigenous peoples and local communities. It was a historic practice governed by customary law, among indigenous peoples in northern Canada to move camps and fishing from one lake to another at various intervals to allow fish stocks to recover. Indigenous peoples from northern Canada, for example, historically would "rotate their fishing grounds and adjust gillnet mesh size according to what they anticipate to harvest, which results in a diffusion of harvesting pressure over space and time, and by species and size-class" (Berkes, 1989, 1998).

Fishers in other areas changing their fishing areas in response to local availabilities of the most valued target species, whether demand is for local or international markets (Cripps & Gardner, 2016). Aside from this essential characteristic of fisheries, however, there are also many continuing examples of seasonal migrations as fishers follow moving fish stocks or rotate through various fishing grounds depending on desired species and/or weather conditions (Kluger *et al.*, 2019, 2020; Piezonka *et al.*, 2020; Wanyonyi *et al.*, 2016). Very often these migrations involve movement across more recently established political boundaries, or temporary settlement in communities with which they have historical understandings of shared space and economic linkages. In some cases, including, for example, that of the indigenous Bajau Laut peoples, migrant fishers and their cultures may not be fully recognized as belonging to any nation. For migrant fishers, traditional resource use strategies that involve continuous movement may conflict with modern boundaries and area-based management, which complicates and hinders their inclusion into resource use and management (Clifton & Majors, 2012), making them highly vulnerable to resource exclusion and unjust prosecution (Cisneros-Montemayor *et al.*, 2018; Finkbeiner, 2015). It is essential that current and future management find proactive ways to include such traditional livelihoods, particularly given the rapid impacts of climate change and human use on local resource availabilities. International agreements and the recognition of the value of these customary uses and management strategies are essential in that regard, both for vulnerable indigenous communities and for broader sustainability goals (Vierros *et al.*, 2020).

4.2.3.2.3 Forced migration – refugees

In 2000, 175 million people lived outside their country of origin. By 2013 this stood at 232 million. Of these migrants, 35% moved from one developing country to another, while 34% moved from developing to developed countries (The Partnership Platform, 2021). In addition to international migration flows, internal (within country) migration is highly significant – especially for movements from rural to urban areas – although data on numbers of internal migrants is much harder to ascertain (Cohen, 2013). People migrate for multiple reasons – from conflict to environmental degradation, access to better resources such as fertile land (Crawford & Kujirakwinja, 2016) disparities between countries, and the desire for economic or education or health or social opportunities.

Migration from regions of areas with high youth populations into high-income countries with older workforces is a critical factor in global migration (Hugo, 2011) and has attendant effects on natural resources (see migration section). These areas with high youth populations also directly overlap with areas of high risk to climate change (Hugo, 2011).

Conflict and migration

Many migration patterns caused by political conflict are leading to unsustainable patterns of wild species use (Begemann *et al.*, 2020; Black, 1994; M. Geiger & Pécoud, 2020; Gushulak, 2021; Hugo, 1996; Jacobson, 1998; McNamara, 2007). See more on this in political drivers' section on conflict.

Environmental refugees

Environmental refugees are a growing concern around the world (Bose & Lunstrum, 2014; Myers, 2002); many peoples are displaced and become "refugees" due to land grabbing (Feldman & Geisler, 2013; Peemans, 2014; Sama, 2016; Zoomers, 2011), the impacts of industrialization (e.g., deforestation) as well as due to the effects of climate change (i.e., forest fire, flooding, drought) (Brisman *et al.*, 2018; Hunsberger *et al.*, 2017; Vigil, 2016). Green-grabbing and forced displacement for conservation goals including the creation of terrestrial and marine parks has also created refugees of many peoples (Agrawal & Redford, 2009; Dowie, 2011; West *et al.*, 2006). Many emerging critiques of removal of indigenous peoples and local communities in the name of conservation and the significant impacts of health, Box 4 19 **Batwa as conservation refugees.**

The Batwa are an indigenous people of Uganda have long histories of use and livelihood in the region; their livelihoods are defined as "hunter-gatherer" were considered highly sustainable for many hundreds if not thousands of years. The Batwa were forcibly relocated from the Mgahinga and Bwindi Impenetrable Forests, to towns and villages, where they have struggled to adapt and sustainable their families and communities. They were never compensated for their displacement and loss of livelihood; many families are now landless squatters. Their ability to access their ancestral home is limited. Tourist operators for the Mgahinga National Park (and Ugandan Wildlife Authorities), benefit significantly from tourism into the park (i.e., reported in the millions annually). This is in sharp contrast to the poverty now experienced by the Batwa many live in extreme poverty on less than 75 cents a day (compared with a Ugandan average daily income of 1.80 United States Dollars).

well-being and transgression of human rights – coupled with lack of marked improvements in biodiversity outcomes, has led to new models of conservation and calls for the end of exclusionary conservation practices (Cernea & Schmidt-Soltau, 2003).

Those peoples whose livelihoods are strongly interrelated with lands under stress tend to be the most impacted. Land evictions can be highly gendered and disproportionately affect women such as in Cambodia (Lamb *et al.*, 2017). They ways in which people respond to these stresses vary as do the associated implications of wild species use. The environmental impacts of these diverse migration flows and dynamics appear to be equally as complex and varied, and relatively underreported in the published literature (Hecht *et al.*, 2015; Hunter *et al.*, 2015). Migration, for example, can have positive or negative environmental implications, with different scenarios expected for sending *versus* receiving areas (Curran, 2002; Fussell *et al.*, 2014) underreported in the published literature (Hecht *et al.*, 2015; Hunter *et al.*, 2015). Migration, for example, can have positive or negative environmental implications, with different scenarios expected for sending *versus* receiving areas (Curran, 2002; Fussell *et al.*, 2014). This is evident in forest transition trends, especially in the tropics, where deforestation has been partly (but significantly) driven by migration into the forest frontier (Rudel *et al.*, 2019), yet forest recovery is seen across global regions as a consequence of people leaving farming and rural areas (Aide *et al.*, 2013; Nanni *et al.*, 2019). In migrant-sending areas, depopulation improves environmental outcomes through reduced resource use (Aide & Grau, 2004; Myerson, 2017), but can impact biodiversity in less obvious (and not always positive) ways through changes to landscape use (Davis & Lopez-Carr, 2014; Lambin & Meyfroidt, 2011). But out-migration facilitates the aging and shrinking of rural populations, thus potentially weakening the social organization, environmental knowledge, and community institutions that underpin sustainable land management systems (Robson *et al.*, 2019). Depopulated communities may also be more vulnerable to land grabs and the incursion of ecologically damaging resource practices (Padilla 2012). In migrant-receiving areas, the arrival of people can help to alleviate such shortfalls. Yet where in-migration takes place in response to the presence of high-value resources/commodities, it drives environmental degradation in often ecologically sensitive areas (Pimm *et al.*, 2014; Wittemyer *et al.*, 2014).

Other migration patterns

The migration of people underpins, and can exacerbate, demographic/population change and urbanization trends. In 1990, 153 million people lived outside their country of origin (International Organization for Migration, 2017). By 2017 this stood at approximately 258 million (OECD, 2018). Of these migrants, close to 35% moved from one developing country to another, while 34% moved from developing to developed countries (International Organization for Migration, 2017). In addition to international migration flows, internal, migration is highly significant – especially for movements from rural to urban areas – although data on numbers of internal migrants is much harder to ascertain (Cohen, 2013; International Organization for Migration, 2017). People migrate for multiple reasons – from conflict to environmental degradation, disparities between countries, and the desire for economic or education or health or social opportunities.

Rural migration patterns

For rural areas, the impacts of migration and urbanization are also complex and varied. Migration, for example, can have positive or negative environmental implications, with different scenarios expected for sending *versus* receiving areas (Curran, 2002; Fussell *et al.*, 2014). For example, in the tropics (e.g., Indonesia, Amazon) legal and illegal logging, illegal mining and clearly of land for commercial cropping (e.g., soybean farming) has been driven, in part, by migration of marginalized populations (i.e., those living in poverty) to seek out new livelihood and economic opportunities. In some areas, reforestation and other forms of forest recovery are being evidenced as as a consequence of people leaving farming and the rural regions (Aide *et al.*, 2013; Grau & Aide, 2008; Nanni *et al.*, 2019).

In migrant-sending areas, depopulation improves environmental outcomes because of reduced resource use

(Myerson, 2017), but impacts biodiversity in less obvious (and not always positive) ways (Aide *et al.*, 2013; Robson & Berkes, 2011; Rozendaal *et al.*, 2019). For example, migration of males to urban areas has been found to result in the increasing feminization of natural resource collection which may impact the contribution of natural resources to households (Zhu *et al.*, 2020). The drivers of migration into rural areas including poverty, but also landscape and resource and degradation due to over harvesting, industrialization and climate change. Migration can also be caused by land use conflict and political unrest. Land use conflicts can range from legal displacements of people and the erosion of their livelihoods due to industrialization or can be associated with large scale conflicts (e.g., ethnic and political violence).

Voluntary or forcible removal of populations due to the imposition of large scale commercial agricultural, hydro-electric dams and mining projects, roads and associated infrastructure is a significant concern. Indeed roads, railways and changes in transportation corridors can lead to relocation, new patterns of settlement and different patterns of use of wild species.

4.2.3.3 Social organization

Key messages:

- Societies that have developed over the long term with a strong dependence upon place and resources have well organized and developed systems of natural resources management, including rules related to the sustainability of species *(well established)* {4.2.3.3.1}.

- Social values expressed at different scales shape perceptions of wild species and the perceived benefits and risks of their use *(well established)* {4.2.3.3.2}.

- Social inequity and poverty are a major driver of unsustainable use however, it is the structures that have created the inequity that are the greater driver *(established but incomplete)* {4.2.3.3.3}.

- To face global changes, new individualistic/opportunistic strategies and competition are developing, calling into question traditional social structures (norms, values, institutions) and contributing to the overexploitation of nature *(established but incomplete)* {4.2.3.3.3}.

Social structure refers to the architecture and dynamics of society; some key dimensions of structure include institutions and social norms, cooperation, social cohesion, involvement, sense of community. The Organization for Economic Co-operation and Development describes a cohesive society as one which "works towards the well-being of all its members, fights exclusion and marginalization, creates a sense of belonging, promotes trust, and offers its members the opportunity of upward social mobility" (OECD, 2011). There are different degrees of rigidity (*versus* flexibility) in social organization (i.e., loosely organized to tightly organized) and different degrees of complexity and specialization. The units that structure a society (e.g., groups, institutions) are generally studied together with the dynamics of social change including how societies innovate, adapt over time and cope with extremal stresses such as a decline in a valued wild species. Those involved in environmental sociology and other disciplines concern with the environment increasingly consider the function of society in terms of a system and the interconnectedness of ecosystems and social systems (i.e., the social-ecological system) (Berkes 1998; Ostrom 2009) (see chapter 1).

A critical consideration in social systems is how individuals and institutions learn and adapt their practices (e.g., hunting, trapping, fishing) and uses to changing ecological conditions including variation and change in the health, abundance and distribution of wild species (Pahl-Wostl *et al.*, 2010; Reed *et al.*, 2010; Sigmund *et al.*, 2010). Drawing on the extensive literature on social learning and natural resource management (and social-ecological systems), it is evident that individual and institutional learning is key to sustainable use outcomes in almost every region of the globe and for a large number of wild species.

4.2.3.3.1 Social organization and place

The practices and uses of wild species by different social groups can be defined as social-ecological systems, many of which are highly complex and characterized by significant uncertainty, non-linearity and self-organization. In other words, they are messy and difficult to manage. For example, populations of wild species can vary significantly over time and the behavior of those who harvest the population can also vary depending on many other factors (e.g., the availability of other species to harvest, alternative economic opportunities, values and norms, etc. (Laird *et al.*, 2010; Steward, 1968; Zimmerer, 2006)).

The extent to which social structures are organized in relation to a particular kind of place, species or ecosystem also affects the extent to which social structures affect sustainable use (Laird *et al.*, 2011). Societies that are more disconnected from place are thought to have less interest in protecting or conserving the species. This is sometimes framed as "sense of place" defined as "the collection of meanings, beliefs, symbols, values, and feelings that individuals and groups associate with a particular locality" (Williams & Stewart, 1998). It "reflects not only experiences with places but also the cultural, religious, historical, and personal meanings of places and the power and economic relationships that shape historical and current interactions with places" (Chapin and

Box 4 20 **Sense of place and sustainability** (reproduced from Chapin and Knapp (2015)).

The following dimensions of sense of place and its effects on sustainability:

- Sense of place best motivates stewardship in homogeneous communities.
- Multiple senses of the same place can generate conflict.
- Globalization and human mobility may foster commitment to more places.
- These trends provide new stewardship opportunities at local-to-global scales.

Knapp, 2015, p.39). As such sense of place shapes, the way wild species are defined (including imagined), understood and valued which in turn shapes use. People who pass through a place as a tourist will have a much different set of norms related to care and use of wild species than a property owner (Cross, 2001; Tonge *et al.*, 2015), who, if only engaged for a short-term period, may in turn behave differently than a long-term property owner or an indigenous person with a long term and multi-generational relationship to place (Chapin & Knapp, 2015; Vaske & Kobrin, 2001).

"Sense of place does not always promote stewardship, however, because attitudes may not lead to actions, some actions do not promote sustainability, and different place identities in the same place may lead to different stewardship goals (e.g., conservation vs. development) (Chapin and Knapp 2015). There is much evidence that the longer one lives within or frequents a place that is associated with positive personal experiences, the greater the attachment to place and in turn the greater degree of conservation-oriented behavior (e.g., lack of vandalism, less waste, the greater the degree of investment of resources in stewardship). This is strengthened where property rights arrangements create incentives for care and investment (i.e., security of ownership creates more significant incentives for conservation). Self-efficacy, or the belief that one has the capacity effect a particular change, can influence whether intentions translate to behaviors consistent with sustainable use. Sense of place and associated pro-sustainable behavior through addressing issues of open access (i.e., securing property rights), education about the specific behaviors and opportunities to improve sustainable use (i.e., to nurture self-efficacy). Globalization and the transience and high degree of mobility tend to lead to poorer sense of place but may be positive if it leads to multiple kinds of place attachments (Chapin and Knapp 2015).

4.2.3.3.2 Social norms

Social constructions of wild species

Wild species are variously defined across cultures and societies. In addition to natural science taxonomies and characterizations, wild species are socially constructed through social-ecological interactions, knowledge shared through research and governance, as well as through popular media. For example, in North American wolf populations have long been considered a threat to people, a perception that was place on experiences of farmers and risks to livestock but has been perpetuated by cultural narratives (e.g., children's fables of the "big bad wolf") (Lappalainen, 2019). One interesting trend of the risk society literature is the extent to which some wild species which might have historically been viewed as a benefit and a contribution to well-being (and cared for accordingly) have been reframed as threats or risks to human health (Beck, 1992; Dempsey, 2013; Sidhu, 2003). For example, in many areas of North America, there are advisories issued by government related to harvesting and consuming many fish species due to the bioaccumulation of contaminants (Burger, 2000; Chess *et al.*, 2005; Oken *et al.*, 2012). Although there is variation in compliance with advisories, on the whole they lead to decreases in harvesting and other kinds of impacts (i.e., increase of catch and release). Advisories can also lead to an amplification of risk; this not only in the area specifically affected by an advisory but in other regions. For example, in Nunavut, concerns about contaminants in some species and some areas, led to changes in dietary patterns that had other kinds of consequences including directions (Furgal *et al.*, 2005; O'Neil *et al.*, 1997).

Depending on the degree of dependency on a species for subsistence (or other value), biodiversity in the region and mobility of harvesters, reports of a problem in one area and one species, can cause harvests to adapt and harvest other species, change to a market diet, or move to new areas to find healthier species (Tisdell & Svizzero, 2015; Winterhalder, 1986; Winterhalder & Smith, 2000). These kinds of adaptive strategies can have significant impact on diet and health (Badjeck *et al.*, 2010; Hovelsrud *et al.*, 2008; Marushka *et al.*, 2019; Ross *et al.*, 1978).

There are other implications for sustainable use. For example, shifts away from the harvest of local fish species for food security has indirectly led to an increase in industrial fishing practice that have impacts on species many thousands of miles away. This pattern is perpetuated by the cognitive dissonance that characterized the global food system; lack of awareness of the ecological and social costs of industrial harvests contributes to perceptions that buying food from the store is healthier than can be harvested locally (i.e., wild species) and in addition that resources from elsewhere are limitless.

Other aspects of globalization shape and, in turn uses, of wild species. For example, public media related to trapping, seal harvesting, whale harvesting and polar bear hunting has had a significant adverse impact on indigenous peoples and local knowledge in northern Canada whose cultures and economies are interrelated with the health of these species. Protests by animal rights activists coupled with popular films and social media sources that are opposed to animal use have tended to artificially construct wild species in more romantic and moral terms rather than those based on science of the knowledge of indigenous peoples and local communities. This moral position of global authorities against 'hunting' is a driver of declining interest of younger generations in cultural practices of hunting and associated with other adverse impacts on cultural continuity and well-being of indigenous peoples.

4.2.3.3.3 Livelihoods and development

A livelihoods approach offers an integrated way of thinking about the way in which societies organize themselves in making a living but also in producing other social, cultural and health well-being benefits (Negi *et al.*, 2011; Rao & McGowan, 2002). A livelihood comprises: "the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers & Conway, 1992). Following the Brundtland Commission on Environment and Development and then expanded by United Nations Conference on Environment and Development (UNCED) in 1992, a large literature related to livelihoods and the ways in which can might be interpreted as sustainable, expanded, among which stressing the sustainable rural livelihoods and targeting the household level:

> "A livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term" (Chambers & Conway, 1992).

Livelihood typologies vary and are also gendered (Oberhauser & Yeboah, 2011). Research and evidence is well developed in almost every global region; and much study highlights the ways in which different social groups are able to create, innovate, adapt and contribute to many dimensions of sustainability including sustainable use of wild species (Koziell, 2001; S. A. Mainka & Trivedi, 2002; Wollenberg *et al.*, 2000). For the purposes of this assessment, the framed livelihoods around practices of wild species use and discuss how the social organization associated with these practices drives different aspects of sustainability.

Artisanal fishing livelihoods

Small-scale fisheries generally present (some of) the following characteristics: (i) low capital investment, (ii) high labor activities often family or community-based, (iii) no vessel or small size vessel (< 12m and < 10 gross tonnage), (iv) relatively low production, which is household consumed or locally and directly sold and (v) operating close to the shoreline on a single day basis. There is a whole gradient, from the individual fisherman on board his dugout pirogue, to crews of more than 20 men on board large, motorized pirogues, all of whom, at least in West Africa, identify themselves as small-scale fishermen. It is therefore not easy to stick to the "official" definition, if not to show the limits of it in terms of the identity of the actors (how they define themselves) and their evolving or adaptive strategies in the face of a changing environment. The small-scale fishermen are organized in fishing units, comprising from 1 to more than 15 men, most often recruited on a family or community basis. Working relations, both on land and at sea, are traditionally tacitly recognized: thus, for small-scale fishing, the means of production (pirogue, motor, catching gear, etc.) are usually the property of the eldest of the lineage, who also acts as captain of the unit (or the canoe); if he is too old to go out to sea again, he entrusts the responsibility to his eldest son. The fishing unit thus includes the captain as well as the crew, traditionally recruited from the extended family (sons, nephews, etc.) or allied members. The operating strategies (or fishing system) are defined by the captain.

Extensive literature on this topic has shown the importance of these strategies (decision-making processes) on resource management and the adaptive capacity of fishermen (or flexibility of fishing systems) for sustainable resource management (Chauveau *et al.*, 2000; S. Garcia *et al.*, 2014; Gustavsson *et al.*, 2017; Kalfagianni *et al.*, 2013; Marín & Berkes, 2010; Sønvisen, 2014). This is critical in many examples of "small scale fishing" as Cambodia and elsewhere (Béné, 2006; Marschke & Berkes, 2006; Mullon *et al.*, 2005; Pauly, 2018; Pauly *et al.*, 2002).

On the one hand, "responsible" and sustainable strategy and flexibility of the system to face the changes: this flexibility is based on the diversity of the elements that make up the fishing system: several fishing gears, various species targeted according to season and location, etc. Fishermen only take the resources they need for their own consumption and selling the surplus to meet their basic needs (or, at least, the reproduction of the system), with well-established and shared rules of use and access to resources, and a system for allocating shares when they return from the tides.

In the other hand: with modernization (motorization, mechanized gear, refrigeration on board, etc.) and professionalization (from part-time to full-time), the specialization of new or "young" fishing units, more concerned with profitability, crews recruited on a capital base (employees) targeting a single species with less selective catching techniques (e.g., large purse seines) for a specific export market (e.g., shark fins to supply the South-East Asian market). These opportunistic strategies are unsustainable, leading not only to biodiversity erosion, but also to increased vulnerability of fishermen and conflicts (Mullon *et al.*, 2005; Pauly, 2018; Pauly *et al.*, 2002). Faced with the crisis of fishery resources, it is also important to note the capacity of fishermen to innovate from a social and institutional point of view, to set up associations and cooperatives on a regional, national or international scale, to have their rights recognized on their territories (e.g., fishermen's committees which manage Marine Protected Areas, which set up set-aside areas for fishing, see section on "political drivers") (Likuge & Munas, 2013; Mbaye *et al.*, 2020, 2020; Sjöstedt & Jagers, 2014).

Gatherer livelihoods

There are many characteristics of gather livelihoods that support sustainable use that are similar to those of hunting livelihoods including flexibility, adaptive capacity (Bunce *et al.*, 2016; Díaz-Reviriego *et al.*, 2016; Maclean *et al.*, 2013; Parlee *et al.*, 2006). The management of landscapes for the purposes of gathering of food resources is an essential area of research, particularly, in relation of indigenous peoples (e.g., cultural burning practices) (Christianson, 2014; Marks-Block *et al.*, 2021; McKemey *et al.*, 2020; McWilliam, 1999). Concern about the risk of bioaccumulation of contaminant in plants valued for food is leading to deterioration of many gatherer livelihoods.

Box 4 21 Biodiversity: Drivers of sustainable use of wild species.

Vaccinium vitis-idaea (*natł'at* in Teetl'it Gwich'in; *puolukka* in Finnish) is a common evergreen dwarf shrub in the Ericaceae Family found across the circumpolar north (Gillespie *et al.*, 2015). *V. vitis-idaea* produces small, red spherical berries and berry production can differ dramatically year to year depending on climatic variables over that past two growing seasons (Krebs *et al.*, 2009). The berries are an essential food source food many northern inhabitants, including grizzly bears, red-backed voles and indigenous people (ibid.). This case study compares the sustainability of *V. vitis-idaea* harvest by people in two circumpolar regions: northern Canada and Finland. Wild *natł'at* berries have been harvested annually in northern Canada since time immemorial. The Teetl'it Gwich'in identify *natł'at* as one of the three most important berries and upwards of 90% of households collect them (Murray, Boxall, and Wein 2005). Annual harvest estimates range from 6-19 liters per household and for a total of 5,100 liters between the four largest Teetl'it Gwich'in communities and commercial harvesting is limited (Murray, Boxall, and Wein 2005; Parlee *et al.* 2005).

Berry picking effectively begins well before fruit production. Harvesters, primarily women, start "checking in" on their preferred patches and sharing information across their social networks (Murray 2002; Parlee *et al.* 2006). Select patches are generally located in easily accessible areas near communities or near family camp or cabin sites (Parlee *et al.* 2006). Berry observations intensify during the picking season and modern technology allows for the information to be shared across a large geographical area (Ibid.). In poor years, pickers may travel considerable distances to access productive patches. For example, Whitehorse, Yukon, had a particularly bountiful *natł'at* crop in 2016 and this enticed four women Caring for particular berry patches is expressed in several ways, including direct management of habitat conditions to promote berry production (Murray, 2002; Parlee *et al.*, 2005). The pickers are also very responsive to climate-driven variation in berry production and use their social networks to locate alternative, more productive patches (Murray 2002; Parlee *et al.* 2006). Across the Arctic Ocean in Finland, harvesting of wild *puolakka* berries is also a prominent activity with deep historical roots. It is estimated that 60-70% of Finns continue to participate in berry picking and harvest ~12 kg of *puolakka* berries/household each year (Peltola *et al.*, 2014; Saastimoinen *et al.*, 2000; Vaara *et al.*, 2013). Unlike northern Canada, commercial harvesting of puolakka has occurred for more than 150 years (Peltola *et al.*, 2014).

The majority of forests in Finland are owned privately; however, people are allowed to harvest berries for domestic and commercial use regardless of land ownership under the principle of "Everyman's right" (Peltola *et al.*, 2014). An estimated 8-10% of the total berry crop are harvested annually (Turtiainen *et al.*, 2011). In Finland, urban as well as rural inhabitants harvest berries; ownership of a summer cottage significantly increases participation in berry picking by urban dwellers (Kangas & Markkanen, 2001; Pouta *et al.*, 2006). Women tend to be more active berry pickers than men (Pouta *et al.*, 2006). There are limited data documenting harvesting practices though the protection of secret berry patches is mentioned (Peltola *et al.*, 2014; Pouta *et al.*, 2006). The long-term harvesting history and small proportion of berry crop harvested annually indicates picking *puolakka* berries in Finland remains sustainable.

Interestingly, despite the limited documentation of customary practices "regulating" berry picking, there is evidence these practices exist. A common complaint with current commercial harvesting is companies have not provided foreign workers with information on appropriate locations and berry picking practices (Peltola *et al.*, 2014). As seen in northern Canada, children are frequently included in berry picking excursions

Box 4 21

which provides the opportunity for these practices to be transferred between generations (Kangas & Markkanen, 2001). The social and ecological context of the Teet'lit Gwich'in and Finnish peoples provide an interesting comparison of wild berry harvesting. The Gwich'in inhabit an expansive, largely undeveloped subarctic region and Finland is a relatively small country with intensively managed forests. Commonalities between the two groups suggest that sustainable harvesting is achieved, at least in part, by having high rates of participation within the population and intergenerational involvement. This ensures shared appreciation for social and culture aspects of berry picking; the development of customary practices to ensure harvest sustainability; and opportunities occur to transfer this knowledge to the next generation. The influence of women as the primary leaders of berry picking is less clear and requires further investigation. Other similarities include the berries are supplementary rather than a staple component of local diet, the quantity of harvest is directly related to local knowledge and the harvest is very responsive to annual variation, harvesting is labor intensive, and mechanization of harvesting is relatively limited. Changes in economic or social pressures that increase barriers to berry picking participation could also threaten populations of Vaccinium vitis-idaea. The fewer people who berry pick could decrease the societal value of berries and reduce incentives to conserve wild berry picking areas.

Hunting livelihoods

Hunting livelihoods are characterized by different characteristics of social organization. In addition to a high degree of mobility (in the case of hunting of migratory species), many hunting societies developed within indigenous cultures share some common characteristics such as strong subsistence *versus* commercial harvest; social networks that facilitate food sharing; flexibility and adaptive to ecological conditions (Armitage, 2005; Granderson, 2017; Lu, 2010; Mulrennan, 2014; Pearce *et al.*, 2015; Ruiz-Mallén *et al.*, 2017), and intergenerational knowledge sharing that supports adaptation. Many hunting livelihoods in indigenous cultures are also based around beliefs, values and practices of reciprocity between wild species and dependent communities (i.e., people take care of the animals and the animals take care of the people) (Fernández-Llamazares *et al.*, 2020; Kimmerer, 2011; Nadasdy, 2007; Nursey-Bray *et al.*, 2010; Peterson, 2013; Welch, 2014; Wenzel, 2000).

Hunting also tends to be a very gendered practice. In many cultures, there are stereotypes of men the hunter, and women as gatherer are well established but have also been critiqued as social constructions of anthropology. For example, the archetype of "man the hunter" is deeply engrained in the anthropological record of the North (Bodenhorn, 1990; Van Voorst, 2009; Vladimirova & Habeck, 2018; Williamson, 2002). This bias has tended to become reproduced in the kinds of research carried out in the North as well as in policy contexts at regional, territorial, and national levels; although some greater attention has been paid to gender biases since the 1970s, there is still relatively little in the academic literature that relates women and hunting. Within this category, the theme of women and hunting is among the most complex. Although not well documented, women in many cultures play pivotal roles in hunting, ranging from spiritual rites to holding spears and other weapons (Geller & Stockett, 2007; Wadley, 2005). The gender bias is not unexpected given that men were the sole leaders of anthropological tradition up until the mid-twentieth century (Parlee, Andre, & Kritsch, 2014). There are more diverse kinds of gender identities than those that follow Judaeo-Christian archetypes (Kuokkanen, 2019; Subramaniam *et al.*, 2016). But the bias is also one that seems to have been easily and unapologetically replicated in other disciplines and research traditions, including that focused on traditional knowledge (Nadasdy, 2003).

In the case of indigenous peoples and local communities, hunting practices are highly intertwined with cultural identities. For example, in the case of the Dene, the practice of hunting is intertwined with what it means to be indigenous, interconnected with physical-spiritual health and well-being. For example, people refer to themselves as "caribou people.". Even when resources have been lost or eroded, species are still intertwined with sense of self, community and spiritual belief systems. As a result, the loss is highly impactful on health and well-being. For example, the collapse of the North American plains bison, which was intertwined with the violent colonization of Canada and the United States of America, has devastated the indigenous people.

Sports and trophy hunting are also strongly interconnected with the identities and social organization of those engaged (Darimont *et al.*, 2017; Ebeling-Schuld & Darimont, 2017; Mihalik *et al.*, 2019). For example, the motivations for recreational and sports hunting can be tied to the desire for self-sufficiency and food security; in other cases, the practice of hunting is strongly interconnected with social relationships and rituals. Although there is much evidence that a primary motivation in hunting may be the desire to connect with nature, hunting of non-edible species is also associated with desires for control over nature (i.e., need for self-efficacy), and "show-off" (e.g., physical dominance) (Child and Dairmont, 2015; Darimont *et al.*, 2017).

Small-scale agricultural livelihoods

Small-scale agriculture has many kinds of organizational structures, including slash-and-burn and other kinds of agricultural practices. Agricultural practices can enhance (agro-biodiversity, such as agroecological practices/agroforestry. The rise in rural settlement and feudal systems in Europe in the 17th century is primarily attributed to land clearing, habitat destruction for some wild species and persecution of others. Other forms of small-scale agriculture are notably not commercial or feudal but tied to subsistence and cultural uses. For example, Huron Indians in southern Canada – were organized in small scale agricultural communities (i.e., corn production) but with mixed engagement with hunting-gathering. The shift away from small-scale agriculture in Europe and the Americas beginning in the 1900s and the mechanization of farming changed social structure in rural areas (i.e., farmers no longer held private property – lost to large-scale farms). Changes in social structures and property rights resulted in people no longer being closer to the land on "family farms" but became workers on industrial farms or left farms entirely (i.e., rural-urban migration). The loss of individual property rights to many small areas of land in the United States of America is attributed to the homogenization of land and resource uses, increasing use of pesticides (leading to habitat degradation and losses of species) including unsustainable uses of wild species (i.e., land clearing). There are exceptions to this trend, including reclaiming of land and the family farm in some areas.

Urban and peri-urban livelihoods

There are important dimensions of urban and peri-urban livelihoods that intersect with wild species use. While most research has focused on dichotomies of urban *versus* rural, the longer-term persistence and importance of "fringe or urban transition zones" have developed since the 1980s (Simon, 2008). Population growth and consumer demand e for "green neighbourhoods" is a driver behind the phenomenon of expanding urban transition zones and urban sprawl and associated wild species habitat degradation. These patterns coincide with increasing concern about the adverse health impacts of living in high-density neighborhoods (e.g., air quality) as in major cities worldwide. It is also being driven partly by growing evidence of the health benefits, particularly for youth and children who are connected to nature (Cheng & Monroe, 2012). In some areas, city planning is offsetting the problem of urban sprawl in response to green consumers and instead comaintaining maintaining of wild spaces within cities for non-extractive uses. Such efforts are also associated with the protection and reclamation and re-wilding of some peri-urban environments

Box 4 22 **Agroforestry's 'roots' in traditional land management systems in Southeast Asia.**

Agroforestry aims to intentionally integrate trees with wild species, crops, and livestock to develop an ecology of symbiosis. A tradition of not separating oneself from these ecological systems is prominent amongst indigenous peoples within the Southeast Asian region, specifically in Malaysia and the Philippines (Adnan & Othman, 2012; Camacho *et al.*, 2016). Histories of colonial rule and the erosion of traditional land management practices and rights of the Malay Forest peoples have created unsustainable deforestation in many regions of Malaysia. In contrast, the resistance to colonialism and maintenance of indigenous practices within the Cordillera Mountains of the Philippines has helped promote sustainable harvesting of fuelwood and ecological health (Camacho *et al.*, 2016). In a 2014 report undertaken by Malaysian feminist Carol Yong, Kuching-based, non-profit Sarawakians Access, and Peninsular Malaysia Orang Asli Village Network (Jaringan Kampung Orang Asli Semenanjung Malaysia); deforestation in Malaysia were intimately linked to a value-system based on a source of income. Massive shifts in forest land-use systems – from local customary land use systems to large-scale commercial, extractive and developmental uses– have caused "harmful impacts on communities' access to forest resources for livelihoods and food security, consequently intensifying livelihood hardship and poverty" within regions of Malaysia. As "pre-existing customary land rights of forest peoples are systematically ignored and overridden," the loss of natural wealth and biodiversity are affecting the Malay people in both material, and non-material ways– livelihoods, cash income, and social-cultural and spiritual needs are arguably the most affected (Adnan & Othman, 2012). For example, value systems associating plants ritual and spiritual purposes (i.e., for ceremony) have been abandoned and ostracized (Adnan & Othman, 2012). An interrogation of customary agroforestry systems can be a viable alternative to current mass extractive uses for sustainable local livelihood. Evidence of sustainable agroforestry practices may be found amongst the Ifugao peoples of the Philippines. (Camacho *et al.*, 2016) explore how the indigenous communities (such as Ifugaos, Isneg, Tingguians and Ikalahans) in the Cordillera region, Philippines have upheld *muyongs* –key indigenous practices in woodlot or watersheds of privately or clan-owned forests – that has promoted sustainable forest management. Following traditional practices, Ifugao do not 'own' land through titles, but rather the rights to land use are community-based. Although *muyongs* are a "major source of fuel wood for the local people," the ways of harvesting fuelwood are guided by customary practices. For example, the conservation of many endemic trees (e.g., *Ficus* spp.) are associated with spirits/*anito*, and are not being harvested for timber and fuel wood. Furthermore, the presence of endemic trees creates agroforestry environments that help maintain sufficient groundwater supply for *muyongs* (woodlots) and *payoh* (rice paddies).

that might otherwise be taken by shopping outlets, etc. Many such examples can be found in western Europe and some parts of North America (Checker, 2011; Kimari & Parish, 2020; Shackleton *et al.*, 2017; Wolch *et al.*, 2014).

4.2.3.3.4 Urbanization

Key Messages:

- Urbanization is a world-wide trend which generally decreases household dependence on wild food sources due to access to the market economy.
- Simultaneously, urbanization in some settings can increase the scale, use and harvest of wild species (to fuel urban markets) *(established but incomplete)* {4.2.3.3.4}.
- Urbanization spatially influences the sustainability of use of wild species; wild species are likely to becoming more depleted in areas closest to cities, whereas in depopulated rural areas, use of wild species is declining *(established but incomplete)*{4.2.3.3.4}.
- Displacement of people due to stressors such as drought, environmental degradation, conflicts and

Box 4 23 **Urbanization and re-wilding in European cities.**

Urbanization and wild species use are a growing issue as in the city of London's Metropolitan Green Belt in the United Kingdom of Great Britain and Northern Ireland and natural areas the Ruhr metropolitan area in Germany. The Ruhr area is the former center of the German coal and steel industry, comprises 20 cities and is one of the most densely populated conurbations in Europe. In both cases government-regulated green spaces were established in the 1920s–1940s to check urban sprawl and to secure recreational areas for the urban populations (Han & Go, 2019; Monclús, 2018; Schepelmann *et al.*, 2016). Subsequent to their establishment the London's Metropolitan Green Belt and the green spaces in the Ruhr area went through very different developments. Due to wide public and political support and firm policy implementation, the London's Metropolitan Green Belt is still largely intact. 24% of the area are designated Areas of Outstanding Beauty and 5% are Sites of Special Scientific Interest. Thirteen percent of London's Metropolitan Green Belt land are priority habitat as identified by England's Biodiversity Action Plan, with 12 out of 20 national priority habitat areas sited in the London's Metropolitan Green Belt (APPG for London's Green Belt, 2019). But the London's Metropolitan Green Belt is increasingly coming under social pressure by calls to allow housing development in the belt area to address shortages in London's housing supply due to its steadily growing population (Elledge, 2017; Papworth, 2016). At the same time there are questions about the ecological quality and biodiversity in the London's Metropolitan Green Belt. In the context of the continuing decrease of biodiversity in the United Kingdom of Great Britain and Northern Ireland, there are calls for the ecological and biodiversity enhancement of the London's Metropolitan Green Belt through a Nature Recovery Network and the upgrading of existing and creation of new wild species habitats (APPG for London's Green Belt, 2019; Lawton *et al.*, 2010; London Assembly, 2020; McNab, 2018). In contrast to the London's Metropolitan Green Belt, the green spaces in the Ruhr area and its main rivers Emscher and Ruhr continued to be heavily polluted and environmentally degraded until the decline of coal mining in the 1960s–1980s. The Emscher served as an open sewerage for industry and households and its hydromorphology and hydrological cycle have been irreversibly impaired through mine subsidence and canalization. For many decades it was the most polluted river in Germany. Growing public dissatisfaction with the severe environmental degradation in the 1960s turned the Ruhr area into one of the cradles of the German environmental movement. In the ensuing decades, industry decline, job losses and shrinking populations were grasped as an opportunity for the social, ecological and environmental 'structural change' of the Ruhr area (Bottmeyer, 2011; Schepelmann *et al.*, 2016; Wuppertal Institute, 2013). The renaturation of the Emscher river and its tributaries through the 'Emscher conversion' and the establishment of a biotope network along the 'New Emscher Valley,' serve both as a beacon for the makeover of the Ruhr area and as literal and metaphorical breeding ground for revitalized nature and biodiversity, social, recreational, cultural and economic change. The species diversity in the Emscher catchment has increased from 170 in 1990 to 450 in 2019. Approximately one fifth of the species now found in the catchment are listed as endangered by state and federal governments. But the ecological rejuvenation of the Emscher catchment is only possible due to a large-scale wastewater management engineering project. New treatment plants and over 400 kilometers of underground wastewater canals have been constructed to ensure that no sewerage will be discharged into the Emscher (GRÜNE LIGA, 2019; Wuppertal Institute, 2013). Biodiversity in the London's Metropolitan Green Belt has largely been preserved since its inception but can also been enhanced to reverse overall trends of declining biodiversity in the United Kingdom of Great Britain and Northern Ireland, help mitigate climate change and provide other ecosystems services. After a severe destruction of biodiversity in the Ruhr area, biodiversity is currently being actively recreated in an interplay of deliberate human actions and nature reclaiming its place. The sustainability of biodiversity in the London's Metropolitan Green Belt in part depends on a willingness of human actors to preserve, increase and enhance habitats and to continue to restrict or limit construction in its area (APPG for London's Green Belt, 2019; CPRE, 2018). The long-term sustainability of resurging nature and biodiversity in the Ruhr region in part seems to depend on technology: "Technical and natural infrastructure in the Emscher region will always be interconnected and technical 'support' for the natural hydrological cycle will be necessary here in the long term because of the subsidence caused by mining" (Wuppertal Institute, 2013).

loss of access to land leads to increased pressure on marginal lands and wild species where migrants, refugees and other displaced peoples now move to *(established but incomplete)* {4.2.3.3.4}.

- Both in-migration and out-migration can destabilize current natural resource use and weaken environmental knowledge systems and existing institutions *(established but incomplete)* {4.2.3.3.4}.

The world is also undergoing substantial urbanization. The number of people living in urban centers increased from 2.3 billion in 1990 to 3.9 billion in 2014 and is 1652 expected to reach 5 billion by 2030 (United Nations, 2014). The total

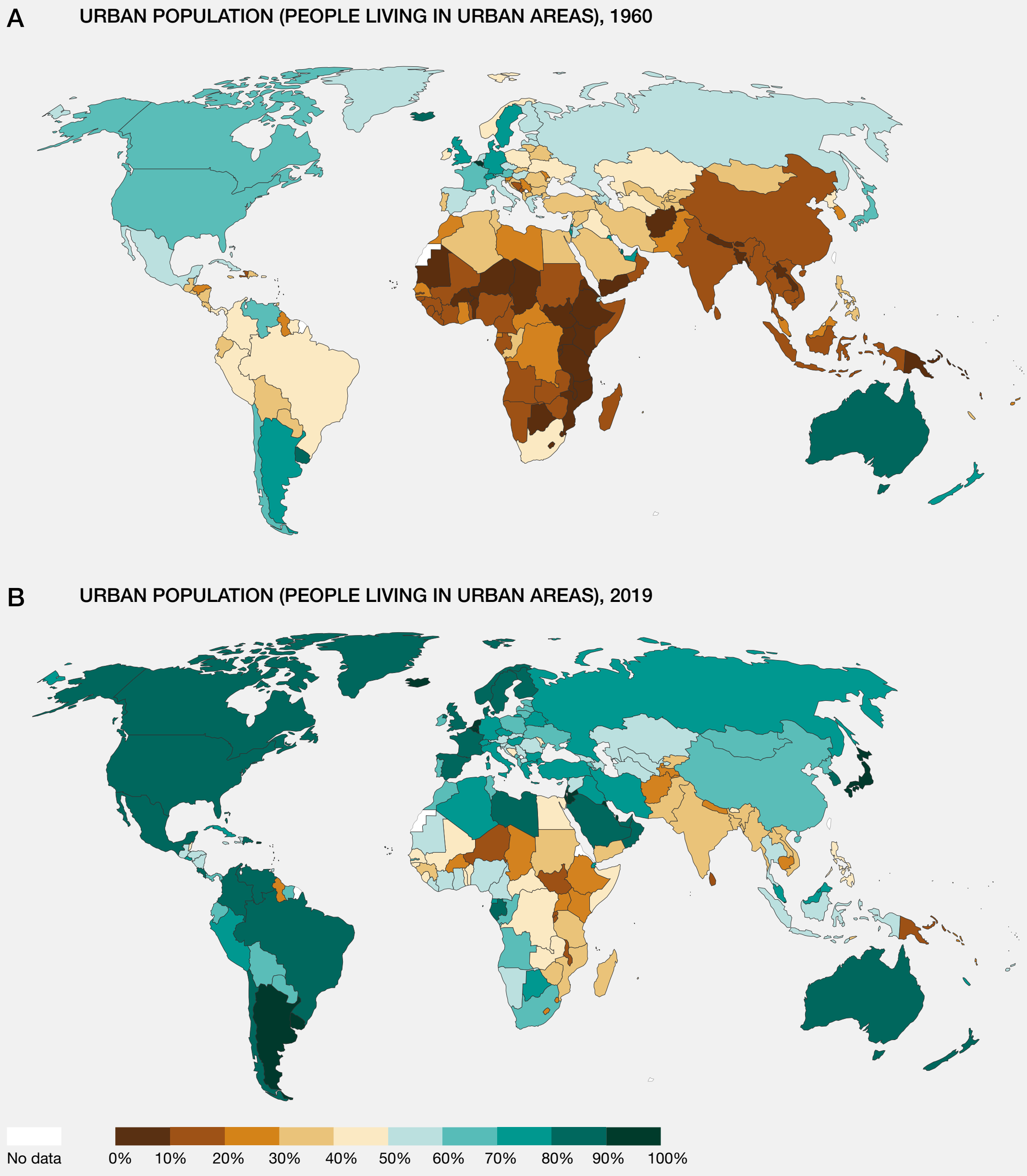


Figure 4 8 **Urban population density.**

This map is directly copied from its original source (United Nations et al., 2019) © 2019 by United Nations and was not modified by the assessment authors. The map is copyrighted under license CC BY 3.0 IGO. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.

area of cities doubled from 1992 to 2015, with impacts to tropical and subtropical savannas and grasslands (IPBES, 2019a). While the number of megacities (populations of more than 10 million people) will continue to rise, the growth of small to medium-sized cities is now a dominant trend, and where most future urban populations will be found (United Nations, 2014). Comparing IPBES regions, Africa, and Asia and the Pacific are urbanizing fastest, with future expansions in Asia and the Pacific expected to occur mainly in China and India (IPBES, 2019a). By 2050, it is likely that as many as 3 billion people will be living in informal areas and slums within cities, mostly in developing countries (Nagendra *et al.*, 2018).

Urbanization is associated with the nutrition transition in which individuals are less dependent on wild food and more dependent on industrialized food production accessed through the market economy (Popkin, 2006; van Vliet, Quiceno, *et al.*, 2015). However, knowledge of the nutrition transition in tropical and low-income countries is more limited (van Vliet and Nasi 2015). The impacts of urbanization on sustainable use are diverse and varied across different contexts and interacts with other factors such as the extent of infrastructure development, other sources of food, and cultural and socio-economic conditions **(Table 4.6)** (Poudyal *et al.*, 2011). For example, urban consumption of bushmeat in the Congo basin is significantly higher in the Congo basin in Africa, than the Amazon basin in South America (Nasi *et al.*, 2011).

The interaction between wealth and urbanization also depends on context, for example in sub-Saharan Africa meat from wild species is consumed by wealthier households in urban areas, but the opposite pattern is observed in lower income rural areas (Brashares *et al.* 2011).

A further issue is the development of the peri-urban regions where densities are urban but economic infrastructure and services are still rural-oriented (Kulabako *et al.*, 2010). These dense peri-urban contexts can lead to overexploitation and unsustainable use in densely populated areas and also to import of wild species from elsewhere (van Velden *et al.*, 2018). Finally, although urbanization can physically separate people from nature, it may also engender awareness of the importance of nature to human well- being. The gentrification of rural areas also has potential to disrupt culturally and economically important plants, algae and fungi collection (Grabbatin *et al.*, 2011).

4.2.3.3.5 Rural communities and development

Key messages:

- Rural peoples play a vital role in sustainable wild species use – indirectly in supporting and sustaining wild species habitats *(established but incomplete)* {4.2.3.3.5}.

- Many rural livelihoods include the harvest of wild species as part of mixed and diversified livelihoods (i.e., that include small scale agriculture, hunting, fishing, etc.); these kinds of livelihoods are on the decline due to the industrialization of agriculture and other large scale development pressures (e.g., clear cutting of forests) *(established but incomplete)* {4.2.3.3.5}.

- Rural regions and livelihoods including the harvest of wild species play a crucial role in supporting the health and well-being of peoples, particularly where other livelihoods fail (e.g., in boom-bust economies) *(established but incomplete)* {4.2.3.3.5}.

Table 4 6 **Examples of practices in urban area.**

Context and Issue	Impact on Sustainable Use	Geographic region and Reference
Recreational Fishing	Recreational fishing is a popular activity in the United States of America. Urbanization measured by the growth in income, employment, structural shifts in demographics, and increases in average commuting time due to sprawling significantly and negatively impact public participation in fishing as measured by fishing license sales determined by regression analysis.	United States of America (Poudyal *et al.*, 2011).
Bushmeat hunting for pigeons	Hunting for pigeons in Samoa is by both rural and lower income individuals as well as wealthier sports hunters from non-rural areas. Wealthier hunters tend to hunt for recreation and personal consumption whereas lower income hunters hunt for sale to restaurants and targeted consumers. Consumers of pigeons tend by the urban wealthy.	Samoa (Stirnemann *et al.*, 2018)
Bushmeat consumption	In the Colombian Amazon rural and urban and residents eat bushmeat, as well as domesticated and industrially processed meat. However, in a rural to peri-urban to urban gradient the frequency of consumption of bushmeat decreases substantially.	Colombia (Van Vliet, Fa, *et al.*, 2015)

Livelihoods – Diversified and Mixed Economies

Many rural livelihoods include the harvest of wild species as part of mixed and diversified livelihoods (i.e., that include small scale agriculture, hunting, fishing, etc.); (Regmi, 2003; Wunder *et al.*, 2014). These kinds of livelihoods are on the decline in many regions due to the industrialization of agriculture and other large scale development pressures (e.g., clear-cutting of forests) (Barrett *et al.*, 2001; Ellis *et al.*, 2004; Fabusoro *et al.*, 2010). Livelihood diversification is particularly important for women (Lakwo, 2007).

The role of wild species within these rural economies can be measured by the proportion of wild meat that contributes to rural diets as in Africa (de Merode *et al.*, 2004; Hasselberg *et al.*, 2020), Asia (Erni, 2015; Pauly, 2018) and in indigenous communities in the Arctic (Kuhnlein *et al.*, 2009) as examples. Changes in the dynamics and opportunities of sustainable rural livelihoods include the impacts of:

- Structural adjustment and economic policies displace small land holders in favour of export cropping and industrialization of resources(Lipton & Ahmed, 1997).
- Mining (Parlee *et al.*, 2018).
- Exclusionary conservation (i.e., protected areas) (Bennett & Dearden, 2014).
- Climate Change (Agrawal & Perrin, 2009; Gentle & Maraseni, 2012; Ziervogel & Calder, 2003).
- Other factors (Devereux, 2001; Shameem *et al.*, 2014).

Rural regions and wild species use – resilience

Rural regions and livelihoods, including the harvest of wild species, play a key role in supporting the health and well-being of peoples, particularly where other livelihoods fail (e.g., in boom-bust economies). Although urban areas are expected to absorb virtually all of the future growth of the world's population (United Nations, 2019), the rural population remains representative (45%). Also, it has major challenges in achieving sustainable development for its dwellers, such as the balance between the environmental, social and economic dimensions. With almost half of the planet's inhabitants still engaged in exploiting natural resources, the conservation of biodiversity cannot be separated from the use of natural resources. This appropriation of natural resources is carried out by a myriad of rural or primary producers through the management of terrestrial, marine and freshwater ecosystems (Toledo, 2001). Many communities living in rural areas around the world depend on the use of wild species for their livelihoods. This is the case of indigenous peoples and local communities, which possess significant knowledge of the wild species surrounding them and often use it for subsistence and other purposes (IPBES, 2019a). The use of wild species can directly or indirectly affect the development level of their regions. Either by common sense or by some areas of knowledge, rural development is usually associated with physical and services improvement in rural area (e.g., roads, infrastructure, access to material assets and immaterial goods-market, credit, internet), but it goes beyond improvements in infrastructure and services.

In the vast majority of times, the improvement of infrastructure in a region aims to increase the exploitation of natural resources in the territory to send the production to different markets (local or for exportation), in some situations, can in fact improve the infrastructure of services and the living conditions of the people who live there. Several cases illustrate the impacts of the transformations in the infrastructure of rural areas in the access and use of natural resources, including those giving origin to emerging diseases by land use changes (Patz *et al.*, 2004), such as logging roads (Wolfe *et al.*, 2000). Thus, it is essential to contemplate the different perspectives related to the concept of rural development and its interaction with the use of wild species, especially considering indigenous peoples and local communities, for whom the Western idea of development is not part of their worldview, causing a permanent tension between the development objectives of nations, founded upon concepts such as progress, and a broader conception which sees humanity as "essentially integrated within its environment and supported by the notion of the good life" (Cuadra, 2015), or the paradigm of *Buen Vivir* (Good Living), which emerged in Bolivia and Ecuador and raises a relationship of society in harmony with nature from a vision of socio-ecological transition (Matiolli & Nozica, 2017).

Although rural development can be associated with aspects of progress and infrastructure improvements in rural areas, with both positive and negative impacts on local biodiversity, it is important to situate the concept more broadly, considering, for instance, to what extent the existence of highways, power transmission lines, access to internet or other services and infrastructure contribute to the development of a region in an effectively sustainable way. For example, on roads near logging areas or close to forest areas, there is an increased risk of fauna loss, such as gorillas and other monkeys in Congo and neighboring countries (Wash *et al.*, 2003). The impacts can also come from agricultural areas, whether recently implemented or not, as in the case of the changes brought about by the Green Revolution, also called conservative modernization specially in Latin America countries (Delgado, 2001), because, despite being associated with the idea of progress, with agricultural production on an industrial scale, and technological packages involving agricultural implements and modified seeds, it maintained the agrarian structure, not promoting improvements in the socioeconomic conditions of the poorest rural populations, and still causing severe environmental impacts.

In the same way that the concept of development, since the 1990s, started to be linked to the adjective “sustainable”, the debate on rural development also started to add the discussion around sustainability and environmental issues, the local and territorial approach, non-agricultural rural activities, rural-urban interrelationships, among others. From that period, the resumption of the debate on rural development takes place mainly around four key elements: the eradication of rural poverty, the question of the role of social actors and their political participation, the idea of territory as a reference unit and the central concern with environmental sustainability (Schneider, 2004).

Rural development can also be understood as a process of social and economic change that occurs in rural areas, where there is a context of expanding interdependence in social and economic relations on an international scale, as one of the effects and conditions of globalization. This process of global transformation, which is increasingly influenced by modern technologies, was most clearly seen in the industrial or secondary production sector. Still, it also had an impact on the forms of productive organization and labor relations in the primary sector, in activities related to agriculture, livestock and fishing, as well as in forestry and plant extraction, for example.

The opening of markets also has caused an intensification of trade and the strengthening of large agri-food chains, changing the configuration of rural areas. In many regions of the world, the rural environment is no longer the specific place for agricultural activities and the varied forms of income complementation allow the income of many families living there to stabilize throughout the year and the children no longer need to leave rural areas to find jobs. In this sense, the notion of pluri-activity (Błąd, 2015) provides a broader meaning than that of diversification of production. Diversification meaning different forms of agricultural production, one oriented at non-food use, with the typical sub-categories of energy crops, fiber crops, herbs for medicinal use, agroforestry (for wood and biomass production), animal breeding, etc. As examples of pluri-activity, there are new on-farm activities, such as farm-based activities (industries, services) not related to food, agricultural production or tourism. Another kind of pluri-activity are new on-farm activities, i.e., farm-based activities (industries, services) that are not related to food, agricultural production or tourism. “Other important forms are sporting activities (not linked to tourism), equestrian activities (e.g., horse breeding), hunting, fishing, bike rental, school farms, offering of workshops/courses, care farms, haulage, etc.” (Błąd, 2015).

An approach to rural development mainly aimed at developing countries focuses on rural household strategies and livelihood diversification (Ellis, 1998), showing that the initiatives and actions that generate significant impacts in improving the living conditions of these populations and that expand their perspectives to guarantee social and economic reproduction are, most of the times, in the very localities and territories where they live, i.e., it is essential to propose economic activities also related to the rural area vocation, not only to reinforce the natural resources but also to valorize socio-cultural aspects, protect immaterial heritage and keep the social reproduction. (Ellis & Biggs, 2001) defines rural development as a set of actions and practices that aim to reduce poverty in rural areas, aiming to stimulate a participation process that empowers rural inhabitants, making them capable of defining and controlling their priorities for change.

In the scientific and policy debates on the future of agriculture and rural development, multifunctional agriculture is another crucial notion. Apart from public goods (landscape, biodiversity, etc.), this includes goods and services produced for non-food markets (energy, care, tourism, etc.) as well as functions provided by agriculture as distinctive product attributes on niche food markets related to food quality, animal welfare, environment friendliness, etc. Functions that cannot be directly associated with goods, services or product attributes but instead represent non-marketable public benefits of agriculture are considered relevant for the analysis of multifunctional agriculture (e.g., quality of life, food security, etc.) (Renting, 2009).

Rural development – wild species

Among the impacts of economic development in a region and the conservation of local biodiversity (Ju *et al.*, 2013), the risks and benefits of changes in land use to human health should also be considered. Land use changes include “deforestation, road construction, agricultural encroachment, dam building, irrigation, coastal zone degradation, wetland modification, mining, the concentration or expansion of urban environments, and other activities” (Patz *et al.*, 2004). They are the primary drivers of a range of infectious disease outbreaks. Logging and road building in Latin America increased the incidence of cutaneous and visceral leishmaniasis (Desjeux, 2001). Road building is also linked to the expansion of wild meat consumption that may have played a vital role in the early emergence of human immunodeficiency virus types 1 and 2 (Wolfe *et al.*, 2000). When cleared for human activities, tropical forests are typically converted into agricultural or grazing lands. This process is usually exacerbated by the construction of roads, causing erosion and allowing previously inaccessible areas to become colonized by people (Patz *et al.*, 2004).

If in some regions the infrastructure in rural areas is expanded, in others, public services to the rural population are increasingly scarce, as the case of running water, electricity or the closure of rural schools and rural regions in several countries that lost their inhabitants due to the exodus in towards urban centers. Despite the demographic reduction, it is important to maintain a minimum of structure in these regions, even to guarantee alternatives to local families and not to exploit nature unsustainably as the only means of subsistence or source of income, also to meet cooking and heating needs when gas or electricity is not available.

The improvement in infrastructure in a rural area mostly benefits the integration of specific supply chains, but impacts considerably the local environment, communities and consequently, biodiversity, especially wild species. Currently, the lack of internet, good roads are an obstacle for rural people to market their products, as is the case of the Payun Matru Cooperativa (Lichtenstein, 2013) that works on guanacos *(Lama guanicoe)* in Mendoza/Argentina. In most cases they have to rely on intermediaries or go to the cities, with a tremendous economic cost. In this sense, access to credit, better roads, electricity and internet supply would enable local people to enter the market in a fairer way.

Current changes related to rural development include the processes of socioeconomic and structural changes in rural spaces, comprising rural and urban approaches, as in peri-urban agriculture and in consortium production models involving wild species and agricultural crops (Jacobi, 2009), as in systems agroforestry (McNeely, 2004) and home gardens (Cruz-Garcia & Struik, 2015; Kujawska, 2018).

In rural regions, agricultural or extractive activities are not exclusively practiced. There are more and more other types of associated activities, such as industrial (agro-industries), tourism and leisure, training, etc. In a more environmental and sustainable rural development perspective, it can also be considered that agroecological conversion initiatives through agroforestry systems can promote not only the recovery of the landscape, but also of biodiversity. In mountainous areas of the Greater Mekong sub-region, government programs, scholars, and private sector interests have promoted cash crop cultivation and harvesting of plants, algae and fungi as strategies for rural economic development (McLellan & Brown, 2017), since they are both important parts of rural livelihood portfolios worldwide. However, little is known about how cash crops and plants, algae and fungi interact in the daily lives and economic decisions of rural people in this region, or how they may differentially encourage forest conservation practices and values.

Improvements in infrastructure, such as rural electrification, also cause changes in the ways of conserving and processing food and medicines, as well as reduction of fuel wood harvest, which is still the dominant source of energy in many rural areas (Giannecchini, 2007). In rural regions where it is possible to use refrigerators to conserve bushmeat or fish, a reduction in collective practices and individualization of marketing processes has been observed. These infrastructure improvements also facilitate the processing of products in rural areas, which generates positive and negative impacts on wild biodiversity. The benefits of rural electrification ripple outward to include increased incomes and economic development, improvements in health and education, protection of water catchment areas and forest environments, and enhancement of gender-balanced development. It also brings the challenge of non-biodegradable wastes. If not properly discarded, broken light bulbs can emit vaporous methylmercury that can easily enter in the bloodstream and also persist in soil and groundwater threatening human population and wild species (Allison, 2008).

Technological innovations can also be focused on processes carried out in rural areas, like in agricultural co-operatives in China since the New Rural Reconstruction movement (Luo *et al.*, 2017). More recently initiatives focused on the

Box 4 24 **Changes in gathering practices in Nepal.**

In Nepal, large-scale gathering of wild species involving tens of thousands of harvesters began after the ban on collection and trade of yarsagumba *(Ophiocordyceps sinensis)* was lifted in 2001 (Shrestha & Bawa, 2013). Yarsagumba, a caterpillar fungus, is used to treat respiratory and heart diseases, and is also known as the Himalayan Viagra. Its harvesting is one of the key income sources for poor mountain communities in Nepal, where the availability of other livelihood opportunities is comparatively low (Shrestha & B3awa, 2014). Regarding the expenditure of income from yarsagumba, the largest proportion of the income was used for savings, followed by food and clothes, and children's education, helping to reduce poverty (Belcher, 2005). The poorer the family, the more dependent on a key species, such as the case of yarsagumba in Nepal. The higher reliance of the poorest households on the income derived from yarsagumba harvesting indicates that the consequences of resource degradation will be severe for households that are already poor. If the market price drops or remains unchanged and the decline in per capita harvest continues, the consequences will be a reduced income for the poorest people, showing the importance to stimulate maintaining a diversity also among the wild species gathered and marketed, but also seeking an alternative solution, like using a natural or compositive substitute. If the resource becomes scarce, communities will lose income. If there is no management work to maintain sustainable harvesting, it will not be possible to guarantee the livelihood opportunities.

Bioeconomy and the development of local or territorial resources have been conducted in different regions (Meis Mason *et al.*, 2012).

There are diverse examples of wild species use and practices that are tied to income generation (Sher *et al.*, 2017). There are cases of communities that depend mainly on a wild species, mainly where agricultural productivity is limited and there are few other livelihoods opportunities. The harvest of fungal species (e.g., for pharmaceutical and other value) in the Himalayas (Nepal) is one example. (Yadav *et al.*, 2019); agricultural activities being limited, the income from yarsagumba accounts for up to 65% of the total household cash income in some communities. Other examples are the cases of small-scale river fisheries in the Democratic Republic of Congo where it contributes up to 98% of the fishers' household income, or yet the case of açaí and other plants, algae and fungi in some regions of the Brazilian Amazon (Brondízio, 2002). Products obtained from forests or other natural environments play a crucial role in sustaining the livelihoods of poor people in developing countries through income generation and the creation of employment opportunities (Shrestha *et al.*, 2019)

Another situation is when the interest of the markets is concentrated in only one species of plants, algae and fungi and the rural dwellers, in order to improve the production, reduce the biodiversity by eliminating other species with minor commercial interest. This is happening in Brazilian Amazon with the acai palm and is known as the phenomenon of "acaization" (Hiraoka, 1994). Local and national policies integrating the sustainable use of wild species and rural development should not focus only on key species, favoring the diversity of species. In the international markets and global chains this condition should also be stimulated. Local people with their multiple worldviews should participate in the definition of conservation strategies as well as local development, including other specific aspects associated with politics, such as corruption and access to technologies and others.

4.2.3.3.6 Social movements

Although there is a considerable deficit of research on the direct impact of social movements on sustainable use and biodiversity conservation, it is possible to establish indirect linkages. One of the most apparent indirect linkages is that occurring though community-based natural resource management and conservation. The international recognition of the benefits of community-based natural resource management to achieve resource and biodiversity conservation (Berkes, 2021; Hulme & Murphree, 2001) has come along with concerns about the vulnerability of local communities to globalization, shortsighted government regulations, marginalization, intensified land competition, and other global political economy threats (Villamayor-Tomás & Lopez, 2021). Increasing attention has been paid to the participation of local communities in social movements against those threats (Goldman, 1998; Peet & Watts, 2004; Scheidel, 2020; Villamayor-Tomas & García-López, 2018). Social movements have been essential promoters of transformative sustainable development agendas internationally, e.g., United Nations's 2030 Agenda (Dressler, 2010; Martinez-Alier *et al.*, 2016); however, they also have strong roots in local environmental conflicts and community-based natural resource management practices. Local environmental conflicts are an endemic phenomenon of societies, with more than 3,000 instances registered (Scheidel, 2020), and potentially thousands more unregistered all over the world. Many of them involve local communities in defense of their livelihoods and encompass therefore both environmental and justice grievances. Communities' capacity to mobilize in defense of their livelihoods and the environment can indeed be considered two sides of the same action phenomenon (Martinez-Alier, 2003). In the end environmental justice movements and their "governance from below" strategies may be indeed the only recognizable challenge to the control of environmental governance by corporate entities and multilateral organizations and their questionable approach to sustainability (Lemos & Agrawal, 2006).

Specifically, social movements can contribute to sustainable use via a number of pathways, including the organization of community-based monitoring, the strengthening of boundaries around community and conservation projects, the generation and promotion of local ecological knowledge, and the forging of "peoples and conservation" alliances internationally (Alessa *et al.*, 2016; Villamayor-Tomas & García-López, 2018; Villamayor-Tomás & Lopez, 2021).

Movements can support local monitoring systems through the involvement of communities in data collection and analysis, the elaboration of environmental impact assessments in collaboration with scientists and researchers, and the organization of patrolling. In Indonesia, the Dayak indigenous movement for forest management rights developed a community-based mapping unit which documents Dayak land-use and traditional ecological information (e.g., flora and fauna, waterbodies, sacred areas, topography) to ensure conservation and prosperity (Alcorn, 2003). In Mexico and Guatemala, the movements for community forestry concessions were followed by the establishment of local governance systems, which included organizing patrols to monitor the forest's uses and physical boundaries at local level (Klooster, 2000; Paudel *et al.*, 2010) and regional level (García-López & Antinori, 2018).

Related to monitoring is the creation and defense of conservation boundaries via exclusive-use zones, such as the "extractive forest reserves" promoted by the rubber tappers movement in the Brazilian Amazon, and local forest communities in Petén, Guatemala (Cronkleton, 2008; Paudel *et al.*, 2010); or the "trawler-free coastal fishing zones" reserved for artisanal fishing communities in Kerala and Goa, India (Kurien, 1991; Sinha, 2012).

Movements can also promote local ecological knowledge. This can occur through different ways, including the actual implementation of said knowledge like in the case of women's Green Belt Movement in Kenya (Turner & Brownhill, 2004); educational and research campaigns, like in the case of the Dayak of Indonesia (Alcorn, 2003); the use of frames or narratives that legitimize said knowledge, like in the case of the Process of Black Communities movement in Colombia (Escobar, 1998); or the elaboration of maps and formal encoding of knowledge (Alcorn, 2003; Roberts, 2016).

The contribution of movements to international "peoples and conservation" alliances has also been well documented. In the forest context, the Mesoamerican Alliance of Peoples and Forests (Dupuits & Ongolo, 2020), the World Rainforest Movement, Friends of the Earth International, and the Global Forest Coalition (Šimunović *et al.*, 2018) frame forest conservation as based on small-scale, autonomous and customary practices, traditional knowledge, and the collective land rights of local indigenous and peasant communities, challenging the dominant market-based discourse linked to Reducing Emissions from Deforestation and Forest Degradation programs. In the fisheries context, prominent examples are the World Forum of Fish Harvesters and Fish Workers and the World Forum of Fisher People (Mills, 2018).

4.2.3.4 Social norms, beliefs and risk perceptions

Social norms are strongly interrelated with spiritual belief systems in some cultures. For example, some resources are attributed as having sacred meaning and value; this belief in the sacred provides the architecture of norms around which sustainable use (conservation) is ensured.

Box 4 25 The fady system in Madagascar.

Sources: Jones *et al.* (2008); Nussbaum & Raxworthy (2000).

Social norms are essential to ensuring sustainable use of resources in Madagascar. A system of norms, known as fady has been developed by indigenous peoples and local communities over many generations. Fady refers to the agreed upon system of behaviors that lead to the prohibition of use of some species or particularly kind of practices to ensure sustainability. It goes beyond "good manners" and is enforced through popular disapproval, and a belief that supernatural retribution will affect the transgressor if the fady is not respected or broken (there are numerous examples of fady leading to the long-term protection of species and habitats in Madagascar, for example, the fady against killing of the radiated tortoise *(Geochelonia radiata)* is highlighted as the primary mechanism that has saved this species from extinction.

Box 4 26 Social risk perception as a driver of species use – what fish should I eat?

Source: Oken *et al.* (2012).

The public receives fish consumption advice from a variety of perspectives, including toxicant, nutritional, ecological, and economic viewpoints. For example, United States of America federal and state agencies that are concerned about exposure to toxicants in fish, such as methyl-mercury and polychlorinated biphenyls, have issued fish consumption advisories recommending that at-risk groups limit consumption of fish (United States Environmental Protection Agency, 2004). However, national organizations of physicians and nutritionists encourage fish consumption for the entire population as a way to increase dietary intake of the n-3 (omega-3) long-chain polyunsaturated fatty acids that may prevent cardio-vascular disease and improve neurological development (Kris-Etherton *et al.*, 2002, 2007). Also, environmental groups have recommended that consumers avoid certain fish on the basis of concerns about species depletion or habitat destruction consequent to farming methods, site of origin, or type of harvesting (Oken *et al.*, 2012). Whether how much, and what kind of fish a person eats are also influenced by economic and market considerations (e.g., cost and availability) as well as by taste, cultural tradition, recreational habits, and access to alternative foods. Thus, the consumer who wants to know "which fish should I eat?" is likely to encounter contradictory advice, especially because much of the available information considers a single perspective, such as maximizing health or minimizing ecological harms. For example, because farm-raised salmon is high in n-3 fatty acids and very low in mercury, it is promoted for its nutritional benefits. However, environmental groups consider it a "fish to avoid" because salmon aquaculture may adversely affect eco-system integrity and wild fish stocks (Oken *et al.*, 2012), and relatively high levels of polychlorinated biphenyls have led to concerns about cancer risk (Hites *et al.*, 2004). Furthermore, it may be difficult for consumers to know whether any given fish is "good" to eat because they often do not have access to the facts, they need to make fully informed choices, such as the size of the fish or how or where it was caught.

Some key examples include the beliefs around the radiated tortoise in Madagascar. (Jones *et al.*, 2008). In other areas, forests or mangroves are considered to have sacred value as in India and parts of west Africa with significant literature point to the value of the social norms and beliefs about their sacredness in ensuring their sustainability (Bhagwat & Rutte, 2006; Lebbie & Freudenberger, 1996; Ntiamoa-Baidu, 2008; Sheridan, 2009). Social norms and beliefs about the sacredness of the whale, the sentience of the arctic ecosystem and norms (developed over generation) of stewardship also underlie sustainable harvesting (i.e., conservation hunting) of whales in Canada and Greenland (Foote & Wenzel, 2008; Freeman, 1999; Freeman *et al.*, 2005).

Social structures also strong affect the way in which individuals, society and institutions perceive risks within their environment including risks related to the use of wild species. There is a large literature on social, cultural and environmental risk perception that details the central role played by formal education, media, science and others. A major issue and insight of much work around wild species and risk perception as well as indigenous knowledge systems is that scientists tend to view risks differently than the public at large differently (Krewski *et al.*, 2008) and as a result, there are often challenges in managing perceived risk and what scientists often define as "real risks". While there are debates as to whether the public misjudges 'real' risk when compared to those in the scientific community, accounting for perceived risk in institutions is as critical in addressing questions of sustainability of wild species.

One aspects of risk perception directly relevant to wild species use related to prion diseases; public information and social media is known to directly impact decisions to hunt in the case of chronic wasting disease. For example, awareness of this disease in Wisconsin, resulted in an 11% decline in license sales (Heberlein & Stedman, 2009). In Alberta, sports hunters were less interested in visiting a site with higher chronic wasting disease prevalence (Zimmer *et al.*, 2011). The e degree of trust of the sources of information is a crucial dimension of this impact: if people trust the agent providing the information, they will trust the information provided to them by these sources; moreover, they are likely to have a lower sense of risk perception as they trust the agents "to take care of any potential problems" (Muringai & Goddard, 2018). The role of indigenous and local knowledge is also directly relevant to understanding how indigenous peoples deal with risk with some exceptions, scientists have historically disregarded indigenous knowledge (Baird *et al.*, 2021; Brook *et al.*, 2009; Kutz & Tomaselli, 2019). At the same time, indigenous peoples themselves have a high level of trust in their own knowledge and capacities to assess wild species health and use this knowledge to make decisions about harvest and consumption of traditional foods as well as in respect of other aspects of conservation (Berkes, 1998; Eichler & Baumeister, 2018; Friendship & Furgal, 2012; Gadgil *et al.*, 1993; Wray & Parlee, 2013). The tendency to trust their own knowledge is rooted in the multi-generational knowledge, practices and beliefs that have been the foundation of successful environmental stewardship for generations (Berkes, 2018).

4.2.3.5 Social inequality and poverty

Key messages:

- Sustainability of wild species use can be understood by many diverse social values (e.g., sustainable use is not only ecological) *(well established)* {4.3.3.5}.
- Poverty and social inequality are drivers of unsustainable use, particularly where there are few livelihood alternatives *(well established)* {4.3.3.5.2).
- The benefits of wild species use are inequitably distributed in many regions. Inequities are evidenced at local, regional and global scales by numerous kinds of indicators (e.g., income, gross domestic product, access to land) *(well established)* {4.3.3.5.2).
- Indigenous peoples are among those who experience a high degree of poverty and social marginalization which greater limited their access to wild species valued for food provisioning and well-being *(well established)* {4.3.3.5.3).

4.2.3.5.1 Overview

Nearly half of the world lives with less than 5.5 United States Dollars a day, and almost half the world's population — 3.4 billion people — still struggles to meet basic needs (World Bank, 2018). Globally, more than 800 million people are still living on less than 1.25 United States Dollars a day; many lack access to adequate food, clean drinking water and sanitation (United Nations Development Program; https://sdgs.un.org). Poor communities, which disproportionately include indigenous peoples, tend to be marginalized from policymaking and government and have little voice in the development of laws that they may be structurally unable to comply with (Wynberg *et al.*, 2015). Although income was historically the primary measure of poverty, even here there has been a shift from absolute poverty (e.g., median income) to relative (e.g., median income relative to the average in a country or region). Income and material wealth indicators continue to be the most common, but well-being, equality, social inclusion, are increasingly recognized as factors contributing to deprivation as an understanding of poverty (United Nations, 2009). A significant challenge arises, however, when attempting to design indicators to be monitored and compared across nations, and even regions within nations; these indicators cannot account for differences in the relative prices of goods, cultural preferences in diets, existing subsidies, social and political marginalization, nutritional requirements depending on types of labor and environments, etc. (United Nations, 2009). Such indicators may thus be helpful in a very limited sense due to their comparability across time but can be poor—and potentially entirely inappropriate—reflections of poverty in given nations (Hagenaars & Vos, 1988; Kapteyn *et al.*, 1988; United Nations, 2009). Indeed, the complexity of poverty as understood by different people and in different contexts should be seen as a main reason to consider the term and design its measurement depending on the specific case (Spicker, 2007).

Poverty has been recognized to be multidimensional in nature, and methods were developed to try to measure poverty through alternative instruments that capture deprivation beyond income and consumption. The creation of effective measures that better reflect poor people's experience enables the design of more effective policies (Alkire *et al.*, 2015). The Multidimensional Poverty Index—shown in the world map **(Figure 4.9)** is the most common international instrument used in this context. Progress to diminish poverty is uneven across the different regions (see supplementary material – Appendix I).

4.2.3.5.2 Poverty and use of wild species

Poverty and environment are closely interrelated. Extreme poverty and biodiversity hotspots can be geographically coincident (Barrett *et al.*, 2011), but the majority of the rural poor in the developing world live in fragile and marginal lands (Barbier, 2010). Poverty is indeed prevalent in rural areas where livelihoods depend disproportionately on natural capital embodied in forests, rangelands, soils, water, and wild species (Barbier, 2010; Barrett *et al.*, 2011). Plants, algae and fungi, fish and shellfish and wild meat have a well-established role in sustaining and protecting the existing living standards of the poor and ensuring that they do not fall into chronic poverty (Brown, 2003). A great diversity of wild species is harvested within subsistence (non-commercial) economies in the Americas, Asia and Africa as a cheap and easily accessible resource (IPBES, 2018a, 2018c). Wood-based fuels are a vital energy source for the majority of the African population contributing at least 70% of total energy consumption in sub-Saharan Africa (IPBES, 2018c). These examples show that most poor people throughout the world rely on the use of wild species for their living. Environmental degradation and resource depletion threaten their livelihoods.

A great bulk of the world's poorest and most vulnerable citizens live in disaster-prone regions and their number

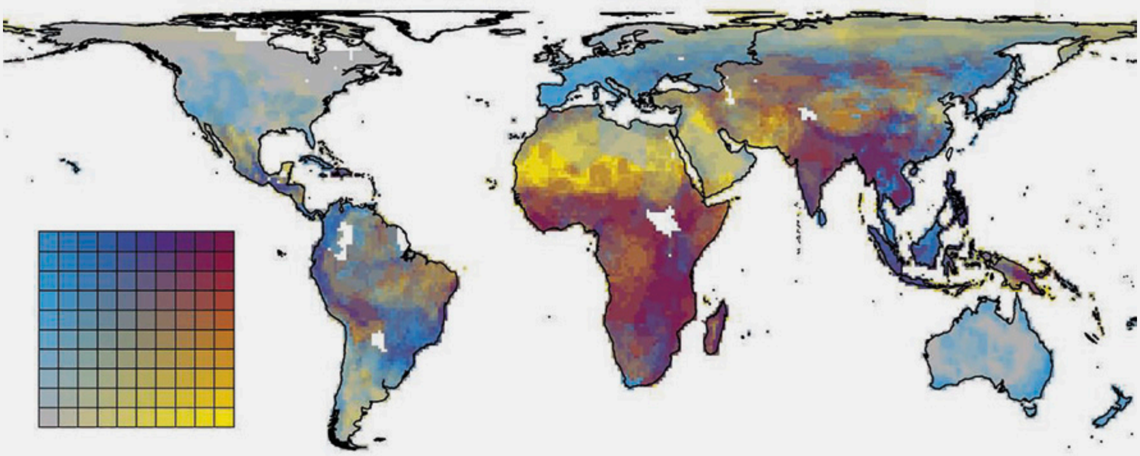


Figure 4 9 **Map of poverty and potential biodiversity loss, showing the level of poverty (proxied by the log rate of human infant mortality) combined with the log number of threatened species of mammals, birds, and amphibians per one-degree grid square (Behrmann equal-area projection).**

White areas represent missing data. *This map is directly copied from its original source Sachs et al. (2009) and was not modified by the assessment authors. The map is copyrighted under license © 2009, The American Association for the Advancement of Science under license 5154810771990. The designations employed and the presentation of material on the maps used in the assessment do not imply the expression of any opinion whatsoever on the part of IPBES concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. These maps have been prepared or used for the sole purpose of facilitating the assessment of the broad biogeographical areas represented therein and for purposes of representing scientific data spatially.*

keeps increasing. Those groups are disproportionally affected by shocks and stresses. According to dominant narratives, people living in poverty are the principal creators of environmental damage, whilst they often bear the cost of environmental damage. This has been proposed as representing a downward spiral, whereby the poor are forced to deplete resources to survive, and this degradation of the environment further impoverishes people. That neoliberalist and neocapitalism narratives often lead, on the one hand, to coercive environmental policies (Blaikie & Brookfield, 1986; Peluso, 1993), and on the other hand, to the privatization of common pool resources and land grabbing (Fairhead *et al.*, 2012; Leach, 2015), that lead to the marginalization of the local people (Benjaminsen, 2015; Braun & Gatzweiler, 2014). When this self-reinforcing downward spiral becomes extreme, people are forced to move in increasing numbers to marginal and ecologically fragile lands or to cities (e.g., Nayak & Berkes, 2010). Other research, however, argues that this approach overly simplifies the poverty-environment relationship, ignores significant impacts from non-poor and industrial activity (Peluso, 1992), and undervalues the capacity of local communities in both perceiving and mitigating degradation when their management systems are in place and recognized (Angelsen, 1997; Scherr, 2000; Swinton *et al.*, 2003; Tiffen *et al.*, 1994). For example, poverty can be ultimately driven not by the state of surrounding resources, but by a lack of assets and access to other forms of labor, markets, and livelihoods, which subsequently limit peoples' options to the use of common resources that may have already been substantially depleted by historical industrial processes (Barbier, 2010; Dasgupta *et al.*, 2005). Other determinants that contribute to poverty include the location of schools and health centers, access to infrastructure, natural resources endowment, access to input and, output markets, and access to jobs.

The current general relationship between poverty and environmental degradation and biodiversity loss may still be represented by a downward spiral, yet the historical large-scale degradation of the environment may likely not have occurred because of poverty, and the ultimate historical drivers of poverty and marginalization are many-fold and not explicitly related to environmental state. There are clear links between poverty/ and unsustainable use of wild species, though, as mentioned above, the initial direction of causality is unclear and very likely context dependent. In short, the question of whether resource users are "poor" because of unsustainable use, or if unsustainable use happens because users are "poor" is much less certain than what was historically assumed (Béné, 2003). In the case of some primary sectors, such as fisheries, the characterization of poverty and agency of users themselves is increasingly being reassessed as better economic data becomes available (Giron-Nava *et al.*, 2018), informal markets and incomes are more recognized (Klein, 1999; Schuhbauer *et al.*, 2019), and more focus is placed on first-hand perspectives (Macfadyen & Corcoran, 2002; Narayan *et al.*, 2001). Another example is that of indigenous communities, including some of the most historically and currently marginalized peoples in the world. Despite high levels of poverty, dispossession, and multiple social stressors (Cunneen, 2005; United Nations, 2009), many such communities have rich and continuing histories of sustainable resource use (Cisneros-Montemayor *et al.*, 2016; M.-C. Cormier-Salem, 2017b; Larrère & La Soudière, 1987; Tsing, 2015). In many cases, strategies for sustainability are intricately woven into culture itself, aside from resource use in and of itself, and yet can work in complement with (or sometimes outperform) "western" models of resource management (Bennett, 2018; Bess, 2001; Capistrano & Charles, 2012; Porten *et al.*, 2016).

Under what conditions and to what extent are "people living in a marginal situation able (or not) to sustainably manage socio-ecological systems and/or to sustainably use wild species? As discussed in the Political Drivers section, it is increasingly recognized that local access rights can allow communities to sustainably use common resources (Ostrom, 2009). This does not necessarily require privatization in a market sense; for example, in marine systems, the recognition and support of local and indigenous traditional and customary management strategies and self-identified objectives can allow for sustainable use of biodiversity, both commercially and for subsistence (Berkes *et al.*, 2000, 2003; Jentoft & Chuenpagdee, 2015). Contrary to the dominant discourses that make shellfish harvesters poor, with divorced, landless marginal women having access only to wastelands, and considering themselves marginal and unworthy, more and more scholars show that shellfish harvesting is a vital activity. It provides a source of nutrition and a very important source of income for women of all ages, who are gaining economic as well as political power through their activities (Burgos & Dillais, 2012; Lau & Scales, 2016).

ARCTIC

Local communities across the Arctic face exceptional challenges stemming from historical and ongoing social, political, and now environmental change. In the Canadian Arctic, these communities are almost entirely indigenous (Inuit) and have been historically dispossessed of lands, resources, language, and culture. Nevertheless, the Inuit remain rooted mainly in traditional territories and rely on traditional diets for both subsistence and cultural identity (Kenny *et al.*, 2018). With significant local declines in caribou (*Rangifer tarandus*, various subspecies), marine resources including fish and marine mammals are particularly important and the traditional ecological knowledge held by these Peoples increasingly recognized. However, movement across traditional fishing and hunting grounds is now restricted due to melting sea ice as a result of global warming. Additionally, methylmercury concentrations in seafood (particularly marine mammals and fatty fishes) pose threats to public health, particularly fetal and cognitive development (Chan & Receveur, 2000). Even as traditional Inuit ways of life are more respected, much more robust and cross-scale policies will be required to support their continued use of resources.

LATIN AMERICA: THE VICUÑA.

Vicugna vicugna has one of the most valuable and highly priced animal fibers on the international market (Kasterine & Lichtenstein, 2018). The luxury garments made from vicuña are sold in the most exclusive fashion houses around the world. Whereas vicuña products are available only to very affluent consumers, the fiber is produced mainly by extremely low-income communities from the Andes that face high levels of persistent poverty and inequality. Despite the high market value of vicuña products, the generation and distribution of benefits to local people has been limited thus far (Lichtenstein, 2010).

Local communities "pay the cost" of vicuña conservation by allowing vicuñas to graze on communal or private land. The production of fiber also relies on a substantial investment that is borne mainly by Governments and local communities. However, most of the benefits are captured by traders and international textile companies. Vicuña fiber prices have historically been related to factors such as: market demand; the bargaining power of the actors involved; actors' cash flow issues; volume of fiber stocked; and number of channels for commercialization (Brewin, 2007; Lichtenstein *et al.*, 2002; Lichtenstein & Vila, 2003; Sahley *et al.*, 2004). It is almost impossible for a remote Andean community (or producer) to negotiate with a European textile company or large trading company on equal terms. Efforts to increase the benefits accrued to the rural poor should explicitly redress access asymmetries and strengthen producer associations.

AFRICA

In Africa, processes of marginalization and mangrove grabbing are largely mainly due to mangrove reforestation campaigns, or carbon policies under the frame of Reducing Emissions from Deforestation and Forest Degradation (Beymer-Farris & Bassett, 2012; M.-C. Cormier-Salem, 2017a). The women, who are making their household's livelihood from gathering oysters and cockles, are the most directly concerned with the preservation of the mangrove. For a long time, they conserved certain sites and developed customary rules that have maintained sustainable use of mangroves such as: defining harvesting season, designating zones shared between lineages and neighborhoods, and sacred places that are prohibited for use. In addition, they have reforested certain habitats with *Rhizophora* plants, and attempted to make better use of their products using appropriate schemes of labelling.

However, women are rarely recognized as part-stakeholder of the environmental policies defined internationally and implemented at national and local scales. They are not informed (or deliberately kept ignorant) of new devices such as Reducing Emissions from Deforestation and Forest Degradation. This has led in some cases to the loss of their access rights to the reforested mangrove areas.

OCEANIA

As expected from ecological theory and models, as oceans warm due to climate change marine species are shifting to cooler areas towards temperate areas or deeper water, with a net loss of marine biodiversity and abundance in tropical regions. This poses many issues for Small Island Developing States that rely on marine ecosystem services. One example is Palau in the South Pacific, which for some time has transitioned into a tourism-based economy focused on coral reef biodiversity. The consumption of reef fishes is still vital in Palauan culture, as is the practice of fishing itself along the island nation; industrial fishing is less developed, but monetary benefits from fishing access agreements for foreign tuna fisheries (that export most catch) do contribute to the national economy. As a response to anticipated effects of climate change, and the growing pressure on local reef fishes from seafood demand by tourists, Palau has initiated a national strategy based on boosting consumption of sustainably caught tuna for the tourist market, thus allowing for the sustainability of local reefs and traditional Palauan subsistence fisheries (Wabnitz *et al.*, 2017). The outcomes remain to be seen, but this is a good example of science-based policies that integrate local goals and that could be further supported through international initiatives.

ASIA

In the Sundarbans, the women, who collect prawn seed along the rivers, are the poorest, and belong to the lowest caste of the society (Jalais, 2010; Lahiri-Dutt & Samanta, 2013). They do not have access to land or the forest. They use a very simple and cheap technique, a mosquito net fixed on pole, for gathering the prawn seed. Thanks to the development of intensive shrimp farms in the North of the Delta, and the huge demand of prawn seed, they are becoming very rich and powerful. They have got a strong identity, not only as "working" women but as "earning" women, daring to reverse the hierarchical order of the village, refusing both tradition and the urban ideals of femininity.

4.2.3.5.3 Poverty and indigenous people

There are about 476,6 million indigenous people in the world today present in over 90 countries. Indigenous communities represent about 6,2% of the world's population but make up 15% of the world's extreme poor, and 1/3 of the rural poor (ILO *et al.*, 2020). According to this recent report, over 73.4% of the global indigenous population live in rural areas, but there are substantial regional variations. The highest proportion of indigenous peoples residing in rural areas is found in Africa (82.1%), followed by Asia and the Pacific (72.8%) and Europe and Central Asia (66.4%). In Latin America and the Caribbean and in Northern America, a majority of indigenous peoples are urban dwellers (52.2% and 69.0% respectively). They live, own and occupy approximately one quarter of the world's lands and waters which represents 80% of the world's biodiversity. Indigenous peoples are nearly three times as likely to be living in extreme poverty as their non-indigenous counterparts represent a sizable share of the global poor (ILO *et al.*, 2020). Indigenous peoples' life expectancy is up to 20 years lower than the life expectancy of non-indigenous people worldwide.

Research conducted by Hall *et al.* (2014) for the World Bank found that poverty among indigenous people manifested in various ways including insecure land and property rights, discrimination, heightened vulnerability to risk and climate change, and a wide range of health, education and other related socio-economic disparities (Hall *et al.*, 2014). Indigenous peoples experience a high degree of socio-economic marginalization and are at disproportionate risk in public health emergencies. They often face impediments to their access to natural resources, essential services, the formal economy, and justice, as well as their participation in decision making. Factors such as lack of access to effective monitoring and early-warning systems, and adequate health and social services resulted in indigenous people becoming more vulnerable to the present COVID-19 pandemic (ECLAC., 2021). Poverty in indigenous groups is probably related to the historical-political conditions that untied indigenous peoples from the control of their territories relegated them to the margins of society or directly excluded them.

4.2.3.6 Gender equity

Key messages:

- The benefits and costs of wild species use are inequitably distributed across genders with women and those of diverse gender identities experiencing the greatest inequity *(established but incomplete)*{4.2.3.6.2}.

- Access to wild species and uses tend to be gendered. This is evident in many indigenous societies. There are various kinds of roles and responsibilities as well as rules of use that apply to women *(established but incomplete)* {4.2.3.6.2}.

- Women have particularly crucial roles in foster sustainable use in many cultures; as they play a primary role in food production and education *(established but incomplete)* {4.2.3.6.2}.

- Many kinds of resource management institutions are gender blind and do not take into consideration the diversity of roles and responsibilities nor the inequities experience by women and gender diverse peoples *(established but incomplete)* {4.2.3.6.3}.

4.2.3.6.1 Overview

Gender shapes the social roles that men and women play and the power relations between them, which can have a profound effect on the use and management of natural resources. Gender is not based on sex or the biological differences between women and men; rather, gender is shaped by culture and social norms. Thus, depending on values, norms, customs and laws, women and men in different parts of the world have adopted different gender roles and relations. Within the same society, gender roles also differ by race/ethnicity, class/caste, religion, ethnicity, age and economic circumstances. Gender and gender roles then affect the economic, political, social, and ecological opportunities and constraints faced by both women and men.

The case for seeing women as having a special relationship to Nature has been made by ecofeminists for more than three decades. The term "ecofeminism" was coined in the 1970s to raise awareness about interconnections between women's oppression and nature's domination in an attempt to liberate women and nature from subordination (d'Eaubonne, 1978). Since then, ecofeminism has attracted scholars and activists from various disciplines, drawing on Marxist critic, animal studies, postcolonialism, and political ecology (Vakoch & Mickey, 2018). The Green Belt Movement in Kenya and the Chipko Movement in India are said to epitomize the essence of ecofeminism.

Conceptualizations of the nature of the link between women and nature vary from asserting a physiological connection (women as birth givers, etc.), to a more socially based view linked to women´s social role (as mothers, farmers, water carriers) (e.g., Shiva, 1998). Other authors consider that reducing women´s decisions to a set of biologically determined characteristics devalues their agency, fails to recognize that they may also align with other identities (e.g., caste, class) and undermines the fact that they are situated in certain localities which impose and offer a specific set of constraints (Mawdsley, 2004). A common ground between these perspectives is that the roles and responsibilities of men and women in the management of biodiversity, and the ability to participate in decision-making, vary between and within countries and cultures.

4.2.3.6.2 Gender-specific roles, needs, dynamics and the sustainable use of wild species

The impact of women´s participation and empowerment on sustainable use outcomes will be stressed through a few examples, illustrating what makes some gender-based practices sustainable. For instance, across Africa, household chores are often divided according to gender; this in turn shapes the different ways in which women and men relate to trees. For example, in the case of the shea tree, women are the custodians of knowledge concerning the gathering and processing of shea products (Elias, 2016). The women have ingenious use of the shea nut, bark, roots and leaves: to increase milk production in lactating mothers, to relieve those suffering from malaria and to make the traditional 'benga' dish. Since they are not the ones to process shea nuts into butter, men are less concerned about the traits of shea nuts that yield quality butter but "male farmers prize the tree (…) for its shade and its role in improving the fertility of the soil in their fields" (Elias, 2016). Women are not the owner of the trees, but they have access thanks to the contributions perceived by men. Nevertheless, with 'globalization' that means trade of forest-based local

Box 4 27 **Women and sustainable use of wild species.**

Women play a central role in the conservation and sustainable use of wild species. This can be highlighted in three main aspects: *First*, they are the most numerous in this activity area, present at all stages of the value chain (extraction, processing, distribution, consumption). *Second*, they depend closely on these species and uses for their livelihood and the well-being of their family. These activities occupy a major place in their calendar; they spend a lot of time for collecting three basic needs: food, water and fuelwood (e.g., fuelwood; Agarwal, 1986). Wild species are a source of essential income for themselves and their families. It is also a means of economic empowerment, social recognition, and status acquisition within the community. Besides, most of the women who use wild species are elderly, widowed or divorced, and have no land tenure rights (see section on poverty and marginalization). *Third*, closely dependent on these resources, they are most concerned with their conservation and sustainable use; they have intimate links with these species. Also, they have knowledge, practices, rules of use and access that preserve and value these species.

Box 4 28 **Women's vital role in social movements to conserve biodiversity in the Brazilian Amazon.**

Deforestation in the Brazilian Amazon has accelerated significantly during the past few years, threatening livelihoods, and becoming a source of carbon emissions rather than a global carbon sink. However, during the period between 2004 and 2012, Brazil decreased deforestation by over 80%. Brazil's Federal government created 89 extractive and sustainable development reserves in Amazonia, between 1990 and 2009, encompassing 24 million hectares. During a 35-year period in Brazil, nearly half of the Amazon rain forest became protected through a system of extractive and sustainable development reserves. This remarkable accomplishment was the result of rigorous research, advocacy leading to policy change and the collective struggle of a robust social movement.

As deforestation accelerates in Brazil today, it is critical to remember the social processes and policies which led to an earlier, highly significant, national, and global conservation gain. As part of this process, women played a pivotal role. Thirty-five years ago, women were not permitted to be members of one of the most prominent organizations of the Amazonian social movement, the National Council of Rubber Tappers. However, the creation of a Secretariat of Women Extractivists within National Rubber Tappers Council was influential in transforming women's roles within the hierarchy of extractive reserves from invisible to one of consequence (Shanley *et al.*, 2011). Over the ensuing years, to be more inclusive, the name of National Rubber Tappers Council was changed to the National Council of Extractivist Populations. The work of women in building capacity, cultivating ties with key governmental agencies and recognizing cultural connections to forests, provided a strong foundation for an increasing role of Amazonian women to promote sustainable management and conservation. The conceptual foundation of extractive reserves – multiple-use and sustainable forest management – are practiced by thousands of rural Amazonian women. Women have played a vital role in understanding the direct value of forests to food security and the health and welfare of families. Traditional knowledge of forest resources was central to determine the categories of extractive reserves, and what type of use and management would be permitted including hunting, fishing, logging, gathering, etc. Local input from rubber tappers and forest-reliant communities contributed to the policies designating various categories of sustainable use. From not being allowed to be part of Brazil's largest Amazonian social movement, women now compose 40% of the of the membership of the National Council of Extractivist Populations and are leaders of 25% of conservation units (Shanley *et al.*, 2018). Brazilian women currently occupy critical positions from leading grass roots organizations to high level positions in government agencies and worker's unions. While rubber tapper and conservationist Chico Mendes succeeded in launching a national campaign to create extractive reserves, women played a crucial role in expanding and making tangible a globally significant conservation movement.

products on international markets and the increasing demand for quality fair trade products, the women often lost the control of the commercial network, and therefore are "marginalized" by men. From a case-study of fairtrade shea butter produced by women in Burkina Faso and consumed by European and North American women, (Elias & Saussey, 2013) showed the low returns for butter producers and doubt the 'fairness' and solidarity aspects of the movement.

In many parts of the world, women often bear the primary responsibility for feeding their families, collecting, processing, cooking, rationing and storing food, nurturing. In many developing countries, women collect and prepare highly nutritious foods from wild species to complement and add flavor to the staples of family meals. In addition, income generated by women from the harvesting of wild species adds to the purchasing power of households and therefore their food security. Men, on the other hand, are more likely than women to be responsible for gathering wild honey, birds' eggs and insects, for hunting and fishing, and in many countries, for the commercial exploitation of a forest's wood resources.

In a review conducted by Meinzen-Dick (2014) suggested that neither men nor women are inherently more resource-conserving; instead, their motives – issues related to closeness to nature, interests and needs for those species- and their material conditions and means – access and use rights to wild species, influences their sustainable practices. Property rights and security of tenure influence the motives and means that men and women have to exploit or conserve natural resources (Meinzen-Dick, 2014). Thus, adoption of sustainable practices requires attention to control rights. In most circumstances there are gender-based differences and inequalities, which tend to favor males. Gender differences are evident in economic opportunities and access to and control over land, biodiversity resources and other productive assets, in decision-making power, as well as in vulnerability to biodiversity loss, climate change and natural disasters.

4.2.3.6.3 Gender and public policies

Most programs to promote sustainability have been gender blind and thus ended up working primarily with men, who are more likely to occupy public spaces (including community organizations and government or external programs) and are often more readily recognized by outsiders as the foresters, irrigators, fishers, and even farmers. Justice and equity concerns are now prominent in national and international policies. For instance, Aichi Target 11 calls for protected areas to be equitably managed by 2020, and Gender equality is called for in Sustainable Development Goals 5. However, understanding of how to consider and incorporate equity and the broader concept of justice into conservation and sustainable use of wild species remains nascent.

4.2.3.7 Indigenous peoples and food systems- impacts of pollution

Indigenous peoples and local communities experience large burdens of environmental pollution linked to the expansion of commodity frontiers and industrial development (Basu *et al.*, 2018; Fernández-Llamazares *et al.*, 2020; Landrigan *et al.*, 2018). Increasing demands on indigenous peoples and local communities' territories from the expansion of industrial resource development and extraction, often result in pollution risks, which endanger the collective continuance of indigenous peoples and local communities, and the foundations of their cultures, subsistence-based livelihoods and ways of life (Armstrong & Brown, 2019; Parlee *et al.*, 2018; Scheidel, 2020; Spice, 2018). Environmental pollution has been recorded in numerous indigenous peoples and local communities' lands worldwide, increasing risks and burdens of disease (e.g., Lewis *et al.*, 2017), and forcing many communities to shift away from traditional lifestyles (e.g., Hoover, 2017). Many health impacts documented among indigenous peoples and local communities are mediated through the consumption of wild foods (Bordeleau *et al.*, 2016; Ostertag *et al.*, 2009), obtained through hunting (Cartró-Sabaté *et al.*, 2019), fishing (Binnington *et al.*, 2016), and gathering (Strand *et al.*, 2002). As a case in point, freshwater crabs and turtles of several rivers in the Amazon Basin, which are both culturally and nutritionally important for indigenous communities, have been impacted by widespread high levels of Hg and Pb pollution (Schneider *et al.*, 2010).

These pressures can generate legacies of intergenerational trauma and reduced cultural engagement, leading to declines in indigenous peoples and local communities physical and mental well-being, ultimately limiting their ability to engage in the many mutually reinforcing aspects of knowing and being (Fernández-Llamazares *et al.*, 2020). For example, numerous studies reports impacts of pollution on indigenous peoples and local communities' mental health, including psychological disorders associated with pollution events (Nriagu *et al.*, 2016). Pollution can also result in fear of consuming traditional wild foods (Turner & Turner, 2008), and the decline in wild species availability due to pollution can foster increased reliance on nutrient-poor and expensive market foods, often increasing the risk of malnutrition and chronic diseases (Fernández-Llamazares *et al.*, 2020). For example, some indigenous communities in British Columbia (Canada) have stopped gathering seaweeds in large amounts due to fears about marine pollution (Turner & Clifton, 2009; Turner & Turner, 2008). Loss of hunting or fishing activities can also result in reductions in physical activity, with significant health implications (Hoover, 2017). Fears over pollution can also lead to declines in the use of traditional plant-based medicines, as documented among Native American communities (Arquette *et al.*, 2002).

Environmental pollution impacts both material and non material cultural dimensions of indigenous peoples and local communities' ways of life, including their knowledge systems (Pufall *et al.*, 2011; Yakovleva, 2011). For example, herbicide treatments have contaminated plants used by California Native American communities for different cultural uses, such as traditional basket weaving (O'Neill, 2003). Other traditional practices, such as harvesting local plants for sustenance, ceremonial, or medicinal purposes, can also increase exposure to pollutants (Arquette *et al.*, 2002). Thus, recommendations to refrain from fishing or gathering plants can affect indigenous peoples and local communities' cultural traditions based on these activities. And undermine the knowledge systems that underpin such practices (Fernández-Llamazares *et al.*, 2020; Kuhnlein & Chan, 2000). Similarly, some studies have documented how pollution risks can affect the spiritual wellbeing of indigenous peoples and local communities (LaDuke, 1999; McCreary & Milligan, 2014; Temper & Martinez-Alier, 2013).

Environmental pollution jeopardizes the complex and intimate relations that many indigenous peoples and local communities establish with their lands and waters (Fernández-Llamazares *et al.*, 2020; Hoogeveen, 2016), thereby affecting prospects for the continuance of indigenous peoples and local communities' practices of sustainable resource use. Because activities associated with gathering wild foods generally serve important community roles (e.g., intergenerational exchange, maintenance of language), concerns related to pollution regarding the sustainable use of biodiversity can also impact the continuance of these subsistence-based practices (Berkes & Farkas, 1978; Hoover, 2017). In response to this, indigenous peoples and local communities are actively contributing to develop innovative strategies to limit the spread of pollution and prevent it from the outset (see Fernández-Llamazares *et al.* 2020 for a review). For example, indigenous peoples and local communities are increasingly leading community-based pollution monitoring programs (Herrmann *et al.*, 2014), engaging in international policy development to reduce pollution burdens (Basu *et al.*, 2018; Selin & Selin, 2008) and articulating different forms of grassroots resistance to polluting activities on indigenous peoples and local communities' lands (Armstrong & Brown, 2019; Scheidel, 2020; Spice, 2018).

4.2.4 Economic drivers

4.2.4.1 Overview

Economic forces are considered among the most critical in addressing rapid declines in biodiversity including the use of wild species; economic systems directly impact species but also shape perceptions and norms about the importance of particular species and their value within society (Diaz *et al.*, 2015). Direct drivers (e.g., a rise in export prices) are of major importance, however, indirect drivers and mediating factors (e.g., access to markets) can also have a significant impact on long term sustainability. Typically, economic drivers and mediating factors jointly determine sustainability outcomes (Mirza *et al.*, 2020). Key element of economic analysis are factors affecting the supply of commodities related to wild species (e.g., lack of alternative employment opportunities) as well as demand (e.g., urbanization). Together, this facilitates trade, i.e., an exchange between buyers and sellers. The interactions between economic incentives, institutions and governance structures, in relation to wider ecological, cultural and social drivers and mediating factors are critical to understand sustainable use of wild species.

4.2.4.2 Methods, limitations, and gaps in knowledge

The content of this section is based on evidence from research in numerous disciplines including, resource economics, agricultural economics, geography, sociology, ecology and conservation biology. The subsections were developed with a systematic literature review, complemented by grey and peer-reviewed literature based on input of the experts. There are some notable challenges in the availability of data. There is growing availability of economic data on the performance of industries relying on wild species in some areas of the world (e.g., reports by the 'Scientific, Technical and Economic Committee for Fisheries' in the European Union), though many regions of the world lack even basic statistics on the economic situation of harvesters. In such case, official trade statistics may offer insights on scale of exploitation, though trade data insufficiently tracks the status of threatened species (Phelps *et al.*, 2016; Phelps & Webb, 2015), and there are considerable discrepancies in official statistics and trade surveys for other species (e.g., ornamental plants in South East Asia). Also, sustainability outcomes cannot be assessed from static data, but require repeated observations, which are rarely available (Allebone-Webb *et al.*, 2011; Coad *et al.*, 2013; Taylor *et al.*, 2015). This limits the quality and quantity of evidence regarding sustainability outcomes.

Key limitations in the literature are incoherent definitions of what sustainable use entails and also lack of objective measurements against some form of baseline. For example, a literature review on the trade in medicinal plants in Central Himalayan reveals that though there is often a degraded resource base, the empirical basis for inferring sustainability outcomes is relatively weak (Larsen & Olsen, 2007). The same is true for economic sustainability. Often, the role of middlemen is perceived to be important, but there is little quantitative evidence on which economic outcomes would be deemed fair or sustainable (Larsen & Olsen, 2007).

Formulating guidelines for assessing sustainability would be an important step to make cases comparable (Cuesta & Becerra, 2013).

Another limitation is a 'survivorship bias' meaning that field studies tend to study what is there (and not what is lost and forgotten). Analysis from a bushmeat market in West Africa (Takoradi, Ghana) finds little evidence for overharvesting and unsustainable uses, potentially because the most vulnerable species have already disappeared in the past due to prolonged hunting (Cowlishaw *et al.*, 2005). Quantitative data that is comparable across countries is often unavailable for subsistence and indigenous economies, particularly in relation to economic impacts and drivers of cultural, spiritual and social uses of wild species. There are also significant gaps in the availability of documented indigenous and local knowledge related to economic drivers at all scales and in relation to all species. This is partially due to remote government officials being mistrusted by indigenous communities, and also due to asymmetric power, different worldview and lack of investment on part of the scientists to have a meaningful collaboration and use of indigenous local ecological knowledge (Brondízio *et al.*, 2021). Despite this gap, indigenous and local knowledge perspectives should be considered critical to our understanding of sustainable use of wild species, particularly as it relates to their social, cultural and spiritual importance to indigenous peoples. Some issues of sustainable use for some countries are also more studied than others. For example, species considered under CITES, particularly related to vertebrates have been a greater focus than other species including plants and invertebrates. There are also gaps in our understanding of the economic drivers of sustainable use issues in some regions. As a result, the data available is uneven and recognition should be given to gaps that require further study and assessment. For example, Taylor *et al.* (2015) document quantity of evidence on the impacts of wild species hunting with data on 177 species from 275 sites across 11 African countries collected over 30 years. They find that research efforts and available information are not evenly distributed. There is less evidence from West Africa compared to Central Africa, and also less information about impacts on birds (Taylor *et al.*, 2015).

4.2.4.3 Structure and composition of economies

4.2.4.3.1 Subsistence economic activity and the use of wild species

Subsistence economies are defined as those that are small in scale and in which the use of resources (including wild species) is limited and exclusively used to meet local needs rather than accumulated or sold for profit (Emery & Pierce, 2005; Natcher, 2009; Schumann & Macinko, 2007). Small scale and decentralized economies are generally characterized by short supply and important focal points for discussion on the sustainability of wild species. What is considered local varies (e.g., 30 miles in the United Kingdom of Great Britain and Northern Ireland – 400 miles in the United States of America) (Galli & Brunori, 2013). The development of small-scale food systems is considered vital to addressing a variety of ecological stresses (e.g., limit carbon footprint as transportation is limited); among these is the impact of food wastage. It is estimated that in North America and Europe, 250-300 kg of food per annum per person is wasted due to inefficient supply chains and large-scale market systems (Galli & Brunori, 2013). Many small-scale economies are characterized by livelihood diversification considered important in dealing with variability in the availability of species (e.g., due to migration, population cycles, etc. periodic drought, fire, etc.). "Livelihood diversification is defined as the process by which rural families construct a diverse portfolio of activities and social support capabilities in their struggle for survival and in order to improve their standards of living" (Ellis, 1998). A growing body of work indicates how de-centralized and small-scale community and household economies adapt more readily to variability and shocks in the availability of wild species thereby are nimbler in ensuring conservation outcomes. For example, subsistence economies also are an insurance against down swings in the wage economy (e.g., mining sector) (Usher *et al.*, 2003). In South Africa, "pastoralism still plays an important role for households, it has shifted from being the core economic activity to being an insurance against unemployment and contributing to subsistence" (Berzborn, 2007).

Wild species are fundamental to the health and well-being of indigenous communities and many remote and rural communities globally. The degree of dependence of a community on a resource for subsistence depends on the condition of resource, its proximity to the community, access rights, and restrictions as well as local and external demand and income opportunities; for communities with few other economic and food resources, dependence on wild species and other wild resources, is likely to be higher (Roe *et al.*, 2002). The central point is that wild species contribute to the nutrition of many rural and indigenous peoples globally. Although not easily quantifiable, harvest studies and nutrition studies in various parts of the globe suggest the nutritional value and estimated replacement value (dollars) of many species (Hickey *et al.*, 2016). "The few studies that have assessed the relative and absolute contribution of wild meat to household economies in the tropics point to a thriving and financially-large informal sector, perhaps of the same order of magnitude, in terms of gross domestic product, as formal sectors like timber exploitation or agriculture" (Coad *et al.*, 2019). Wild meat is critical to the food security of rural and remote communities comprising up to 90% of available protein in the diet. In northern Australia, for example, wild meat comprises up to 81% of protein intake for indigenous communities. As a result, there are complex and deeply embedded informal economic practices that allow for the sharing and trade of wild meat within small and medium sized communities. For example, in Yangambi, Congo, harvesting and trade of wild meat is illegal, but enforcement by the state is limited. This quasi-open access system may jeopardize sustainability in the long run, though for now "emblematic" species seem to persist while at the same time local communities are able to meet their daily food needs (van Vliet *et al.*, 2019).

Box 4 29 **"The fish of the rich devours the fish of the poor."**

Key messages:

- Wild fish species cover the provision of micronutrients and proteins that are vital for millions of people, especially in developing countries
- The multiplication of fishmeal factories can lead to unfair competition with the artisanal fishing sector, an acceleration of the overexploitation of wild fish resources and the accentuation of food insecurity for local communities.

It is often suggested that aquaculture has potential to alleviate some of the fishing pressure applied to wild stocks. However, this development has been and, still is, strongly dependent on the availability of fishmeal and fish oil obtained from capture fisheries (FAO, 2020b; Péron *et al.*, 2010) besides, industrial fish farming has negative impacts on environment (loss of habitat e.g., destruction of mangrove areas, invasive species, etc.) and local livelihood, depriving people of employments and competing domestic value-chain (Belhabib, Sumaila, & Pauly, 2015; Hoanh, Tuong, Gowing, & Hardy 2006, Konar *et al.*, 2019). This last point is particularly worrying in developing countries, where international agreements are promoting fish exports to match the growing demand for fish in the markets of high-income Western countries and East Asia (FAO 2020). But, for millions of people, fish cover the provision of micronutrients and proteins, that are essential for a balanced diet, particularly for children under five years old (Hicks *et al.* 2019).

On the northwestern coast of Africa (Senegal, Mauritania, Gambia, Bissau-Guinea), international agreements in favor of fishing by fleets from the European Union, Russia and East Asia and high fish exports to the European Union, have led to local fish scarcity and price increases, that have made fish increasingly inaccessible to local consumers (Kaczynski & Fluharty 2002; Gagern & van den Bergh 2013; Corten, Braham, & Sadegh 2017; Thiao, Leport, Ndiaye, & Mbaye 2018). The fisheries in the African Large Marine Ecosystems have reached their peak, and in many cases, move beyond peak catches to a declining trend (Zeller *et al.* 2020). In addition, the development of industrial aquaculture at the international level has led to a new demand for fishmeal and fish oil. This development is questionable from an ecological viewpoint, as aquaculture depends on wild fish and terrestrial crops (which are also consumed by humans) for feeds and freshwater and land for culture sites (Troell *et al.*, 2014). It is also questionable from a social viewpoint, as the multiplication of fishmeal factories leads to unfair competition with the artisanal fishing sector and to an acceleration of the overexploitation of fish resources (such as sardinella/pelagic species), the accentuation of food insecurity, repercussions on employment, environmental nuisances and danger to public health (Aprapam, 2017; Troell *et al.*, 2014).

In Senegal, 22 fish processing plants have been set up since the 2010s to manufacture fishmeal and fish oil from wild pelagic fish, mainly *Sardinella* spp. and *Ethmalosa* spp. to supply the Chinese industrial aquaculture and, ultimately, the markets of Europe, America and China (Aprapam, 2017; Greenpeace, 2019). In Mauritania, 29 factories of fishmeal were in activity in 2015, and two new ones had also been built in Gambia (Thiao *et al.* 2018). Sardinella (round *S. aurita* or flat *S. maderensis*) and Bonga shad *(Ethmalosa fimbriata)* are popular wild fish in West Africa because of their low price and constitute the primary source of protein (up to 80% of animal protein in some areas of Senegal) and nutrients for local human populations. These wild resources are thus fundamental for food security but also a key driver of social cohesion and a sign of cultural identity (Cormier-Salem & Samba 2010; Thiao *et al.* 2018). Fish is the staple of the national dish called *"cee bu jen"* or rice with fish, traditionally prepared with white grouper *(Epinephelus aeneus)*. Since the 1990s, as demersal species are less abundant, costly and export-oriented, this dish is mainly cooked with pelagic species, notably fresh Sardinella or processed Sardinella called *kejax* (Mbengue, Cormier-Salem, & Gueye 2009). The deterioration of fish affordability for the local consumers due to a substantial increase in the price of the main consumed fish products since 2006 has ultimately resulted in a significant decrease in the quantity of consumed fish (from 36.5 kg/person/year in 1993 to 23.9 kg in 2013), which is further of lower quality (dried Sardinella crumbs replacing more and more fresh fish, (Thiao *et al.* 2018)). At the same time, fish exports, primarily through fishmeal and oil, jumped from 3,000 tones to 17,000 tons in 2003 and 2014, respectively (Thiao *et al.* 2018).

Using pelagic species like Sardinella to make fishmeal for farmed fish does not reduce the pressure on wild fish. Moreover, it deprives people in vulnerable situations of previously affordable, nutritious local fish and have a substantial impact on diet and public health (Pauly 2019). To face the multiplication of fishmeal factories and the unfair international agreements, a few initiatives are conducted, such as "SOS Yaboye" (SOS Sardinella) citizen mobilization in Senegal, that led to the shutdown of a new Chinese factory in the Gambia borders and public inquiries.

4.2.4.3.2 Indigenous economies and the sustainable use of wild species

Indigenous economies refer to both traditional and self-governing economies that are grounded in the cultural norms, practices and belief systems of one or more indigenous peoples (Appiah-Opoku, 1999; Argumedo & Pimbert, 2010; Cullen *et al.*, 2007; Koptseva, 2015). While the concept of local (or small scale) is often equated with sustainability and conservation, some small-scale economic practices are not sustainable (Blaikie, 2006; Schumacher, 2011). Critical reviews of case studies have produced design principles that make both local economic benefits and sustain ecological values.

Interrelationships between indigenous economies and the sustainable use of wild species are complex given such economies have substantial social, cultural and spiritual dimensions. "The significance of traditional economies in indigenous communities goes beyond the economic realm—they are more than just livelihoods providing subsistence and sustenance to individuals or communities"(Kuokkanen, 2011). Many aspects of indigenous economic practices and associated resource management systems are considered well aligned with the sustainable use and conservation. Indigenous economies are more likely to manage resources including use wild species in ways that are socially, culturally and ecologically sustainability when there is, a) security of tenure, b) a well-developed management system informed by indigenous knowledge, c) clear incentives and d) equitable sharing of benefits from sustainable use (Bawa & Gadgil, 1997). Market economies can also significantly influence the sustainability of indigenous economies and their use of wild species (Godoy *et al.*, 2005). For example, in the Xingu territory of the Amazon Basin in Brazil, 28 villages in the northern Xingu region opposed large scale logging and mining operations and are producing 1-2 tons of certified organic honey annually which is being sold in one of Brazil's largest supermarket chains (Schwartzman & Zimmerman, 2005). The Soligas of the Biligir Rangan Hills of India harvest fruits from local fruit trees which are made into products (e.g., jams) which are exported from the region and provide local incomes (Bawa & Gadgil, 1997). Also, the Mumeka outstation economy in Australia is "as sustainable in 2003 as it was in 1979; indeed, this economy is structurally the same hybrid economy with customary (hunting), market (arts production and sale) and state (income support transfers) sectors in both periods" (Altman, 2003).

4.2.4.4 Globalization and telecouplings

A primary driver of sustainable use is increased mobility and connectivity, which implies that the use of wild species is affected by telecouplings, i.e., processes taking place in regions where the species are not endemic. Broadly, this happens along several dimensions. First, along the flow of goods and commodities, i.e., trade. Secondly, along the flow of financial transactions and money flows. Third, along the flow of people to watch and enjoy wild species, i.e., tourism. These three flows will be discussed in turn.

4.2.4.4.1 Trade

Key messages:

- Wild product trade often forms part of an income diversification and risk reduction strategy for rural poor households in developing countries *(well established)*.
- Trade revenues can facilitate and incentivize conservation, but if regulation is absent or not enforced it often encourages overexploitation and unsustainable use, including local extinction. The sustainability outcomes depend on mediating factors such as the total demand and scale of trade, governance arrangements, trade relations and local incentives for conservation, and species characteristics *(established but incomplete)*.
- Sustainability outcomes depend on enforcement of local management plans, national laws, and international cooperation. Lack of enforcement and monitoring bears the risk of undermining the potential for sustainable use that may provide critically needed revenue and incentives for conservation, while at the same time fail to discourage illegal harvests and trade *(established but incomplete)*.
- Trade bans have played overall a vital role in halting unsustainable use of threatened species, but in some cases, they may have negative consequences on sustainability outcomes and local livelihoods *(established but incomplete)*.
- Empowering local communities to capture the benefits from wild species conservation with legal user rights and co-designing regulation contributes to sustainable use of wild species *(established but incomplete)*.

This section will provide a conceptualization of trade, and analyze its impact at different scales, including the role of trade relations. The role of markets as drivers either for sustainable or unsustainable use will be explored as well as the importance of economic incentives to engage local communities in sustainable practices. The direct and indirect impacts (e.g., through invasive species, teleconnections, shifts of economic activities) of trade on the use of the target species and local communities will be presented. Trade is a basic economic concept involving the buying and selling of goods and services, or the exchange of goods or services between parties. Trade decouples the consumption of a commodity from the place of origin. When it comes to wild species this may involve the wild species directly (when the species is traded or body parts of it) or indirectly, when commodities derived from these species' habitat are traded, potentially leading to land conversion and loss of habitat. Hence, trade allows consumers in importing regions to buy certain goods that are not available domestically or only at higher prices, while sellers in exporting markets can sell volumes and obtain prices that are potentially higher than what could be obtained at local markets. International trade flows imply a diffusion of responsibility between importing and exporting regions in protecting wild species and biodiversity more general (Lenzen *et al.*, 2007). Trade has particularly adverse effects on wild species, if the resource is left to open access, as potential trade revenues increase the incentive to harvest more or harvest illegally, undermining conservation (Brander & Taylor, 1998). Trade revenues do not always benefit local communities who may be the ones harvesting, but largely depends on the relations along the trade value chain. For example, fish traders often supply fishers with (loans for) equipment, which could enable sustainable or unsustainable exploitation (Elsler, 2020). In absence of functioning regulation, trade tends to put pressure on wild species in exporting regions, while alleviating biodiversity pressures in importing regions (Brander & Taylor, 1998). The scale of trade may range from the very local scale, where products are brought to the next bigger town, to the global scale.

As it was noted in IPBES global assessment (2019), expanding trade means that consumption affects practices and uses of wild species elsewhere. Essentially, trade established telecouplings, making use of wild species and ultimately biodiversity loss a global (rather than local) systemic phenomenon, at least if trade is a contributing driver (Lenzen *et al.*, 2012). Also, international trade and human transport is now recognized as an essential and rapidly growing source of introduction of exotic invasions and diseases worldwide (Hulme, 2009). Lenzen *et al.* (2012) found that 30% of threatened global species are due to international trade, excluding considering the role of invasive species. Marques *et al.* (2019) concluded that trade was driving 25% of the global impacts on biodiversity in 2011, with significant regional differences. For example, 33% of Central and Southern America and 26% of Africa's biodiversity impacts were driven by consumption abroad.

Trade relations

Trade relations encompass bi- and multilateral ties between harvesters, middle(wo)men, traders, countries, and companies involved in the exchange of wild species. Complex harvester-trader relations, producer cooperatives, and exporter-importer relations can be observed for fishing (Elsler, 2020), but also for hunting (Allebone-Webb *et al.*, 2011). Trade relations operate at and across local and global scales. Local scale trade relations include those between harvesters and traders and harvesters and middle(wo)men, who are often imbalanced and characterized by dependence from harvesters on traders/middle(wo)men. Examples of global scale trade relations include trade relations between countries (through trade agreements), importers and exporters. Local and global scale trade relations are often intertwined through international market value chains.

Local scale trade relations, between and amongst harvesters, traders, and middle(wo)men include harvester-trader relations and producer organizations that commercialize harvests such as fishing cooperatives. They are often associated with artisanal harvesting. Harvester-trader relations can provide important social benefits (e.g., Merlijn 1989). However, they have also been associated with unsustainable use of wild species (B. Crona *et al.*, 2010). At the same time, harvesting cooperatives that enable collective action have been associated with sustainable species use (e.g., McCay 2014; Ostrom 1990).

Local trade relations are often multi-dimensional including essential functions, such as providing loans for operations and investments (Drury O'Neill *et al.*, 2019), access, information, and infrastructure (Bailey *et al.*, 2016; Ferrol-Schulte *et al.*, 2014), or advice, and support next to the exchange of seafood with different consequences for species use (Basurto *et al.*, 2012; Ferse *et al.*, 2014). Their different functions and characteristics can determine the outcomes for the use of wild species and the trade partners and affect incentives for the use of wild species. For instance, access to new markets can promote non-selective capture (Nascimento *et al.*, 2017) and credits can decouple species harvest from environmental fluctuations (Crona *et al.*, 2010; Kininmonth *et al.*, 2017). In cases, where local trade relations promote sustainable use, trade relations have been found to promote self-governance or commercial interests align with conservation objectives, such as in the case of Indonesia where traders' loans enable fishers to reduce fishing pressure in an overfished marine ecosystem.

Some local trade relations promote self-governing strategies and contribute to local level institutional diversity (Basurto *et al.*, 2012). This aspect is important because informal governance at the local level can be more effective or contribute to centralized governance. Trade partners can contribute to devising informal social norms and contribute to rulemaking. Traders may influence social norms through their key positions of channeling information to local communities (Crona & Bodin, 2010; Glaser *et al.*, 2010). Also, traders may devise new rules. For instance, in the case of the Mexican squid fishery, traders have become influential in the fishery due to collusion and have set quotas to fishers which prevents catch discards (Frawley *et al.*, 2019). On the downside, the traders' power allows them to significantly reduce the beach price fishers fetch for their catch (Elsler *et*

Box 4 30 **Trade relations in an Indonesian multi-species fishery.**

In the Spermonde (Indonesia) multi-species fishery, fisher-trader relations are highly influential (Ferse *et al.*, 2012; Glaser *et al.*, 2010), as in many other tropical small-scale fisheries (e.g., Ferrol-Schulte *et al.* 2014; Merlijn 1989). The sustainability of fishing can be affected by fisher-trader relations through their influence on the reinforcement and emergence of fishing practices (Crona *et al.*, 2010; Ferse *et al.*, 2014). Schematically, two mechanisms shape fisher-trader relations' influence on fishing practices: first, interactions within the relation going beyond the exchange of fish (Pelras, 2000) and, second, fishers and traders' relations with other fishery actors (Radjawali, 2012). The fishing practices fisher-trader relations enable cannot *a priori* be classified as sustainable or unsustainable. Fishing migrations can reduce pressure on locally overfished marine populations but also expand depletion of fisheries elsewhere (Berkes *et al.*, 2006; Merino *et al.*, 2011). To enable fishing migrations, the trader provides large credits to the fisher (Ferse *et al.*, 2014; Navarrete Forero, 2015). During the migration fishers would sell fish at sea and return after several months to repay the credit to the trader. Traders need to trust the fishers whom they loan vast credits. Trust either derives from kin relations or a history of working successfully together (Acciaioli, 2000). In Spermonde, fisher-trader relations also enable destructive fishing (e.g., blast fishing, cyanide fishing) which negatively impacts marine populations and their reef habitats (Mous *et al.*, 2000). To enable destructive fishing, traders maintain relations with high-level authorities to circumvent enforcement of fishing regulations that ban destructive fishing (Nurdin & Grydehøj, 2014). Through this relation, the trader can guarantee to protect the fisher from prosecution (Radjawali, 2010). In consequence, fishers who work for a trader with such connections could use destructive fishing without risk of punishment (Glaser *et al.*, 2015).

al., 2021). Finally, traders and middle(wo)men can contribute to formal decision-making processes that harvesters, due to their limited financial and administrative capacities, do not have access to (Basurto *et al.*, 2012; Frawley *et al.*, 2019; Maryudi & Myers, 2018).

The functions of local trade relations can promote social sustainability. Traders and middle(wo)men may give insurance during hardship, personal support, and creating contingencies between supply volumes and demand (Ferrol-Schulte *et al.*, 2014; González-Mon *et al.*, 2019; Radjawali, 2010). This is particularly prominent in committed trade relations based on kinship, friendship, or strong social norms of reciprocity (Drury O'Neill *et al.*, 2019; Ferse *et al.*, 2014; Nascimento *et al.*, 2017; Sharp, 2016). However, committed relation do not necessarily promote sustainable species use. In Indonesia, for instance, fisher's use of blast fishing depends on their trust to a trader who can protect them from prosecution (see **Box 4.30**). In contrast, in relations in which commitment is lacking and strong power asymmetries due to gender differences or high indebtedness are present, exploitation and misconduct have been observed (Drury O'Neill *et al.*, 2019; Matsue *et al.*, 2014).

A nascent literature has started drawing first links between global trade relations and sustainable use of wild species. This literature highlights that the structure and dynamics of trade relations and trade networks matter, that multiple trade relations allow to divert trade routes from source to destination (Stoll *et al.*, 2018), and that links to global traders changes local trade relations (Wamukota *et al.*, 2014). Along global value chains there are different compositions of trade relations, for instance, there might be few exporters interacting with many local middle(wo)men (Purcell *et al.*, 2017; zu Ermgassen *et al.*, 2020). The resulting global trade network structure and its dynamics can be shaped by the expansion of exploitation of a particular species (Anderson *et al.*, 2011; Berkes *et al.*, 2006; Eriksson *et al.*, 2015). Expansion can help cater increasing demand but also mask declines of wild populations in one area (Crona *et al.*, 2016). The emerging global network structure has consequences for future propagation. For instance, the presence of multiple trade relations enables diverting trade routes from source to destination to avoid trade barriers (Stoll *et al.*, 2018). High connectivity in trade networks can allow supply shocks to propagate through redistribution of sourcing (Gephart *et al.*, 2016; Tu *et al.*, 2019) and have been associated with unsustainable biomass levels of fish populations. Access to international market value chains can affect local trade relations. For example, they allow diversification of harvested species (Abbott *et al.*, 2015), can increase income for harvesters (Elsler *et al.*, 2019), and reduce incentives for collective action (Bennett & Basurto, 2018). This last point is particularly important because self-governing strategies may shift from collective towards more individual based harvest and selling (Bennett & Basurto, 2018; Frawley *et al.*, 2019; Lindkvist *et al.*, 2017).

Wild species trade

Wild species trade is any commercial exchange (involving money or barter) by people of wild animals, fungi, and plant (including algae) resources, both at local levels and across legal jurisdictions and international borders. Wild species trade can be legal or illegal, formal or informal; domestic or international, and can result in a sustainable or unsustainable use of animal and plant species. Wild resources are traded in many forms to produce a wide variety of products such as homeware, healthcare (including traditional medicines), food, cosmetics, ornaments, furniture, pets, fiber, and building supplies (Lee *et al.*, 2020; ‘t Sas-Rolfes *et al.*, 2019). Several wild species are hunted around the wild for their perceived potency of certain body parts in traditional and religious practices, as well as for trophy collections (Atuo & O’Connell Timothy, 2015; Sinovas *et al.*, 2016). Use for those purposes occurs regardless of the rarity or conservation status of those species. If anything, the perceived value of a species often increases with rarity (though this may not be true for some species; Sumaila *et al.* 2019)), leading to even more aggressive harvesting (Atuo & O’Connell Timothy, 2015) which may result in commercial or local extinctions (Ulman *et al.*, 2020). Globally, the predominant direction of the trade of products derived from wild species is South-to-North, mainly driven by consumer demand from affluent developed countries and their profitable fashion, medical, and food industries (Ripple, Abernethy, *et al.*, 2016; Sand, 1997). The value of legal wildlife trade from 1997 to 2016 totaled between 2,9 and 4,4 trillion United States Dollars. The top commercial categories were seafood (82%), furniture (7%) and fashion (furs and hides) (6%) (Andersson *et al.*, 2021).

According to the latest update of the International Union for Conservation of Nature Red List of Threatened Species (July, 2019), improperly managed national and international trade is driving the decline of species in the land, oceans and freshwater. Trade can affect sustainable use of wild species directly through harvests and indirectly, for example by shifting towards practices that affect wild species through use and transformation of habitat (e.g., unsustainable logging /land use change). Naturally, those effects will be very different for terrestrial than for marine species (Bulte & Barbier, 2005). 72% of the species listed as threatened or near-threatened, (6,241) are being overexploited for commerce, recreation or subsistence (Maxwell *et al.*, 2016). The same study revealed that unsustainable harvesting is now the most prevalent threat affecting threatened marine species and is the second most pervasive (after agriculture/aquaculture) for terrestrial and freshwater species. Overfishing has pushed two families of rays to the

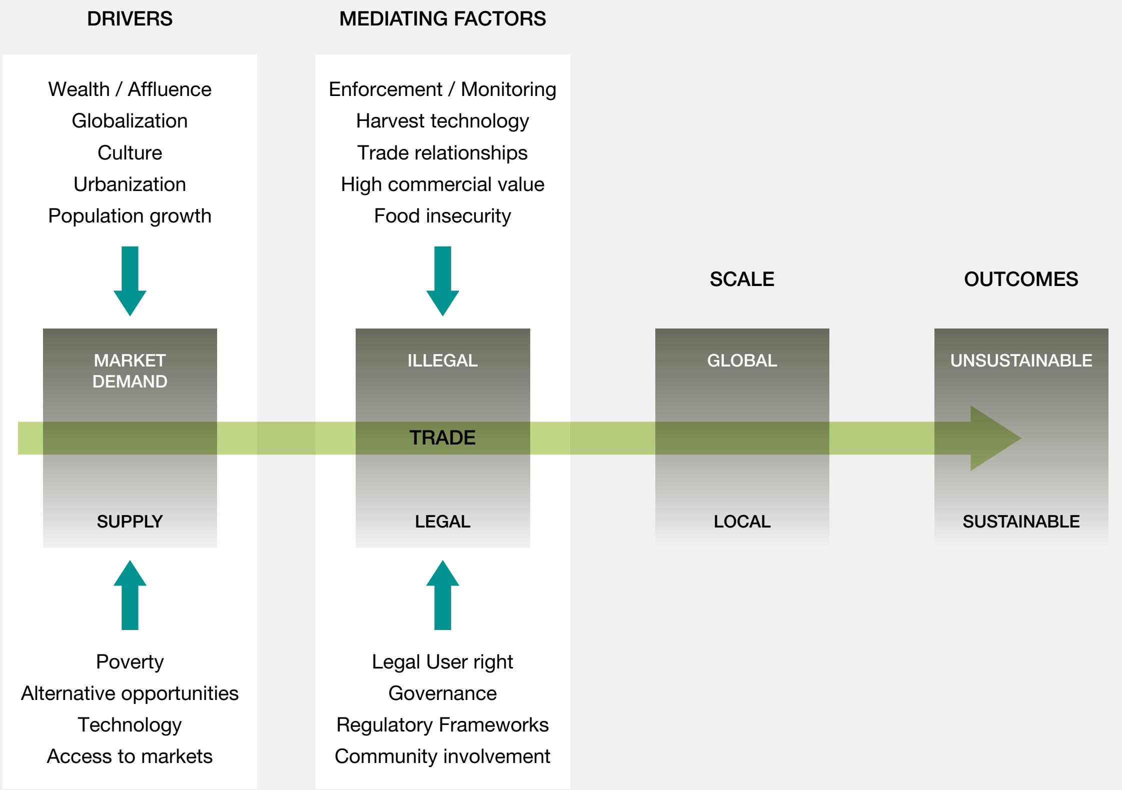


Figure 4 10 **Wild species trade and sustainability of wild species.**

Several drivers can have an impact on wild species trade. The drivers are affected by mediating factors and result either in legal or illegal trade. Unselective harvesting methods, incoherent regulatory frameworks, and lack of ability to recognize protected species imply that the line between legal and illegal trade is often fuzzy. Either legal or illegal trade can happen at local through global scale and be sustainable or unsustainable. For example, when there is market demand (a driver) for certain species as pets or for use in traditional medicine, poor enforcement (a mediating factor) may affect the sustainability outcome of such species that are traded legally and illegally in local and global context.

brink of extinction. Bushmeat hunting for mostly food and medicinal products is driving a global crisis whereby 301 terrestrial mammal species are threatened with extinction in developing countries (Ripple, Abernethy, *et al.*, 2016). A recent quantitative meta-analysis of wild species trade revealed that overall wild species trade caused a 61.6% decline in species abundance (Morton *et al.*, 2021). Extraction for bushmeat trade caused declines of 59.7% (excluding subsistence studies), while pet trade precipitated extreme decreases of 73.0% (Morton *et al.*, 2021). National and international trade significantly reduced species abundance by 76.3% and 65.8%, respectively, whereas local trade had limited impacts. Though impacts of trade on wild species are widespread globally, one can identify certain hotspots of human impact (Allan *et al.*, 2019). Di Minin *et al.* (2019) identified global centers for unsustainable commercial harvesting of species. 4.3% of the land and 6.1% of the seas contain 82% of all species threatened by unsustainable harvesting and more than 80% of critically endangered species. Those centers of unsustainable commodity are found globally but are especially concentrated in Asia and North and South America, in areas where harvesting intensity was the highest and governance and political stability the lowest. The regions with the most mammal species threatened by unsustainable levels of hunting and trade of bushmeat were found to be in Asia (especially South-East Asia) and Africa, whereas the countries with the most mammal endemic species threatened include Madagascar, Indonesia, Philippines, Brazil, Papua New Guinea, India and China (Hughes, 2017; Ripple *et al.*, 2015; Ripple, Abernethy, *et al.*, 2016; Ripple, Chapron, *et al.*, 2016; Symes *et al.*, 2018). Although overhunting of wild meat is primarily a problem in developing countries, wealthier nations can exacerbate or possibly even drive the problem by inflating demand and prices for meat, trophy, medicinal and ornamental product (Lee *et al.*, 2020; Ripple, Abernethy, *et al.*, 2016). However, whether or not this is the case depends on a number of other factors (e.g., see **Figure 4.10**).

An analysis of CITES trade data from 1975 to 2014 revealed that on average over 100 million whole organism equivalents were reported in trade per year between 2005 and 2014 (Harfoot *et al.*, 2018). In total, between 1975 and 2014, plant whole organism equivalents were traded at the highest volume (1.80 billion reported by exporters), followed by reptiles (152 million), invertebrates (79.8 million), birds (24.1 million), mammals (13 million), fish (12.8 million) and amphibians (1.07 million). There was a substantial shift from wild to captive sourced over time. Both the volume and value of international wild species trade are expanding (Roe, 2008). According to the IPBES global assessment (IPBES, 2019a), the international legal wild species trade has increased by 500% in value since 2005, and 2,000% since the 1980s, albeit a proportion of this increase may reflect enhanced captive breeding or ranching. TRAFFIC has estimated legal international trade, including timber and fisheries products, at 323 billion United States Dollars in 2009 (Cooney *et al.*, 2015).

Wild species trade: Fishing

Of all food items, fish and fish products are amongst those that are traded most widely in the world (Pavitt *et al.*, 2021). Fisheries exports have been identified as a contributing factor to unsustainable exploitation, contributing to overfishing, and also fish stock collapses (Lenzen *et al.*, 2012; Gars and Spiro, 2017; Crona *et al.*, 2015). Using global export data from 1950–2006, Eisenbarth (2022) finds that exports have a significant effect on the probability of stock collapse. At the same time, the impacts from trade are primarily mediated by governance arrangements that organize access and regulation of fisheries (Erhardt 2018; Copeland and Taylor, 2009). This implies that trade will be a driver of unsustainable use in absence of functioning rules and regulations that safeguard sustainability.

Trade, and especially demand of fast-growing Asian economies is the most important driver of the depletion of shark stocks on a global scale (Erhardt & Weder, 2020). The diversity of traded shark species makes it more difficult to ban and discourage unsustainable practices, as species substitution could mask depletion of vulnerable species (Fields *et al.*, 2018). Basking shark *Cetorhinus maximus*, is especially sensitive to exploitation and is listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Magnussen *et al.*, 2007). Yet, tracking trade in basking shark products is difficult as shark products are often visually indistinguishable and therefore one cannot easily identify single species and origin (Cardeñosa *et al.*, 2018; Magnussen *et al.*, 2007). Full traceability, and strict control and enforcement of fishing regulations would contribute towards sustainable fishing (Bailey *et al.*, 2016). In Tanjung Luar in East Lombok (Indonesia), almost half of the shark catch comprises CITES -listed species, and insufficient management regulations are in place to incentivize or enforce avoidance of threatened stocks (Yulianto *et al.*, 2018). The Arabian Seas Region plays an important role in the global trade of sharks and rays, where the United Arab Emirates and Yemen can be characterized as major regional trade hubs (Jabado & Spaet, 2017). Reported shark and ray landings represent 28% of the regional total fish catches, amounting to 56,074 tons in 2012, with most catches taking place in Iran, Oman, Pakistan and Yemen (Jabado & Spaet, 2017). While the fishery is mostly artisanal, some gear types (e.g., dynamite fishing) and exploitation levels have potentially unsustainable impacts (Jabado & Spaet, 2017). The large geographic area, complicate trade dynamics, and ongoing political instability and convoluted governance and administrative make a centralized control approach inherently difficult (Jabado & Spaet, 2017). The whole genus of seahorses was listed in CITES Appendix II in 2002 because of the adverse effects of harvests and trade on sustainability of wild populations. Evidence from Thailand suggested that seahorses were often caught as bycatch in trawl fisheries, allowing fishers to continue fishing if harvesting the target species was not so profitable, for example due to overexploitation (Kuo *et al.*, 2018). Declining abundances, as reported in Malaysia and Thailand suggests that current harvest rates are unsustainable (Kuo *et al.*, 2018; Perry *et al.*, 2010).

Wild species trade: non-lethal fishing

From 1990 to 2016, the number of direct export transactions of Appendix II Convention on International Trade in Endangered Species of Wild Fauna and Flora -listed marine species increased sevenfold (from around 14 000 in 1990 to about 98 000 in 2016) (Pavitt *et al.*, 2021). Approximately 97%of those exports fall into the group of corals (Pavitt *et al.*, 2021). This is only a small fraction of the total trade, as many fish species can be can be traded with few regulatory and monitoring systems in place (Biondo & Burki, 2020). For example, it has been estimated that trade in coral reef fishes alone range from 13 to 35 million fishes being traded annually (Biondo & Burki, 2020). More generally, pet trade can be an important driver of biodiversity loss and overharvesting of wild species (Baker *et al.*, 2013; Bush *et al.*, 2014; Ng *et al.*, 2016). It can also be an indirect driver such as a vector for invasive species (Fitzpatrick *et al.*, 2018; Lötters *et al.*, 2018; Martel *et al.*, 2014; Travis *et al.*, 2011; Woeltjes *et al.*, 2011; Yuan *et al.*, 2018). The trade of living marine species for aquaria has become a major business (Rhyne *et al.*, 2017). 20% of recent wild species trade reports are due to demand for pets or animals for use in entertainment (Baker *et al.*, 2013; Bush *et al.*, 2014).

In 2011, 6.9 million individual fish and 3.6 million individual invertebrates have been imported into the United States of America (Rhyne *et al.*, 2017). Singapore is an important global hub of the ornamental aquarium trade in general, and freshwater mollusks in particular (Ng *et al.*, 2016). A quarter of the sampled traded species have a history of introduction, which includes 19% that are either certainly or potentially causing negative impacts in their invaded habitats (Ng *et al.*, 2016).

The endangered redline torpedo barb *(Sahyadria denisonii)* from the Western Ghats region (Sri Lanka) are caught for the aquarium trade. While this activity provides income to the local communities, the unmanaged fishery has led to unsustainable levels of exploitation, and some populations of torpedo barb have declined sharply, making the danger of a collapse immanent (Raghavan *et al.*, 2018). International trade also threatens the sustainability of the Banggai cardinalfish *(Pterapogon kauderni)* that is a popular aquarium fish (Vagelli, 2008). Overall, critical knowledge gaps pertain to the scale and scope of trade of ornamental fish and corresponding sustainability outcomes (Biondo & Burki, 2020).

Wild species trade: Gathering

While roughly a third of all terrestrial plant species are at risk of extinction, the scale of exploitation is often inconclusive (Corlett, 2016). Also, the contributing role of trade in enabling unsustainable practices in absence of well-functioning regulations is established, but the exact scale of trade, as well as the sustainability impacts are often incomplete. Especially Southeast-Asia is a region where a massive commercial and often illegal trade of wild collected ornamental plants occur (Hughes, 2017; Phelps & Webb, 2015). Observed cross-border trade tends to be orders of magnitude larger than government-reported and the Convention on International Trade in Endangered Species of Wild Fauna and Flora statistics (Phelps and Webb 2015). Plant populations are declining across South-East Asia because of overharvesting to meet high demand from Chinese traditional medicine and herbal products industry. There are also many documented cases of trade in plants, algae and fungi leading to resource depletion (e.g., Belcher *et al.* 2005; Neumann and Hirsch 2000). In a comparative study on plants, algae, and fungi trade in Asia, Africa and Latin America, Kusters *et al.* (2006) conclude that trade of plants, algae, and fungi products tends to lead to positive livelihood outcomes, though perhaps also higher inequality between households. At the same time trade leads to resource depletion if left unmanaged.

Trade is an important driver that threatens orchids globally. All 29,000 orchid species are listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which comprise 70% of all species listed (Gale *et al.*, 2019; Hinsley *et al.*, 2018). In spite of being officially protected, many orchid species around the world are under threat from illegal and unsustainable trade for horticulture, food and medicine (Hinsley *et al.*, 2018). While orchid trade is concentrated in Asian countries, such as China and Nepal (Hinsley *et al.*, 2018; Subedi *et al.*, 2013), it takes place at a global scale. In Mexico, wild orchids are frequently traded on local markets (Cruz-Garcia *et al.*, 2015). The harvesters and sellers are mostly women, with little or no formal schooling and come from indigenous communities. Often, the orchid trade is not the sellers' only economic activity, but an important part of a poverty alleviating strategy (Cruz-Garcia *et al.*, 2015). Different harvesting practices persist, in particular *in situ* techniques (removing flowers and leaving roots and renewal buds) and *ex situ* techniques (extracting entire wild plants), where the latter is thought to be less sustainable. Though trading of wild species is regulated by Mexican law, these laws are often not known to harvesters, and also not applicable as trade of wild orchids is considered a traditional practice and therefore locally allowed (Cruz-Garcia *et al.*, 2015).

Cacti are among the most threatened taxonomic groups assessed to date under the International Union for Conservation of Nature Red List Categories and Criteria, with 31% of the 1,478 evaluated species threatened, demonstrating the high anthropogenic pressures on biodiversity in arid lands. The dominant drivers of extinction risk are the unscrupulous collection of live plants and seeds for horticultural trade and private ornamental collections, smallholder livestock ranching and smallholder annual agriculture (Goettsch *et al.*, 2015).

Across the literature, there was inconclusive evidence regarding whether trade could be contributing towards incentivizing sustainable use via higher prices and stability of income provided to livelihoods. Also, the social and economic impacts were often inconclusive. Gathering is a practice often conducted by women of all ages with little or no formal education, who do often not have access to alternative economic activities. In Sierra Leone, more than 30 plant species are traded for medicinal purposes, three of which are considered vulnerable under the International Union for Conservation of Nature Red list: *Garcinia kola, Fleroya stipulosa,* and Nauclea diderrichii (Jusu & Sanchez, 2014). Whether or not harvesting practices are mainly sustainable depends on the actions of the collector. However, in a few cases (e.g., *P. guineense*) the species are never sustainably harvested (Jusu & Sanchez, 2014). Medicinal species that are traded in the largest volumes, sell at the highest prices, and travel the greatest distances, are most likely to be unsustainably harvested. A key issue in unsustainable use is the harvesting technique, as a number of species are harvested unsustainably (e.g., removing whole plants; ring debarking) (Jusu & Sanchez, 2014) Caterpillar mushroom *(Ophiocordyceps sinensis)* is a medicinal fungus found in alpine grasslands in the Himalayan mountain regions and the Tibetan Plateau (He, 2018). The harvest practices of communities involved in a co-management scheme of the nature reserve were more sustainable than those communities not engaged in such a scheme. This difference was mainly due to clarity and security or tenure and resource access, and also because of external support and training in sustainable practices (He, 2018). An obstacle towards ecological and economic sustainability is the difficulty to generate more excellent local benefits along the value chain, also when it comes to product grading which could incentivize more sustainable practices (e.g., not harvesting pre-mature mushrooms) (He, 2018). In the Palas valley (Pakistan), several species of morels (*Morchella* spp.) are collected by local families and traded all over Pakistan. A continuous decline in supply was observed, potentially indicating unsustainable use in the past (Sher *et al.*, 2015). Though morels could play a role in supporting livelihoods, unsustainable collection techniques, unfavorable trade practices and limited income generation along the value chains pose obstacles (Sher *et al.*, 2015). Stimulating and incentivizing the use of best practices of sustainable harvesting and collection methods can be an important step towards sustainable use (Becerra, 2009).

In central Australian rangelands, several native plant products (including *Solanum centrale* J.M. Black, *Acacia* Mill. spp.) are commercially harvested and traded in a small scale (Walsh & Douglas, 2011). While there is no evidence of overharvesting yet, narrow economic margins may increase future pressure on the resource. Also, sustainable practices rely heavily on future generations having necessary knowledge and skills (Walsh & Douglas, 2011). In Transkei, located in the Eastern Cape province of South Africa, hand brushes made from fronds of the wild date palm *(Phoenix reclinata)* are locally made and traded to nearby urban areas (Mjoli & Shackleton, 2015). The key actors involved in harvesting and trading are middle-aged to elderly women with little formal education and opportunities to earn cash income elsewhere. The trade of palm brushed played a significant role in supporting livelihoods of local traders. Demand is stable, if not increasing, in spite of increasing availability of synthetic substitutes because of cultural and practical value attached to palm brushes. As of now, there is no evidence that current practice is unsustainable (Mjoli & Shackleton, 2015). In the Congo Basin, bush mango (*Irvingia* spp.) nuts are harvested from forest landscapes for own consumption and trade, contributing on average to 31% of harvester's annual incomes (Ingram *et al.*, 2017). Evidence regarding sustainability of harvesting is mixed. On the one hand, harvesters tend to gather fallen fruits, and trees are left or actively managed on farmland, suggesting sustainable use. On the other hand, reports of declining wild resources, the need for harvesters to travel longer distances, together with clearance of the species' natural habitat, low levels of cultivation, continuing high demand, and a lack of consistent regulation and enforcement may threaten sustainability (Ingram *et al.*, 2017). Across the Congo basin, the leaves of the *Gnetum* spp. forest lianas have long been harvested from humid forests for consumption and traded as a popular vegetable (Ingram *et al.*, 2012). At least 2,550 people work across the value chain, *Gnetum* contributing on average to 62% of a harvester's annual income. Over 50% is unsustainably collected from the forest and rising demand, increasing prices and low levels of cultivation put further pressure on the resource (Ingram *et al.*, 2012). Trade is mostly illegal, and sporadic customary governance and enforcement, and an rudimentary framework cannot ensure trade to be sustainable (Ingram *et al.*, 2012). Gaharu (agarwood) is a highly valuable fragrant derived from *Aquilaria* spp. (Thymelaeaceae) that is traded internationally. In Indonesia, traditional harvesting practices are declining as more nonlocal collectors become involved, leading to more intensive harvesting practices. More intensified and less careful collection suggest that the current Indonesian trade in gaharu is not sustainable (Soehartono & Newton, 2002). In the case of argan oil, the boom has enabled some rural households in Morocco to send their girls to secondary school, increase consumption, but also increase their goat herds which impact negatively on the argan forest as well as privatization pressures (Lybbert *et al.*, 2011). To use wild medicinal plant resources sustainably, both conservation strategies (e.g., *in situ* and *ex situ* conservation) and resource management (e.g., good agricultural practices) should be considered (Chen *et al.*, 2016; Lichtenstein, 2010).

Wild species trade: Terrestrial animal harvesting

Excessive hunting pressure, due in large part to commercialization and trade, is unsustainable and has reduced the populations of many tropical large mammal species (Benítez-López *et al.*, 2017; Brashares & Gaynor, 2017; Lee *et al.*, 2005; Milner-Gulland & Bennett, 2003). Regarding socio-economic impacts, hunting provides income and protein to local hunters, but if it does not go hand in hand with ecological sustainability, it will also negatively affect livelihoods in the long run (Bowen-Jones & Pendry, 1999; Cowlishaw *et al.*, 2005; Taylor *et al.*, 2015). Trade mediates demand from one region to another, potentially giving incentives to hunt in large scales, which together with uncontrolled access and poorly enforced regulation negatively affects the sustainability of protected and unprotected species (Bowen-Jones & Pendry, 1999). Wild meat (also known as bushmeat) hunting is usually not only practiced for subsistence, but is generally traded and serves local markets, as well as urban or even international markets (Bowen-Jones & Pendry, 1999; Brashares *et al.*, 2011; Lindsey *et al.*, 2013; Nielsen & Meilby, 2015). Typically, domestic trade is substantially larger than international trade (Brashares *et al.*, 2011). There is established evidence that trade in wild animals for meat is one of the most critical threats to wild species in Central and West Africa (Bowen-Jones & Pendry, 1999; Cowlishaw *et al.*, 2005; Lindsey *et al.*, 2013; Thibault & Blaney, 2003). At the same time, there is incomplete information about the scale of wild species trade and also how this maps to sustainability outcomes. Evidence is mainly anecdotal, for example it has been documented that around five tons of wild meat is smuggled in personal baggage through Paris Roissy-Charles de Gaulle airport per week (Chaber *et al.*, 2010).

Taylor *et al.* (2015) document evidence on the impacts of wild species hunting with data on 177 species from 275 sites across 11 African countries collected over 30 years. They find that research efforts and available information are not evenly distributed. There is less evidence from West Africa compared to Central Africa, and also less information about impacts on birds (Taylor *et al.*, 2015). The International Council for the Exploration of the Sea data reveals that about 18 000 individuals of wild species mostly traded as hunting trophies were exported annually from South Africa between 2005 and 2014 (Sinovas *et al.*, 2016). Wild meat trade is as a severe problem in forest biomes and savannas, though it is extremely difficult to accurately quantify the number of wild species hunted or quantity of wild meat traded (Lindsey *et al.*, 2013). However, case studies from 15 African countries suggest that given the scale and ubiquity of wild meat hunting, current uses are ecologically unsustainable, at least without immediate interventions (Lindsey *et al.*, 2013). Ultimately, the expected loss of wild species will lead to severe economic and social impacts (Lindsey *et al.*, 2013). In many cases, wild meat hunters are male, poor, without formal employment, and with little education and few livestock, though wild meat hunting can be quite lucrative (Lindsey *et al.*, 2013). Social impacts of illegal wild meat trade include negative effects on food security in the long term through unsustainable harvesting, loss of potential tourism-based revenues and employment, and also loss of wild species heritage (Lindsey *et al.*, 2013). A key element of unsustainable use tends to be high demand, much more than technology, in combination with absence of effective regulation (Bowen-Jones & Pendry, 1999). Increased urbanization and access to formerly remote areas are mediating factors that increase hunting pressure (Allebone-Webb *et al.*, 2011; Bowen-Jones & Pendry, 1999; Brugiere & Magassouba, 2009; Lindsey *et al.*, 2013). Economic activities that rely on a large number of personnel, such as the oil industry may drive up demand, increasing incentives to hunt, which can put additional pressure on wild species (Thibault & Blaney, 2003).

According to data using the standard classification schemes for utilization and threat types for the International Union for Conservation of Nature Red List, at least 45.7% of extant bird species (4,561 species) are used by humans, principally for pets (37.0%) and for hunting for food (14.2%), but other uses include sport hunting, ornamentation and traditional medicine (Butchart, 2008). International trade is a key driver, involving at least 3,337 species (33.9%, substantially higher than previous estimates), mostly for pet trade (Butchart, 2008). Trade generally correlates with declining abundances, and also increased risk of extinction, though other drivers are even more important (Butchart, 2008). Marsh *et al.* (2020) expand those results, also using International Union for Conservation of Nature data show that across the 25,009 species in 10 taxonomic groups, 10,098 (40%) had some purpose of use documented. The proportion of species documented as having at least one purpose of use coded ranged from 15% (crustaceans) to nearly 100% of cone snails (544 of 545 species) among aquatic groups, and 11% (amphibians) to 76% (conifers) among terrestrial groups (Marsh *et al.*, 2021). In Africa, more than 354 bird species are hunted for that purpose in 25 countries (Williams *et al.*, 2014). Atuo *et al.* (2015) analyze the trade in avian body parts around major protected areas in the Cross River region of south-eastern Nigeria, which is an economic activity pursued primarily by younger people and villagers with low monthly income.

In spite of three of the top 5 most reported species being globally threatened, knowledge of the threat status of species was not common among hunters and traders (Atuo & O'Connell Timothy, 2015).Twelve (42%) species were known to be declining and 5 (18%) are already listed as globally threatened under the International Union for Conservation of Nature /BirdLife threat criteria (Atuo & O'Connell Timothy, 2015).

A case study from the Hkakaborazi National Park reports that commercially valuable species that had been previously targeted by hunters (tiger, otter, pangolin) appear to be completely absent from current harvest records, which may suggest population decline and very low abundances (Rao *et al.*, 2010). Though farming is the predominant occupation (70% of surveyed population) hunting was conducted by a quarter of the surveyed people, and hunting was reported to be a significantly higher source of income than any other livelihood activities (Rao *et al.*, 2010). In Myanmar, a critical mediating factor that facilitates the ongoing illegal hunting and trade is weak enforcement of laws and regulations (Rao *et al.*, 2010; Shepherd & Nijman, 2008).

In Japan two species of bears (*Ursus thibetanus* and *U. arctos*) are traded for their gallbladder and meat. Yet, information about the scale of trade is poorly documented and also obscured by the fact that hunting bears is allowed in Japan, as long as it meant to control nuisance caused by bears (Mano & Ishii, 2008). Though most Japanese bear populations are considered to be at a sufficient level to sustain hunting if well-managed, reconciling (perceived) threats of bears to the public and sustainability goals poses challenges to the bear nuisance management system (Mano & Ishii, 2008; Sakurai *et al.*, 2013).

In North Sumatra, hunting and trade of blood pythons *(Python brongersmai)* is an important activity, with around 50,000 individual snakes hunted each year since 1997 (Natusch *et al.*, 2020). Comparing changes in numbers, demography (e.g., sex ratio, proportion of adults vs. juveniles), and life-history traits (e.g., body size at maturation) of snakes brought to processing facilities in 1997 *versus* 2015 suggest that harvesting rates are unsustainable. (Natusch *et al.*, 2020). Wild species breeding farms can help to enable sustainable use, though there is a danger that illegally caught wild animals are 'laundered' and traded through the legal channel (Lyons & Natusch, 2011). Hunting of Scorpion Mud Turtle *(K. scorpioides)* is an activity practiced by artisanal fishermen (only men) on Marajó Island, Brazil (de Cristo *et al.*, 2017). While the scorpions are hunted for own consumption, a sizable number is traded and sold at urban centers. Current uses are often unsustainable, for example by setting fires in the grasslands, which causes scorpions to move into open areas where large quantities can be caught regardless of sex and size (de Cristo *et al.*, 2017).

In Cambodia, an estimated 6.9 million snakes of seven species are estimated to be harvested from Tonle Sap Lake annually (Brooks *et al.*, 2007, 2010). The most significant driver of snake exploitation is the domestic trade in snakes as crocodile food, and to a smaller extent demand from international markets for exotic leather, luxury food and traditional medicine (Brooks *et al.*, 2010). The key driver, demand for snakes as crocodile food is strongly influenced by the price of alternatives, such as fish (Brooks *et al.*, 2010).

Non-lethal terrestrial animal harvesting

Pet trade can be an essential driver of biodiversity loss and harvesting of wild species (Baker *et al.*, 2013; Bush *et al.*, 2014; Ng *et al.*, 2016). It can also be an indirect driver as a vector for zoonotic diseases and invasive species more generally (Borsky *et al.*, 2020; Fitzpatrick *et al.*, 2018; JNCC, 2021; Lötters *et al.*, 2018; Martel *et al.*, 2014; Travis *et al.*, 2011; Woeltjes *et al.*, 2011; Yuan *et al.*, 2018). Another indirect effect of pet trade is the habitat destruction caused by non-lethal harvesting, for example the collection of reptiles (Auliya, Altherr, *et al.*, 2016; Goode *et al.*, 2004, 2005).

Twenty percent of recent wild species trade reports are related to pets or animals for use in entertainment (Baker *et al.*, 2013; Bush *et al.*, 2014). At least 45.7% of extant bird species (4,561 species) are used by humans, from which 37% as pets (Butchart, 2008). In a systematic literature review, birds were the most species-rich class reported (585 species) in trade, followed by reptiles (485 species) and mammals (113 species) (Bush *et al.*, 2014). The most common avian orders in reported trade were parrots (Psittaciformes), song birds (Passeriformes), and falcons (Falconiformes) (Bush *et al.*, 2014). The capture of wild birds is a major source of population decline and wider environmental problems in Brazil, with about 23% of all bird species, (i.e., 295 out of 400) being hunted for pet trade (Alves *et al.*, 2013; Fernandes-Ferreira *et al.*, 2012). Trade as pets also threatens sustainability of parrots in Africa and Madagascar (Martin *et al.*, 2014). Repeated bird surveys in Sumatra (Indonesia) have documented that trapping for pet trade depleted bird populations in the wild (Harris *et al.*, 2017).

Pet trade is also an important driver for the decline of many reptile species globally, and particularly in Southeast Asia (Auliya, Altherr, *et al.*, 2016; Böhm *et al.*, 2013; Natusch & Lyons, 2012; Nijman, 2009; Nijman, Shepherd, *et al.*, 2012; Nijman, Todd, *et al.*, 2012; Shaney *et al.*, 2017; Wakao *et al.*, 2018). 35% of all reptiles are traded online, which is very hard to regulate (Marshall *et al.*, 2020). This includes many endangered or endemic species with over 90% species and half of traded individuals taken from the wild. Especially the European Union plays a major role in reptile trade, having imported officially more than 20 million live reptiles between

2004 and 2014 (Auliya, Altherr, *et al.*, 2016). Reptile trade threatens wild populations and effective control is hampered by ineffective regulation and monitoring (Auliya, Altherr, *et al.*, 2016; Auliya, García-Moreno, *et al.*, 2016). A survey in the Indonesian provinces of Maluku, West Papua and Papua, documented that at least 44% of amphibians and reptiles were traded illegally (Natusch & Lyons, 2012). Inability to identify species correctly, weak governance and harvesters being economically vulnerable (receiving little income compared to middlemen and exporters) are key obstacles towards sustainable use (Natusch & Lyons, 2012). Pet trade has, next to habitat destruction, been a major driver threatening the turquoise dwarf gecko *(Lygodactylus williamsi)* that is endemic to two small forests in eastern Tanzania (Flecks *et al.*, 2012). Also, many turtles are traded as pets, potentially causing population declines in their natural habitat (Bush *et al.*, 2014; Ceballos & Fitzgerald, 2004; Lyons *et al.*, 2013; Nijman & Shepherd, 2015). In particular, Asian turtles are also being kept as pets, in addition to being collected or farmed for food and traditional Chinese medicine and hence have been reported to be heavily exploited and threatened (Cheung & Dudgeon, 2006; Nijman & Shepherd, 2015).

Primate species have also been threatened by the pet trade around the world (Ni *et al.*, 2018; Norconk *et al.*, 2020). Over two thousand individuals from seventeen Indonesian primate species continued to be sold in numerous open wild species markets as recorded intermittently from 1990 through 2014 (Nijman *et al.*, 2017). In the early 2000s while orangutans, gibbons, langurs, macaques and slow lorises were all commonly traded, only the latter two groups made up the bulk of the trade in the last decade.

Except pet trade, fibre trade is an important driver of sustainable use of wild species. Vicuñas *(Vicugna vicugna)* produce one of the finest natural fibres in the world. Due to its fineness, vicuña occupies a position in the luxury fashion market. It is used to produce garments, shawls and stoles for retail mainly in high end shops in Italy, Japan and Dubai. Before 1980, vicuñas were almost extinct due to overhunting. By 1960, it was estimated that the vicuña population had dropped from its pre-colonial population of 2 million to an estimated 10,000 individuals **(Figure 4.11)**. International, regional and national conservation efforts were successful in halting further population decline. Strict conservation regulation, through the Vicuña Convention, and the entry into force of the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1975, helped to rebuild populations (Lichtenstein, 2010). After a successful first stage of absolute protection, a second stage started with the involvement of local communities in the national programs for conservation and management of the species. In 1979 the Convention for the Conservation and Management of Vicuña, was signed, which promoted the economic exploitation of the species

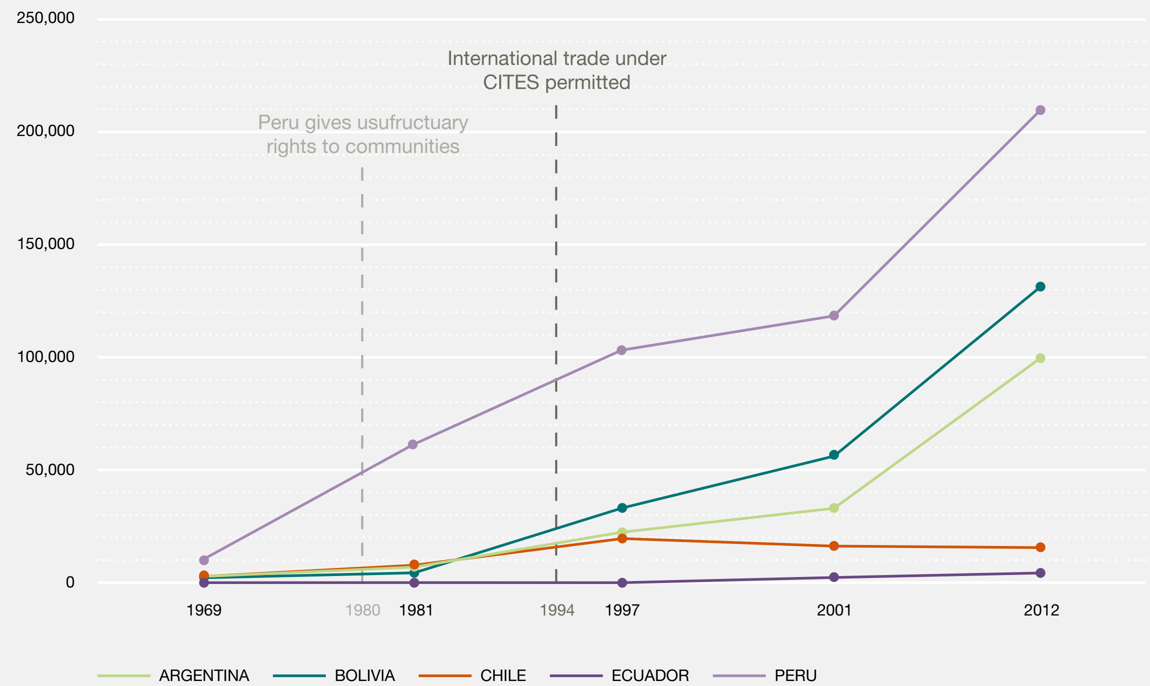


Figure 4 11 **Change in vicuña numbers in the Andean countries 1969–2012.**

Source: Katerina and Lichtenstein (2018).

"for the benefit of the Andean people" (Article 1, Convention for the Conservation and Management of the Vicuña, 1979). The involvement of local Andean communities in vicuña management, and fibre trade was key to the recovery of the species (Lichtenstein, 2010). On top of the historical strong cultural link between Vicuñas and Andean communities (Vilá *et al.*, 2020) (see chapter 1), vicuña have become an economic asset to communities, reducing poaching and motivating communities to carry out anti-poaching and protection. From the community perspective, vicuña management also fulfills non-economic objectives. In the cases of Bolivia and Peru, these entail enhancing community identity, social cohesion, revitalizing communal work, reaffirming community boundaries and a means to solidify land claims (Lichtenstein & Ros, 2021). Participating in vicuña use probably also helps remote (and usually neglected) communities to become visible to local and central governments and be in a better position to ask for credit, schools, health service, better roads, infrastructure and support for economic activities (Lichtenstein, 2010). At present vicuñas are categorized as Least Concern (International Union for Conservation of Nature SSC Red List), and the current population trend is increasing (Acebes, 2019). Sustainable use through legal trade was key to success (Cooney, 2019). Without trade in vicuña fibre it is likely that communities will lose motivation and capacity to conserve vicuña and this could spark poaching and conflicts with domestic livestock (Vilá *et al.*, 2020). Overall exports of vicuña fibre from range countries were approximately 60,000 kg of fibre over the period 2007–2016. Peru is the main exporter of vicuña fibre, accounting for 80% of exports (Kasterine & Lichtenstein, 2018). Peru produced 58,8 tons of fibre from 2012 to 2018 as a result of shearing 34200 vicuñas (Ministerio de Agricultura y Riego 2019).

Wild species trade: Logging

There is established evidence that trade is an important driver affecting sustainable use of forests. However, there is incomplete information regarding under which conditions trade alleviates and when it aggravates pressures. Chaudhary *et al.* (2017) use a model to project species extinctions of four vertebrate taxa (mammals, birds, amphibians and reptiles) due to wood extraction in 174 countries. Globally, 485 species are projected to go extinct due to current forest land use, where 32% of this projected loss can be attributed to exports. At the same time, trade reduces pressure on forests in importing countries. If the same consumption level would have to be met by only domestic sources, an additional 334 species are projected to go extinct (Chaudhary *et al.*, 2017). Hence, trade may encourage sustainable ways of use in some areas, and lead to unsustainable uses in others.

There may also be important socio-economic dynamics as wild species are exploited over time (Marchak, 1995). In some cases, when commercially valuable tree species are gone, highly capitalized loggers may be replaced by lower budget loggers. Also, logging and land conversion for agricultural purposes often goes hand in hand. In some cases, landholders may convert the stocking forests even without using one single log because agriculture is so much more attractive, yet in other may even use the cash generated from timber to convert forests to plantations. Some smallholders making a living in forest landscapes supplement their incomes from logging (Angelsen *et al.*, 2014) but as far as the rapidly depleting forests still allows it. Another important group depend on chainsaw milling with intensities that vary, leading to incremental forest degradation (Eba'a Atyi *et al.*, 2016). Only limited number of communities have proven successful to sustain their commercial timber operations over time and remain competitive in timber market (Bray, 2020; Medina & Pokorny, 2011; Pokorny, 2013; Stoian *et al.*, 2018) yet that results from a combination of different factors, mainly long-term external support, willingness to maintain relatively lower extraction rates, access to high value timber species, and strong market engagement (Pacheco, 2012).

In tropical countries, trade liberalization has contributed considerably to deforestation in the past (Abman & Lundberg, 2019; Kaimowitz & Angelsen, 1998; Marchak, 1995; D. Pearce *et al.*, 2003). In the period from 2001 to 2012, enacting regional trade agreements has led to significant increases in deforestation, with cumulative effects of 19%–26% above the annual average three years after removing the trade barriers (Abman & Lundberg, 2019). Often, deforestation is mediated by unclear property rights, corruption and overall insufficient incentives to conserve tropical forests (Bulte & Barbier, 2005; Ross, 2001). Though logging contributes to deforestation, conversion towards agricultural land is an important mechanism explaining deforestation as well (Abman & Lundberg, 2019; Faria & Almeida, 2016).

Big-leaf mahogany *Swietenia macrophylla* King (Meliaceae) is an important timber species in Latin America that is globally in high demand. Over the past decades, lacking enforcement and unsustainable harvest have depleted local stocks (Blundell, 2004; Kometter *et al.*, 2004). As a result, it has been the first commercial timber species that has been listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which implies that trade is restricted and controlled (Blundell, 2004). As a result, mahagony harvests have slowed down considerably in most regions (Grogan *et al.*, 2010). For example, in Peru export volumes reached 52,138 m^3 in 2002, while they gradually reduced to 3,071 m^3 in 2007 (Grogan *et al.*, 2010). At the same time, transforming an unsustainable timber sector towards sustainability, bears the risk that illegal extracted timber enters the legal channel. In the Peruvian Amazon, efforts are made to promote sustainable logging in the tropics. Peru introduced a legal concession timber harvesting system in 2000, which was later also part of the United States–Peru Trade Promotion Agreement, to curb illegal and unsustainable practices (Finer *et al.*, 2014). Yet, there is evidence that legal concessions are used to also harvest trees in unauthorized areas, thus undermining conservation efforts (Finer *et al.*, 2014). Illegal extraction is hard to detect if illegal harvests outside the concession are declared as authorized timber harvesting. Unless someone inspects the exact location where the logging should have taken place (and notices that the tree is still there or was never there in the first place) the violation will not be detected further down the value chain (Finer *et al.*, 2014). Since most controls take place outside the forests, violations will not be detected easily.

Rosewood, mostly originating from Africa, is a highly priced commodity and tropical forests are threatened by increasing global demand since the early 2000s (Waeber *et al.*, 2019). In 1992, Brazilian rosewood *(Dalbergia nigra)* was placed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix I in 1992. In 2013, Siamese rosewood *(Dalbergia cochinchinensis)* and all Malagasy species of *Dalbergia* and *Diospyros* (ebony) were added to Appendix II (Waeber *et al.*, 2019). Yet, lack of clarifity about which rosewood species are exploited and how to identify those makes it notoriously difficult to separate legal harvests from illegal ones. Rosewood comprised 35% of the value of all global wild species and forest product-related seizures from 2005 to 2014 (Waeber *et al.*, 2019). A key challenge remains that the Convention on International Trade in Endangered Species of Wild Fauna and Flora regulations are based on individual species, while even experts are often unable to identify and distinguish different species. Also, harvesters do not consider individual species (or genera), but rather consider the quality of the wood (Waeber *et al.*, 2019). As a result, harvesters often end up in illegal practices, intentionally or unintentionally. If taxonomic confusion and weak governance render sustainable use impossible, uplifting to Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix I may be the only way to prevent overexploitation, as has been suggested for Malagasy rosewood (Waeber *et al.*, 2019). While the Convention on International Trade in Endangered Species of Wild Fauna and Flora regulations are often very specific, information further down the value chain is much more crude, which makes enforcement and detection very difficult. For example, United Nations Comtrade Harmonized System (HS) Codes are often fairly general with broad descriptions, opening a channel for illegal harvests (e.g., 26% of seafood trade is declared as "Fish" and 22% of furniture trade is declared as "Tropical wood" (Andersson *et al.*, 2021).

Mediating factors of trade

Formal international wild species trade can link the high market with local indigenous/rural communities (e.g., python breeding (Lyons & Natusch, 2011); vicuña fibre trade (Lichtenstein, 2010)). Where local stakeholders benefit directly from a resource (with cash and also non cash benefits), they may have an incentive to protect it (Salafsky & Wollenberg, 2000). This is of course only possible if the different practices and wild species trade can be regulated, monitored, controlled, and enforced. In practice, enforcing regulation turns often to be unfeasible and difficult (Nielsen & Meilby, 2015). In such case, trade bans can play an important role in halting unsustainable use of threatened species. One example here is the International Whaling Comission that have contributed to the recovery of many whale species (Hurd, 2012; Roman *et al.*, 2015). Also, trade relations are salient for sustainability outcomes. if most of the revenues from trade go to outsiders (e.g., middlemen), there may be little incentive to conserve for local communities (Elsler, 2020; Natusch & Lyons, 2012). Appropriately governed, trade may provide incentives to relevant local stakeholders to conserve and generate economic support to area-based conservation initiatives ('t Sas-Rolfes *et al.* 2019). However, the mere fact that conservation would be beneficial to local communities, does not imply that strong incentives to conserve exist and conservation materializes. A study on the wildlife trade in Madagascar revealed that the households who are most dependent on the resource (and were expected to have the strongest interest to conserve) did not have different perception on conservation or were more inclined to take conservation efforts (Robinson *et al.* 2018). In the Columbian Amazon, most hunters now primarily hunt for subsistence, with only little pressure on wild species, but also little incentives to conserve (Ponta *et al.*, 2019). While trade could be part of a strategy to incentivize conservation and also sustainable harvesting, there is also the risk that hunting rates outpace any efforts to implement conservation programs and rules regulating access and sharing of benefits. Hence, to ensure ecological and economic sustainability trade should go hand in hand with clear rules and regulations, ideally co-designed and co-enforced by local communities (Ponta *et al.*, 2019).

If – and only if – trade generates benefits to local communities, it may promote rural development, contribute to avoid rural migration, return equitable profits from nature conservation to local communities, catalyze community investments in nature conservation, law enforcement and stewardship of wild species (Cooney *et al.*, 2015; Jaramillo Castro, Lorena, 2012; Roe, 2009); but see Dzvimbo *et al.* (2018). Therefore, wild species trade can give incentives to conserve habitat and species, potentially leading to species recovery (e.g., crocodiles in Australia (Fukuda *et al.*, 2011), the Amazonian pirarucu (Campos-Silva & Peres, 2016)). Empowering local people to capture legal benefits from wild species trade can be an important step in reducing excessive illegal harvests, when efforts to provide alternative livelihoods are unsuccessful (Ripple, Abernethy, *et al.*, 2016).

Local livelihood outcomes of wild species trade may provide incentives for conservation but also for overexploitation and extirpation (e.g., endangered frog M *cowani* in Madagascar (Andreone *et al.*, 2006), parrot harvest (*Ara ararauna, Ara macao* and *Amazona amazonica*) in Peru (González, 2003), plants, algae and fungi gathering (Kusters *et al.*, 2006; Lybbert *et al.*, 2011)). Balancing livelihood outcomes and conservation goals results in trade-offs, and sometimes it is challenging to reconcile both objectives (Robinson *et al.* 2018).

International demands, and high market value of traded species may encourage intensified exploitation, intensification or captive breeding, causing in some situations resource stocks to decline (Fischer, 2010). Moving from wild harvest to intensive management systems, including captive breeding for animals and cultivation, plantations and/or artificial propagation for plants, fungi and algae, can create benefits for or risks to conservation and livelihoods (Cooney *et al.*, 2015). Concerns over the conservation, animal welfare, and local livelihoods impact of captive breeding were raised for several species. Captive breeding provides little or no incentive for *in situ* management and conservation (Lichtenstein & Vilá, 2003; Lyons & Natusch, 2011; Natusch & Lyons, 2012); it may create incentives for converting natural habitats (Weinstein & Moegenburg, 2004), depleting wild populations to secure breeding stock and reduces incentives for *in situ* management and conservation (Cooney *et al.*, 2015).

Although international wild species trade is a big business, the distribution of benefits along the commodity chain remains usually uneven, with resource owners and users receiving only a fraction compared to intermediaries and retailers (Jenkins *et al.*, 2002; Kasterine & Lichtenstein, 2018). Interventions aimed at enhancing benefits to local communities, and minimizing impacts on collected species, could be considered to promote opportunities from the trade (Robinson *et al.*, 2018).

Informal wild species trade within countries, i.e., domestic, contributes to food security for millions of people, particularly in developing countries (Cawthorn & Hoffman, 2015; Coad *et al.*, 2019). Despite its lack of recognition in national level accounting, rural people, including indigenous peoples and local communities, rely on trading wild resources, by selling and consuming wild meat, fish, insects and plants, extracting timber and forest products, and many other activities (Roe *et al.*, 2020). Domestic trade can support the survival of traditional knowledge and culture by linking local communities in local/regional markets (Tinitana *et al.*, 2016).The literature identifies three primary roles for wild species trade in supporting rural livelihoods: (i) supporting current consumption, (ii) providing safety-nets in response to shocks and gap-filling of seasonal shortfalls, and (iii) providing means to accumulate assets and providing a pathway out of poverty (Angelsen *et al.*, 2014).

Illegal wild species trade and the role of regulation

The illicit trade in animal products for consumer markets is global and putting many species at risk of extinction (Challender & MacMillan, 2014; Duffy, 2016; MacMillan *et al.*, 2017; Phelps *et al.*, 2016; Rosen & Smith, 2010; ‘t Sas-Rolfes *et al.*, 2019). Recent estimates of illegal logging, illegal fishing, and illegal wildlife trade in 2016 are between 69-199 billion United States Dollars a year (World Bank, 2019). However, the full impacts, including impacts on ecosystem services, are estimated to be between 1 and 2 trillion of United States Dollars per year (World Bank, 2019). In the case of elephants, an estimated 100,000 elephants of both savanna elephants (Loxodonta africana) and forest elephants (L. cyclotis) were poached between 2010 and 2013. In some countries, elephant populations declined by over 50% in under 10 years. Chase *et al.* (2016) estimated a population of 352,271 savanna elephants on study sites in 18 countries, representing approximately 93% of all savanna elephants in those countries. Elephant populations in survey areas with historical data decreased by an estimated 144,000 from 2007 to 2014, and populations were currently shrinking by 8% per year continent-wide, primarily due to poaching (i.e., illegal hunting) (Chase *et al.*, 2016).

Concerns are growing that illegal hunting to procure ingredients for traditional medicine, is becoming the major threat to the survival of high-value conservation species including tiger *(Panthera tigris)*, pangolins (e.g., Chinese pangolin *(Manis pentadactyla)*) and rhinoceros (e.g., Rhinoceros spp). Increased urbanization and a growing middle class in Asia have increased demand for wild meat and are fueling the lucrative illegal wild species trade, and potentially undermining rural livelihoods and food security (Lee *et al.*, 2014, 2020)).

In the South Fly region of Papua New Guinea, illegal trading of Bêche-de-mer (dried sea cucumbers), shark fins, and fish maw (dried swim bladders) is a serious threat to sustainability of marine species (Busilacchi *et al.*, 2021). While legal and illegal commodities typically served the same Asian cities, the channels travelled different routes. In spite of prices offered by illegal middlemen being significantly lower than those offered by legal buyers, many fishers engage in illegal market (Busilacchi *et al.*, 2021). The underlying reasons were dependencies to middlemen or kinship ties, urgent need for cash or inaccessibility of legal markets, or simply lacking information about legal alternatives (Busilacchi *et al.*, 2021).

Illegal trade is often also supplied by species that were caught or hunted unintentionally. The inability to select or choose target species may imply that protected species may be caught. For example, snare traps capture most forest mammals, birds and reptiles regardless of protection status (Bowen-Jones & Pendry, 1999; Mbete *et al.*, 2011; Noss, 1998). Also, many in fisheries many protected species are caught as by-take or by-catch (Lawson *et al.*, 2017). For example, seahorses are often caught as bycatch in trawl fisheries (Kuo *et al.*, 2018).

Many orchid species around the world are under threat from illegal and unsustainable trade for horticulture, food and medicine (Hinsley *et al.*, 2018). A key challenge is that insights on the legal and illegal trade dynamics, and how those channels interact are largely incomplete (Hinsley *et al.*, 2018). To transform the orchid trade towards sustainability, it is vital to track, trace, and sanction illegal trade and harvesting and also incentivize sustainable methods (Hinsley *et al.*, 2018). This could involve uplisting orchid species from Appendix II to Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, use DNA barcoding to identify individual species and also establish small scale sustainable orchid breeding businesses (Subedi *et al.*, 2013). Illegal wild species trade has been consistently tied to unsustainable levels of exploitation. Trade that is illegal and unsustainable, but preserves some level of social legitimacy among harvesters, and consumers, can undermine policies. Even though very large overall volumes of illegal wild species trade are observed, trade structure is very complex (e.g., role of corruption) and highly heterogeneous, and extracting information from the trade is difficult because it is illicit, posing challenges to enforcement actitivies and policy solutions. Moreover, the illegal trade of wild species is often interconnected with the legal trade. There is therefore a strong need for legal trade to be heavily monitored and regulated (van Uhm & Moreto, 2018).

Harvesting and trade of wild species is often regulated through a large number of laws and regulations –sometimes internally contradicting, undermining sustainability goals (de la Torre *et al.*, 2011). A comparative analysis in Colombia, Ecuador, Peru, and Bolivia on plants, algae and fungi identifies the inconsistency of legal norms, such as internal contradictions between national legislation and indigenous rights, and lack of clarity regarding legal requirements or e responsibilities of individual authorities as the main obstacles (de la Torre *et al.*, 2011).

In most African countries, hunting is regulated by legal instruments, usually controlled through systems of licensing and quotas. Wild species are generally either considered to be without ownership *('res nullius)* or owned by the state or president (Lindsey *et al.*, 2013). What make sustainable uses more difficult is the use of unselective capture techniques. For example, the use of snare traps are not species-specific, but capture most forest mammals, birds and reptiles (Bowen-Jones & Pendry, 1999; Mbete *et al.*, 2011; Noss, 1998).

In 2001 the Indonesian Department of Forestry and the Wild species Conservation Society established the Wild species Crimes Unit in North Sulawesi, to curb over-exploitation of wild species. Over a two-year period, 6963 wild mammals on their way to markets were encountered, which is about 8 individuals per hectare and 96,586 wild mammals were documented during market surveys (Lee *et al.*, 2005). While the trade of some protected mammals declined significantly over this period, overall trade in wild mammals increased by 30%, indicating that traders switch from controlled to uncontrolled species (Lee *et al.*, 2005). For example, high volume of trade in non-protected species such as the Sulawesi pig *Sus celebensis* and large flying foxes (Pteropodidae), imply a greater risk of unsustainable harvesting for unprotected species (Lee *et al.*, 2005).

Trade creates higher revenues in exporting countries, which may imply a shift from open access towards stricter enforcement (Copeland & Taylor, 2009). There may have higher revenues, mediated through trade may initiate a transition towards more private property, but also common property, depending on what makes monitoring easier, as shown for the case of palm trees in Nigeria (Fenske, 2014).

The International Tropical Timber Agreements, for the first time signed in 1983, encourage trade from sustainably managed forests. Global data reveals that total timber exports from member countries have not decreased as a result, but rather exports have shifted from member to non-member countries. Also exports have shifted across timber categories (Houghton & Naughton, 2017). In particular, tropical country members increased plywood exports.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international treaty to prevent species from becoming endangered or extinct because of international trade. Under this treaty, countries work together to regulate the international trade of animal and plant species and ensure that this trade is not detrimental to the survival of wild populations. Any trade in protected plant and animal species should be sustainable, based on sound biological understanding and principles. In 2021, CITES has 183 Parties, and it regulates international trade in approximately 35,800 species, 84% of which are plants. It includes species in its three appendices with corresponding trade controls implemented through national legislation and enforcement measures. Endangered species are listed in several Appendices that have different legal implications and give different protection status. 3% of species (~1,000) are included in Appendix I, prohibiting any commercial international trade in wild-harvested specimens. Ninety-seven percent of species (35,000) are included in Appendix II, requiring trade to be closely regulated and subject to a nondetrimental finding by the exporting country's Scientific Authority. This may also involve a process of setting and controlling trade quotas.

Appendix III is a list of species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation, and it encompasses 220 species.

Overall, CITES listings have a positive impact on sustainability by regulating trade, though it does not close all loopholes and may give adverse incentives when it comes to conservation (Conrad, 2012; Harfoot *et al.*, 2018; Phelps *et al.*, 2010; Rivalan *et al.*, 2007b). Since CITES has been implemented, trade has shifted towards captive-sourced trade, alleviating pressure on wild species. At the same time, there is a risk that what is documented on paper does not match harvesting from the field and illegal harvests are declared and traded as legal (Finer *et al.*, 2014; Lyons & Natusch, 2011). In Southeast-Asia, at least 35 million animals (0.3 million butterflies; 16.0 million seahorses; 0.1 million other fish; 17.4 million reptiles; 0.4 million mammals; 1.0 million birds) that were listed by CITES were exported in the period 1998–2007 (Nijman, 2010a). Of those, at least 30 million animals, which comprises about 300 species had been caught in the wild (Nijman, 2010a). Also, 18 million pieces and 2 million kg of live corals were exported (Nijman, 2010a). The main importers are European Union and Japan, while main exporting nations are Malaysia, Vietnam, Indonesia and China (Nijman, 2010a).

Trade bans may reduce the risk of biological invasions in destination countries (Cardador *et al.*, 2019). A limitation of the effectiveness of CITES lies in its very nature that it regulates international trade, while trade often is domestic. For example, in Japan two species of bears (*Ursus thibetanus* and *U. arctos*) are hunted and traded for their gallbladder and meat mostly domestically. By removing legal trade, incentives to preserve wild species may diminish; this can push trade 'underground' where it is unmonitored, uncontrolled, and ultimately the preservation of a species can be ineffective and lost (Biggs *et al.*, 2013; Conrad, 2012; Hutton & Dickson, 2000; Hutton & Leader-Williams, 2003; Rivalan *et al.*, 2007b). Prohibition on trading wild species products such as tusks and timber reduce supply (which is the whole point), but this also tends to drive up illegal prices. Often, markets are supplied illicitly despite the trade's prohibition under CITES as poaching gangs are incentivized largely due to very high prices for these illicit goods (MacMillan *et al.*, 2017).

Also, prohibiting trade does not necessarily create incentives for conservation, which could be especially relevant if the habitat of a species interacts with alternative land uses. Red Sanders (RS, *Pterocarpus santalinus* L.) is an endangered timber tree species in Andhra Prades in Southern India. The species was put on the list of endangered species by CITES, restricting international trade substantially. Only a small quantity auctioned by governmental agencies enter the international market. High demand and limited supply from private landowners, creates strong incentives for illegal removals from public forests. Local communities do not tend to benefit from timber harvesting (as it is illegal) and does not create any incentives to conserve the forest. Providing incentives to private landowners to grow red Sanders on private land and ensuring that local communities benefit are key elements to encourage practices that are economically and ecologically sustainable. Yet, facilitating sustainable trade, without also creating opportunities to intensify illegal harvests is perceived as very challenging by various stakeholder groups.

A further challenge in implementing CITES Appendix II listing of species arises if species are caught as by-take or by-catch. The whole genus of seahorses was listed in CITES Appendix II in 2002 because of the adverse effects of harvests and trade on sustainability of wild populations. Evidence from Thailand suggested that seahorses where often caught as bycatch in trawl fisheries, allowing fishers to continue fishing if harvesting the target species was not so profitable, for example due to overexploitation. Globally, most of these by-catches were sold and traded without entering official statistics. As a result, official CITES data is often substantially lower than actual catches. Declining abundances, as reported in Malaysia and Thailand suggests that current harvest rates are unsustainable. What hampers sustainable use is the fact that CITES process of listing or uplisting can be slow and respond with a delay to evidence on how threatened-status of a species. Also, sustainable use would be further facilitated if trade data collected by public authorities mostly for tax reasons were closer aligned with individual species to provide insights on scale of trade.

4.2.4.4.2 Global financial flows

Key messages:

- "Tax havens" and global crime facilitate unsustainable use of wild species *(established but incomplete)*

- Micro-credits and foreign investments can play a positive role in enabling sustainable uses if properly combined with wider enabling factors such as investments in human and social capital, but investments may also enable destructive, and unsustainable use *(inconclusive)*

- In some cases, remittances play a role in supporting livelihoods and may reduce pressure on resources, but may also provide the capital to enable unsustainable uses and practices *(inconclusive)*

Financial actors, such as international development and commercial banks and institutional investors are increasingly interested in sustainability, and play a role in ecosystem change (Galaz *et al.*, 2018). 'Green' finance, with the explicit goal to have positive ecological and social impacts holds potential to contribute to sustainable use of wild species, though it is currently a niche market, as green bonds account for less than 0.6% of the total market (Scholtens, 2017). Also, most 'green' initiatives tend to focus on reducing emissions, rather than ecosystem change (Galaz *et al.*, 2018). Conservation finance is a promising instrument to facilitate and incentivize the sustainable use of wild species (Huwyler *et al.*, 2014; Meyers *et al.*, 2020; UNEP, 2021). Conservation finance can be defined as 'mechanisms and strategies that generate, manage, and deploy financial resources and align incentives to achieve nature conservation outcomes" (Meyers *et al.*, 2020). Obstacles around conservation finance are related to underfunding, and also inefficient use of available funds, i.e., funds not ending up where they would make most sustainability impact (Anyango-van Zwieten, 2020, 2021). Financial standards may play a positive role in promoting sustainable practices. The recent Principles for Investment in Sustainable Wild-Caught Fisheries (www.fisheriesprinciples.org), launched in 2018 represent a voluntary framework to provide guidance to financial institutions in ensuring that investments in wild-caught fisheries are in line with environmental sustainability and social responsibility (Jouffray *et al.*, 2019). While there is established but incomplete evidence of large flows of finance being channeled through tax havens enabling unsustainable practices, there is much fewer, and generally inconclusive evidence of global financial flows being used to enable sustainable practices regarding the use of wild species. Literature on foreign investments targeting the sustainable use of wild species is limited to examples of micro-credit schemes and remittances, with a noteworthy absence of literature on larger foreign financial flows. Also, while large (foreign) corporations tend to have a key impact on sustainability, evidence on the question under which conditions those key actors can contribute to sustainable use of wild species is inconclusive.

The role of "tax havens" and global crime

An increasingly globalized financial system may create opportunities and loopholes to engage in unsustainable and illegal practices. While it is well established that tax havens can have a decisive role in enabling the unsustainable use of wild species, evidence on the size of the actual impact is incomplete. Recent estimates show that between 10 and 30% of all foreign direct investments are channeled through tax haven jurisdictions (Galaz *et al.*, 2018). Galaz *et al.* (2018) investigated flows of foreign capital from financial actors based outside Brazil, to the nine largest companies operating in the soy and beef sectors of the Brazilian Amazon — two sectors representing key drivers of deforestation. Between October 2000 and August 2011, 68% of all investigated foreign capital into this region was transferred through tax havens, representing 90–100% of foreign capital for some companies investigated (Galaz *et al.*, 2018)

In the fishing industry, 4% of all registered vessels worldwide are currently flagged in a tax haven (Galaz *et al.*, 2018). Belhabib, Greer, and Pauly (2018) used the database of the Criminal Record of Fishing Vessels, that includes all vessels that were caught or identified as involved in illegal, unreported, and unregulated fishing within national, regional and high seas jurisdictions, to investigate whether or not the vessels (2,800) and their associated companies or owners (900) were blacklisted. Using such list, less than 2% of fishing vessels caught or observed specifically engaging in unreported and unregulated activities were flagged in tax haven jurisdictions at the time of the offence, and only 11% of the total number of offending vessels belonged to companies whose address was listed within a tax haven jurisdiction (Belhabib & Le Billon, 2018). Still, tax havens play a larger role when looking at the vessels that have been caught violating more often and are consequently blacklisted. Using a list of 209 blacklisted vessels by regional fisheries management organizations and the vessels for which a purple notice was issued by the International Criminal Police Organization, Galaz *et al.* (2018) found that 70% of the known vessels engaging in illegal, unreported and unregulated fishing are, or have been, flagged under a tax haven jurisdiction, in particular Belize or Panama.

The use of tax havens is problematic firstly because of substantive losses in tax revenues, undermining public investments in accordance with, among others, the ambitions of the United Nations Sustainable Development Goals. Secondly, the use of these jurisdictions reduces financial transparency, making it difficult to track the contribution of distant financial flows to sustainable use of wild species in land- and seascapes globally (Galaz *et al.*, 2018).

While vessels have a salient role, ports are important, too. There are 4764 ports across the globe where fish might be offloaded, and approximately 2395 of these ports are under no legal obligation to implement the Food and Agriculture Organization of the United Nations Agreement on Port State Measures requiring inspections (Telesetsky, 2014). Also, complex financial transactions that may involve third-party state tax havens, and digital currencies play a role in facilitating the sale and trade of illegal catches (Telesetsky, 2014). Enforcing sustainable fishing practices through monitoring, control and surveillance projects requires substantial investments and maintenance costs. In West-

African coastal countries, this implies reliance on foreign funding, where the longevity and stability can be uncertain (O'Neill *et al.*, 2018).

Global drug-trafficking has an increasing impact on the sustainable use of wild species. It has been estimated that the contribution of fishing vessels to drug trafficking has tripled between 2010 and 2017 and may account for 15% of the global retail value of illicit drugs (Belhabib *et al.*, 2020). This may fuel overcapitalization of fishing fleets and intensify fishing efforts and ultimately undermine conservation goals. In a similar vein, cocaine trade has been shown to lead to deforestation in Central America (Wrathall *et al.*, 2020). Drug trafficking has negative impacts on conservation, as it (i) undermines social relations and participation that are needed for conservation, (ii) fuels a highly extractive and unsustainable activity taking place in remote, and often conserved areas, and (iii) erode conservation institutions and replace them with new rules around resource use and access (Wrathall *et al.*, 2020).

Foreign investments and role of large corporations

If extractive resource use is capital intensive, large corporations tend to play a large role in sustainability outcomes, though the exact impacts are inconclusive. Foreign investment in forest products, such as timber, pulp, and paper can be a factor in driving forest conversion (Seymour & Forwand, 2010). Large capital requirements and the ability to cope with price fluctuations in certain industries tend to attract larger and vertically integrated companies, the Ghanaian tuna fishery being one example (O'Neill *et al.*, 2018). Here, smaller companies showed to be weakly resilient to the constant fluctuations in prices, landings and wider financial-market dynamics typical for the global fishing industry. Bigger companies were more resilient, being protected by larger parent corporations with access to substantial capital, often less reliant on and less beneficial to local economies (O'Neill *et al.*, 2018). In fishing, large corporations have a sizable impact on global marine stocks and can play influential roles in political decision-making. These corporations can thus be seen as keystone actors in the global seafood industry, with the ability to play a key role for positive and negative outcomes sustainability in this industry (Österblom *et al.*, 2015).

On the Solomon Islands, unregulated investment in tropical timber harvesting, has led to ecologically unsustainable outcomes and created economic and political vulnerabilities (Firth, 2007). A study from the Fujian Province in China, where deforestation has been a major problem shows that more sustainable practices using a mix of longer standing species offer a potentially better return (Ying *et al.*, 2010). Property rights reforms that stimulate private, and also potentially foreign investments, have played a role in a transition towards more sustainable practices in that case (Ying *et al.*, 2010).

Micro-credits

Loans in the form of micro-credits combined with trainings or briefings by the loan provider on the environment have shown to be effective in positively changing attitudes towards ecosystems in coastal communities. In a case study on coastal community livelihoods in Aceh, Indonesia, a community-based micro credit program resulted in 35% of respondents reporting a positive change in behavior towards the marine environment, among which a large group of fishermen (Novriyanto *et al.*, 2012). These behaviors included acting if they found someone littering the ocean or removing coral. Reasons for this changed behavior included understanding the importance of protecting the marine environment but also general abiding by the micro-credit provider's conservation principles (Novriyanto *et al.*, 2012). A micro-credit plan that was combined with training on, e.g., health and hygiene, coastal ecology and home industries in coastal villages in India, has had a positive impact on the economic status of women, as well as increased awareness of the importance of conserving the coastal ecology (Lakshmi & Rajagopalan, 2000).

However, loan programs can be ineffective when improperly targeted. For instance, a micro-credit loan scheme of the Indonesian government to promote smallholder timber production gained insufficient interest among smallholder farmers due to mismatches between the loan scheme and the characteristics of borrowers. These mismatches include: a minimum loan size that is too large for small farmers to manage, an overly burdensome application and reporting process, a lack of loan management at the local level, and improper geographic targeting (Nugroho *et al.*, 2013).

Also, a study in coastal villages in the Iloilo Province, Philippines, shows that external financial support from non-governmental organizations can be an important mechanism to diversify economic activities and curb overfishing (Andriesse, 2019). However, financial capital will always be a complement to social and human capital, and the combination of those will affect sustainability outcomes. Hence, programs aimed at encouraging fishers' livelihood diversification to reduce overfishing need to take all those forms of capital into consideration (Andriesse, 2019). While various independent studies have shown the potential of loans to support sustainable use of wild species, the overall evidence how these maps to sustainability outcomes is incomplete.

Remittances

Overseas remittances constitute a substantial foreign financial flow in a number of developing countries, and an important source of income for many rural and coastal households. For such households, remittances can be a poverty alleviation strategy, especially in the short term.

The evidence of remittances leading to sustainable or unsustainable use of wild species is inconclusive.

In the coastal community of Lofanga, Tonga, overseas remittances were identified as a supporting factor for local fishing practices not yet turning into overexploitation of the open access fishery system. Remittances in this community are a sustaining factor for current, traditional ways of living and fishing, without perceptible detrimental impact on the local fish stocks (Kronen & Bender, 2007). In Java, Indonesia, remittances sent home by mobile (mostly female) family members are used to invest in rural resources, such as dairy cows or planting of elephant grass as a fodder crop (Peluso & Purwanto, 2018) with positive impacts on local livelihoods.

Yet, remittances can also provide capital for changing to capital-intensive land uses such as timber production, potentially undermining sustainable use of wild species (Mayer, 2019). Still, the use of remittances for changing practices remains limited. Often, only a small fraction of remittances is used in capital formation, the largest share being used for daily consumptive purposes (Andriesse, 2019; Cedamon *et al.*, 2018). In the Sierra Gorda Biosphere Reserve in Mexico, most people rely to a large degree on remittances from emigrants. These remittances reduce financial pressure, but do not necessarily reduce incentives to hunt illegally (Arroyo-Quiroz *et al.*, 2017).

In coastal communities reliant on fishing as primary livelihood, using remittances for investments can be especially difficult due to characteristic limiting factors, such as poor infrastructure, weak human, financial and social capital and attachment to traditional ways of living (Andriesse, 2019). The impacts of investments – and the lack thereof – on sustainability outcome is inconclusive.

4.2.4.4.3 Tourism

Key messages:

- Activities related to tourism and supporting infrastructure may disturb wild species and undermine sustainability outcomes. At the same time, revenues from tourism can be used for conservation projects which have positive impacts on sustainable use of wild species *(unresolved)*.

- Traditional practices that are ecologically more sustainable, but economically less profitable may be supported when linked to tourism activities that generate additional revenues. At the same time, certain tourism related activities, such as the sale of wildlife parts and the use of live animals in entertainment, incentivizes unsustainable and sometimes illegal practices *(unresolved)*.

- In some cases, extractive forms of tourism (i.e., terrestrial animal harvesting and fishing) has a positive impact on ecological, social, and economic sustainability by generating revenues for conservation and livelihoods. However, in many cases the revenues do not reach local communities, do not contribute to conservation, and extractive tourism is unsustainable *(unresolved)*.

Mostly, tourism can be categorized as a non-extractive practice, though tourism based on trophy hunting and fishing can be described as extractive. Tourism itself is not a driver, but a practice, where the underlying driver is increased mobility. More specifically, the opportunity to travel recreationally has increased on a global scale, and also possibilities to reach places that were inaccessible in the past for tourists.

Non-extractive forms of tourism

Non-extractive forms of tourisms, i.e., observing wild species affects sustainability in various ways. First, as a direct driver, tourist activities and infrastructure can disturb wild species, acting as a stressor. Second, tourism generates revenues which may allow for conservation investments. Third, revenues from tourists may give incentives to users to adapt practices that may be more or less sustainable. Hence, whether tourism has a positive or negative effect on ecological sustainability is highly context dependent. Pegas *et al.* (2015) assess how tourism affects the sustainability of 547 locally culturally important species. While a third of those were part of some form of nature-based tourism only three percent were actually threatened by tourism. This suggests that threats from tourism are mostly indirect, while it can play a big role in supporting species conservation and protect traditional practices.

Investment in conservation areas is an important dimension of tourism that contributes to the sustainable use of wild species. Tourism to protected areas generates an estimated 600 billion United States Dollars annually (World Bank 2018). In the United States of America alone, park fees contributed 21 billion United States Dollars in 2019 (National Park Service, 2019). In Africa, 14 countries generate an estimated 142 million United States Dollars in park entrance fees (UNWTO, 2015). Despite the growth in tourism investment over the past decade, it is estimated that African protected areas are currently experiencing at least a 1.25 billion United States Dollars funding shortfall for effective management and conservation of threatened species like lions *Panthera leo* (Lindsey *et al.*, 2016). Marine reserves cover 6.97% (25.3 million km^2) of sea area protected globally (Jantke *et al.*, 2018) compared to 14.7% of terrestrial systems (Jones *et al.*, 2018).

Responsible tourism, i.e., nature-based tourism, can play a role in conservation of wild species, provided that tourism flows and protected areas are carefully managed, and benefits are fairly shared (Das & Chatterjee, 2015; Fennell, 2020; INTOSAI WGEA, 2013). There are multiple examples where nature-based tourism as an economic development strategy has significant social and conservation benefits (Coria & Calfucura, 2012). For example, the Potato Park in the district of Cuzco, Peru is implementing an agro-nature-based tourism program, highlighting the diversity of native potato varieties, and other Andean grains such as quinoa and kiwicha (Argumedo & Stenner, 2008). It is managed by local economic collectives, where income is generated through walking tours, a restaurant using local ingredients, and through the sale of crafts and medicinal plant products (Argumedo & Stenner, 2008).

Tourism is also seen as a crucial tool, and perhaps the only viable tool, to conserve gorillas in Africa (Litchfield, 2008). For example, without mountain gorilla tourism in Uganda, it is unlikely that the small Mgahinga Gorilla National Park (34 km^2) would even exist (Litchfield, 2008). Yet, it remains unclear to what extent gorilla tourism is sustainable. Most importantly, economic and ecological sustainability ask for an optimal number of visitors to visit gorilla tourism sites, which requires appropriate governance arrangements (Litchfield, 2008).

Economic revenues from tourism in Africa amount to 4.2 billion United States Dollars in 2013 (UNWTO, 2015). Potential revenues through tourism can also play a role in stimulating more sustainable use, by incentivizing non-extractive practices, such as tourism tours overfishing or hunting. For example, Manta rays (Manta alfredi and Manta birostris) are charismatic fish species that are vulnerable to extinction. Globally, direct revenue to dive operators related to Mata rays are 73 million United States Dollars annually and direct economic impact, including associated tourism expenditures, are 140 million United States Dollars annually, making tourism substantially more profitable than Manta ray fishing (O'Malley *et al.*, 2013). In the Ningaloo Marine Park, Western Australia, manta ray interaction tourism is suggested as a non-extractive alternative towards the hunting of reef manta ray, *Manta alfredi* (Venables *et al.*, 2016). The shark-diving industry generates 18 million United States Dollars to the economy of Palau annually, benefiting several sectors of the economy, while ensuring the ecological sustainability of shark populations (Vianna *et al.*, 2012).

Nature-based tourism can also help to preserve traditional practices that are ecologically more sustainable, but economically less profitable. This is in part because of the location of indigenous communities in remote locations and ecosystems characterized by ecological diversity including wild flora and fauna, and often indigenous economic practices are less consumptive and ecologically more sustainable. For example, mycological tourism can play an important role in preserving or achieving sustainable use of wild fungi, though it is important that such activities are carefully tailored to local context to ensure that local communities are benefiting and use is indeed sustainable (Jimenez-Ruiz *et al.*, 2017). Yunnan is one of the hotspots of edible fungi in China, which has more than 600 species of edible fungi, and 30% of the edible fungi species in the world (Liu *et al.*, 2018). Increasing demand triggers overexploitation and threatens ecological sustainability and income of farmers. Traditionally, local people harvest wild fungi without destroying their hyphae, while today young harvesters often simply uproot the fungi, which is much less sustainable. The traditional culture and rich fungi resources are becoming popular destinations for eco-tourism, which may help preserving sustainable practices (Liu *et al.*, 2018).

Tourism can also play a role to maintain fishing activities using traditional gear that is less disruptive, but also gives lower yield than modern gear. One example comes from the Streat of Sicily in the Mediterranean Sea where bottom longline is a traditional fishing gear that is not used anymore, but the practice could be revived when combined with tourism activity (Cillari *et al.*, 2012). As a cautionary note, whether or not traditional indigenous practices are (more) sustainable, depends on the specific context. Traditional fishing gear is often unselective, which may lead to a more balanced catch profile, which gives ecological and economic benefits, as well as costs (Burgess *et al.*, 2016; Kolding & van Zwieten, 2014). For example, on the Galapagos islands a traditional unselective longline fishery has caused substantial undesired bycatch of protected megafauna species, such as turtles (Cerutti-Pereyra *et al.*, 2020).

Tourism can also act as a stressor, though the negative impacts of non-extractive wild species tourism on population health of wild species is poorly understood, as many studies are site-specific and lack long time series (Burgin & Hardiman, 2015). Unregulated tourism centered around wild species attractions tends to have adverse effects on wild species populations. Negative impacts stem from touristic activities, the intensification of tourism infrastructure, destruction of habitat (Mbaiwa, 2003) that can even result in reduced recruitment and juvenile survival in species like the cheetah *Acinonyx jubatus* (Broekhuis, 2018). Also, marine provisioning-tourism in the Cayman Islands has had an impact on the physiology of southern stingrays *(Dasyatis americana)*, through non-natural food, higher injury rates from boats, and higher parasite loads from crowding conditions (Semeniuk *et al.*, 2009). Increased boat traffic has also had an adverse impact on behavior and stress levels in the Scandola marine protected area (UNESCO World Heritage Site, Corsica island), on the population of the Osprey *Pandion haliaetus* (Monti *et al.*, 2018). Birds use less time to search for prey, and are more stressed, indicated by corticosterone levels in chick feathers being three times higher in high-traffic areas compared to places with lower touristic flow (Monti *et al.*, 2018). On Panaon Island in the

Visayas region of the Philippines whale shark *(Rhincodon typus)* tourism is a growing industry, where the impacts on the shark population remains unclear (Araujo *et al.*, 2017). 56% had anthropogenic scars from boat propellers, fishing gear or vessel collision, though it is not clear to what extent these are caused by tourist activities (Araujo *et al.*, 2017). This shows that motorboats can be a threat to marine species, and rules around speed limits, and also distance regulations can mitigate some of those threats.

Tourism can degrade coral reefs through coastal development, as well as through unsustainable tourist activities (Gil *et al.*, 2015). In the touristic region of the Mayan Riviera, Mexico coral cover decreased by 79% from 2011 to 2014 near the peak snorkeling area in the bay (Gil *et al.*, 2015). In a control region that was less exposed to tourists, a similar decline was not observed, suggesting that uncontrolled tourist activities were the main cause of the decline (Gil *et al.*, 2015). Improvements can be made by targeting tourists directly and educating them about how to sustainably dive or snorkel. Showing tourists a video message about sustainable use prior to a trip has led to a five-fold reduction in the rate of contact compared to a control group in an experiment in Puerto Rico (Webler & Jakubowski, 2016).

Tourism can also encourage unsustainable uses of wild species, snake charming being one example. While snake charming in Marocco is practiced for at least 500 years, it now mostly used to attract tourists (Pleguezuelos *et al.*, 2018). Mortality during transport and captivity is high and hunters select predominantly snakes that have certain traits that appeal to tourists (e.g., large body size), undermining population sustainability (Pleguezuelos *et al.*, 2018). Consequently, a population decline of Egyptina Cobra *N. haje* has been observed, though it not established to what extent this is due to hunting (Pleguezuelos *et al.*, 2018). Similarly, gathering shells and selling those to tourists has adverse effects on marine ecosystems, as shown in Zanzibar, Tanzania (Gössling *et al.*, 2004).

In some cases, nature-based tourism has resulted in unintended consequences for biodiversity (Hinch, 1998). For example, tourists may increase demand for locally caught seafood. A case study from Fernando de Noronha, located about 345 km offshore the Brazilian coast illustrates that tourists consume 70% of the caught fish, posing further sustainability challenges (Lopes *et al.*, 2017). Also, ecotourists can have very different views and relationships to nature than indigenous communities. Therefore, careful consideration of the alignment between the conservation values of the nature-based tourism enterprise and the social and cultural values of communities is critical for sustainability outcomes (Hinch, 1998).

To mitigate negative effects of tourism on wild species, it is important that management schemes are in place that make sure that tourism is taking place sustainably. This implies steering the number of tourists, which is often managed through licenses, as well as the practices, which often implies enforcing rules of conduct, and giving out licenses. For example, in the Ningaloo Marine Park, Western Australia, a management plan is implemented to make sure that whale watching takes place sustainably (Andersson *et al.*, 2014). The number of whale shark tours at Ningaloo increased by approx. 70% and the number of interactions with whale sharks by 370% between 2006 and (Andersson *et al.*, 2014).

While sustainable tourism needs to carefully regulate the number of tourists and type of tourist activities, this may create tensions. An unfair distribution of benefits within communities and inability to coordinate on a larger scale may undermine sustainable use, as was illustrated in the case of whale watching in Baja California, Mexico (Young, 1999).The poaching of African elephants is estimated to represent 25 million United States Dollars in lost revenue annually (Naidoo *et al.*, 2016). However, those annual losses to tourism are small compared to the estimated 597 million United States Dollars that ivory from Africa's poached elephants was worth annually on Chinese black markets from 2010–2012 (Naidoo *et al.*, 2016). Also, the potential benefits from conservation do not necessarily trickle down to local communities, who may still experience crop losses and damages from elephants Blignaut and de Wit 2008). Hence, the investment in conservation areas for elephants for tourism may not be as successful as it might be if communities were benefiting directly (Naidoo *et al.*, 2016). A way to counter this is to involve local communities directly into the benefit sharing of wild species populations. This can be done through either providing communities a portion of entrance fees, as done in Uganda (Ahebwa *et al.*, 2012) or including them into private land conservation schemes, as done in Kenya (S. Blackburn *et al.*, 2016).

Marine protected areas are important governance arrangements to make sure that marine resources are sustainably used. Support for such measures depend on how the costs and benefits are distributed. For example, on Mafia Island (Tanzania) a marine protected area faced local opposition because fisheries closures were affecting mostly those who live near those closed areas or have been fishing there historically. Gear and size regulations that affect all fishers similarly did not meet similar opposition (McClanahan *et al.* 2008). In a survey among locals at the Pacific Coast of Costa Rica within a 30 km radius surrounding the Manuel Antonio National Park, perceived tourism to have positive effects on biodiversity through increased values of flora and fauna and decreased hunting and deforestation (Broadbent *et al.*, 2012).

Common property rights arrangements can be an important tool to control unsustainable tourism growth and make sure that the benefits are distributed in a fair way. Such management approach was also ranked as the most favorable one among stakeholders in long-term whale shark *(Rhincodon typus)* tourism in Bahia de Angeles, located in the oriental coast of Baja California, Mexico (Rodríguez-Dowdell *et al.*, 2007). Further evidence on potential success factor of community-based management comes from Bigodi Village, located in the Kamwenge district of western Uganda. The is managed by a community-based organisation that tries to reconcile ecological, economic, and social sustainability (Gosling *et al.*, 2017). Tourism initiatives include guided walks, homestays with local households and visits to the houses of crafters, healers, and elders, where the Bigodi community benefits from the wetland sanctuary as 75–80% of the tourism generated funds are invested into village infrastructure, including a school, library, a clinic, roads, pathways, sanitation and training courses (Gosling *et al.*, 2017). Territorial user rights have shown to be a promising governance arrangements, though it requires trust and careful consideration of local contexts to foster sustainable use and reconcile conflicting objectives and practices (Biggs *et al.*, 2016).

Extractive forms of tourism – terrestrial animal harvesting and fishing

So-called 'trophy hunting' is one dimension of tourism that is fiercely controversial (F. Nelson *et al.*, 2013). The idea – and images – of the hunting of iconic species for recreational value is unappealing to a growing urban population (Biggs *et al.*, 2019; Manfredo *et al.*, 2017; Parker *et al.*, 2020). Hunting can at times have adverse population consequences (e.g., Packer *et al.* 2011), especially in combination with environmental factors (Wilfred & MacColl, 2016). The revenues by trophy hunting are sizable, but small compared to total tourism expenditures and often not benefiting local communities, leaving conservation benefits unclear in many cases (Campbell, R, 2013; Chardonnet, 2019; Grijalva, 2016; Naidoo *et al.*, 2016). In Tanzania, for instance, hunting operators distributed to the communities an average annual sum of 1.04 million United States Dollars, i.e., 0.08 United States Dollars per hectare per year (Chardonnet, 2019). For comparison, the Maasai Mara conservancies in Kenya – where trophy hunting is forbidden – distribute around 40 United States Dollars per hectare per year, while also contributing to local employment (Chardonnet, 2019; Oduor, 2020).

However, systems of trophy hunting have been shown to have potential to ensure the sustainable use of wild species if managed appropriately (Baker, 1997; Begg *et al.*, 2018; Dickman *et al.*, 2019; IUCN, 2016). For example, in Namibia, wild species have multiple economic uses and values including that of wild species tourism and trophy hunting, often on the same property (Naidoo *et al.*, 2016; Richardson, 1998). Moreover, they are often a primary source of revenue in regions that are either non-conducive for commercial photo tourism safaris or politically unstable (Lindsey *et al.*, 2007). Trophy hunting often provides vital financial resources needed for conservation, though it also puts pressure on a population, which – unless well-regulated and managed in line with scientific principles – undermines sustainability goals. Sustainability may be especially threatened in the presence of illegal harvesting and interaction with other drivers (Muposhi *et al.*, 2016). Community-based hunting of the snow leopard, *Panthere uncia*, in Tajikistan offers an example of the benefits of well-managed trophy hunting. There, adequate revenue-sharing and transparency community- based trophy hunting programs have improved the availability of food resources for the snow leopard by incentivizing communities to protect and manage wild ungulate populations at levels that can sustain trophy hunting as well as predation by snow leopards (Kachel *et al.* 2017).

However, while trophy hunting creates revenues, conflicts arise if benefits of various conservation activities are distributed unequally. In the Tarangire National Park in the Maasai Steppe (Tanzania), widespread conflicts between centrally-issued trophy hunting concessions and village–private tourism ventures have been observed (Sachedina & Nelson, 2010). These conflicts arise because local communities capture revenues directly from tourism whereas hunting revenues go to the state, putting a constraint on the viability of community-level tourism ventures (Sachedina & Nelson, 2010). A key challenge regarding sustainable use remains setting appropriate quota in light of insufficient scientific evidence (Lindsey *et al.*, 2013). Hunting quota are often too high or insufficiently taking into account population dynamics, especially if populations are declining and abundances are low (Packer *et al.*, 2009). Examples include African lions and leopards in Tanzania (Packer *et al.*, 2009), lions in Zimbabwe (Loveridge *et al.*, 2007), leopards in several African countries (Trouwborst *et al.*, 2020) and elephants across parts of Southern Africa (Selier *et al.*, 2014). Differences in ecosystem productivity may call for a variable and more selective hunting pattern, while quotas are often constant over time and unselective (Muposhi *et al.*, 2016). Also, several countries have a system of 'fixed' quota, where the operators are charged for a quota, regardless of whether animals are actually hunted. Such a system is likely to encourage less selective hunting and a higher probability of killing an animal upon sighting (Diekert *et al.*, 2016).

African lions, *Panthera leo* attract the highest mean price for all tropic species and are estimated to generate 5-17% of gross trophy hunting income (Lindsey *et al.*, 2012). At the same time, hunting pressure has declined the abundance of lion populations with the most severe contraction occurring in West Africa (Lindsey *et al.*, 2013; Packer *et al.*, 2011). A key element of sustainable use is to incentivize users to hunt more selectively, e.g., by sparing younger animals. In Niassa National Reserve, Mozambique, a system was introduced to incentivize hunters to select older individuals, reducing overall harvesting pressure to sustainable limits (Begg *et al.*, 2018). Also, the way hunting concessions are handed out affects sustainable use. Usually, hunting blocks are allocated with a tender process with limited benefits for local communities (Lindsey *et al.*, 2013). An exception is Namibia, where user rights were given to communities, resulting in larger local benefits and also increases in wild species populations (Lindsey *et al.*, 2013). In Tanzania, hunting concessions are leased in block to companies. Shorter leased blocks tend to generate higher revenues for the government (133 United States Dollars per km^2) compared to 62 United States Dollars per km^2 from long-term tenure blocks. However, long-term blocks had a significantly lower hunting offtake, which were also closer to the sustainable limits (Brink *et al.*, 2016).

Also, if monitoring, quotas, and age-based harvesting are difficult to enforce, a full moratorium or a complete ban may be a good option to ensure sustainability (Mweetwa *et al.*, 2018). Finally, while conservation and management are often done on a single species level, there may be important interactions when it comes to the financial viability of trophy hunting (Lindsey *et al.*, 2012). Banning hunting of single species, for example lions, may imply that trophy hunting as a whole may become unviable. As a result, local communities that depend on trophy hunting for income, as well as funding for anti-poaching activities, may be adversely affected, having repercussions on sustainable use of wild species (Lindsey *et al.*, 2012).

Sportfisheries create income and hold the potential to provide alternative and diversified livelihoods for coastal villages (Barnett *et al.*, 2016). At the same time, they can generate significant environmental benefits by creating incentives to conserve targeted species and their key habitats. However, a truly sustainable sportfishery in the developing world should produce benefits for, and be supported by, local people (Barnett *et al.*, 2016). Potential conflicts may arise if historically important fishing spots for locals are used as tourism sites, creating a conflict overfishing space. One example comes from the Alligator Rivers Region of Kakadu National Park in Northern Territory of Australia where Aboriginal people indicated that tourist activity limited access to their favorite hunting and fishing sites and aggravated fishing pressure, leading to population decline (Ligtermoet, 2016).

4.2.4.5 Consumer values, behaviors, choices

Sustainable use of wild species implies that consumption takes place within sustainable limits. Therefore, overconsumption can be considered one of the key factors undermining or preventing a regime of sustainability. Consumption of wild species varies by country, socio-economic and demographic factors as well as by species. To understand the trends in the use of wild species, thus requires consideration of other economic and sociocultural trends. By virtually any measure—household expenditures, number of consumers, extraction of raw materials—consumption of goods and services have risen steadily in industrial nations for decades, and it is growing rapidly in many developing countries (Gardner *et al.*, 2014; UNCTAD, 2013). Consumption is one of the determining factors of global impacts, surpassing other socio-economic-demographic factors, such as age, household size, qualification or dwelling structure (Wiedmann *et al.*, 2020). A lifestyle and culture that became common in Europe, North America, Japan, and a few other pockets of the world in the twentieth century is going global in the twenty-first century. While the consumer class thrives, great disparities remain. In the beginning of the twenty-first century the 12% of the world's population that lives in North America and Western Europe accounted for 60% of private consumption spending, while the one-third living in South Asia and sub-Saharan Africa accounted for only 3.2% (Gardner *et al.*, 2014). However, rapid growth in many of the developing countries over the past decades may well have changed the situation (United Nations 2019; UNCTAD 2013).

In a globalized world and with increasing demand for food and changing consumption patterns the strain on ecosystem and biodiversity is growing substantially. The consumption of goods and services has become a defining characteristic of modern-day (industrial) societies and is accompanied by an enormous and continuously increasing use of natural resources. Consumption also has a significant impact on the provision of ecosystem services worldwide. This section analyzes and illustrates the impacts of consumption patterns on sustainable use of biodiversity.

Despite the high level of concern and awareness among the general public about the need for conservation, there have not been considerable changes in personal actions or widespread patterns of behavior and so individuals in developed nations continue to consume high levels of resources in unsustainable way (Schultz, 2011). The conditions for conservation can only be achieved by changing behavior. Nevertheless, the driver for this behavior change is not proportional to increasing knowledge through education, but rather motivation, or a reason for action, such as self-interest, social responsibility, and self-transcendent values.

Consumer behavior is related to how individual customers, groups or organizations select, buy, use, and dispose of ideas, goods, and services to satisfy their needs and wants. It refers to the actions of the consumers and their main motivations. Individual, social and situational factors influence this decision process. Concerning social factors, societal norms, cultural context and mass media can influence consumer behavior and choices (Terlau & Hirsch, 2015). In the case of experiences of sustainable use of wild fauna that, as a necessary condition for profitability of local communities, require their conservation in order to be successful, it is essential that consumers be able to identify, distinguish and give preference to products that meet the condition of sustainability at the expense of those who do not, thus reducing the development of other productive activities that generate negative impacts on wild species (Banchs & Moschione, 2006). An emblematic example is the case of talking parrot *(Amazona estiva)* in Argentina, where the ban on exporting the animal to the European Union, its main buyer, increased illegal trade and did not have the resources to carry out controls on the management of the parrot, resulting in a genuine loss of income for the local population, a decline in the population of the parrot and the loss of forests (Coconier & Lichtenstein, 2014).

4.2.4.5.1 Media and consumer behavior

Media vehicles (press, television, cinema, radio and internet) may have a positive or negative influence on consumer behavior. Considering the influence of the media on consumer behavior with regard to wild species, there are more cases related to animal species, such as advertising campaigns to reduce consumer demand on wild species in general, or for exotic pet more specifically (Wallen & Daut, 2018). On the other hand, media may also stimulate demand for wild species, by creating awareness about its existence and highlighting positive health benefits of consumption, as in the case of products known as superfoods (Sikka, 2019) or with wild mushrooms (Barroetaveña *et al.*, 2020; Peris *et al.*, 2021). This is especially relevant for plant species that have been traditionally used as medicinal herbs by rural communities who gather wild native species. Those plants may now also be demanded by urban consumers that rarely are informed about the risks of extinction or biodiversity losses due to high consumption and demand of those products.

Consumer demand is a significant and inherent driver of illegal wild species trade and biodiversity conservation depends on the management of consumer behavior as well as changing behavior as well as changing behavior of other actors, such as in the case of marine recreational fishery, where efforts should be also oriented towards the preferences, motivations and demands of fishers regarding fisheries (Guidi *et al.*, 2021; Llompart *et al.*, 2012).

In the context of illegal trade, behavior change methods are rarely applied and usually not well-documented. However, some organisations are emphasising application of behavior change methods, as the example of TRAFFIC, a wild species trade-monitoring network of researchers and practitioners hosted by World Wildlife Fund (WWF) and the International Union for Conservation of Nature (IUCN). They developed a Wild species Consumer Behavior Change Toolkit, which has been made widely available (Wallen & Daut, 2018). Another example of media as a communication tool to address awareness regarding wild species conservation concerns consumption of palm oil and orang-utan threatening, where an education video presentation played at the Melbourne Zoo, Australia, as well as on the YouTube platform, mobilized celebrity ambassadors and social media (Pearson *et al.*, 2014).

Although there is no regulation about selling and buying some wild species, such as marine ornamental fishes online (Borges *et al.*, 2021), social media and social networks are gaining more and more importance and are being used to influence consumer behavior in many situations. On the one hand, this may promote demand of products related to wild species, as the internet increases exposure to those commodities and facilitate its consumption by suggesting suppliers, including related products or recommending on modes of consumption, such as with wild mushroom species (Barroetaveña *et al.*, 2020; Peris *et al.*, 2021). On the other hand, social media helps to inform consumers about potential negative effects of certain commodities, such as palm oil (Carrasco *et al.*, 2017). If there is sufficient critical mass among consumers, a societal tipping point may be passed, changing social norms and affecting business practices (Gladwell, 2006; Nyborg *et al.*, 2016).

Although not typically considered to be part of the conservation science toolbox, but also related to media vehicles, are marketing techniques to influence human preferences and behavior. Marketing professionals use techniques to influence the public to buy particular products by developing relationships or creating positive associations with that particular item or service. While marketing is ubiquitous in commerce, the same techniques can be used to positively influence public behavior regarding conservation matters (Wright *et al.*, 2015).

The purchase decisions of green consumers, for example, can be influenced by factors that are intrinsic and extrinsic to the consumers. The actual behavior is a result of consumers' regular habits, their product knowledge and the situational factors such as promotional campaigns (Kumar & Ghodeswar, 2015). Nevertheless, it is observed that attitudes towards sustainable consumption deviate from the actual consumption behavior. Closing this attitude-behavior-gap (or attitude-intention behavior gap) remains a challenge (Terlau & Hirsch, 2015). Also, gaps between best practice in social marketing and current practices in the design of demand reduction campaigns are frequent (Greenfield & Veríssimo, 2019). Understanding the impacts of different outreach efforts remains limited and it is a challenge for conservation scientists and practitioners to apply the same scientific rigour as in other parts of conservation practice (Veríssimo & Wan, 2019). MacFarlane *et al.* (2020) found that mass-media campaigns and incentive programs were ineffective or short-lived, while advertising bans, social marketing, and locations bans seemed to be more promising approaches, but need more high-quality evidence to draw firm conclusions. Finally, demand reduction can play a role in reducing unsustainable use, but to be impactful it requires thinking about wider systemic effects (Thomas-Walters *et al.*, 2020).

4.2.5 Cultural drivers, value systems, customs and beliefs

Key Messages:

- World views, religions, customs and belief systems have direct and indirect influence over the practices and uses of wild flora and fauna *(established but incomplete)* {4.2.5}.

- Indigenous and local knowledge includes cultural norms and ethics support sustainable use *(established but incomplete)* {4.2.5}.

  - Observation is central to sustainable use, allowing indigenous peoples and local knowledge to closely monitor and assess resources over time and providing a strong foundation on which to build sustainable management plans *(well established)* {4.2.5.2.5}.

  - Indigenous and local knowledge is poorly documented when compared to other knowledges; where it has been documented and embraced there are greater sustainable use outcomes. It also offers a crucial foundation for sustainable use in and beyond indigenous peoples and local communities. Realizing its full benefits will require enhanced documentation as well as greater recognition of Indigenous rights *(well established)* {4.2.5}.

- Cultural norms often mediate practices and uses of wild species; where there are long term relationships between people-nature, norms around stewardship and care of wild species are more common *(well established)* {4.2.5.2}. Cultural taboos against harvest, consumption and other uses of wild species, play an important role in the conservation of some key species (e.g., sacred groves) *(well established)*, {4.2.5.2.2}.

- Beliefs about the perceived medicinal value of wild species (coupled with clinical evidence about improved health outcomes) are a driver of the harvest and use of some flora and fauna *(well established)* {4.2.5.7}.

- Spiritual beliefs that wild species have equal value to humans (e.g, are relatives, or are gifts from the spirit world), are common in some cultures, particularly those of indigenous peoples. These beliefs often include recognitions or demonstrations of respect (e.g., ceremonies) when flora-fauna are harvested or used *(well established)* {4.2.5.2.5}.

- In many indigenous cultures, practices that facilitate good relationships with wild species (e.g., take only what you need) are interconnected with cultural values norms of community well-being of communities *(established but incomplete)* {4.2.5.2}. Take only what you need, is not a common principle or value in cultures tied to globalization and industrialization tend to focus more on accumulation of wild species for profit.

- Many indigenous peoples and local knowledge have traditional norms and practices to ensure appropriate, or sustainable, relationships with wild species. These norms and practices are based in indigenous and local knowledge and frequently central to spiritual practices. Often, they include significant sanctions or punishments when violated *(established but incomplete)* {4.2.5.2.7}.

- Human treatment of wild in a humane way is also highlighted in the Convention on Biological Diversity's Addis Ababa Principles and Guidelines for the sustainable use of components of biodiversity *(established but incomplete)* {4.2.5.2.4}.

4.2.5.1 Overview

Human societies are distinguished by their culture, which affects their behavior, consumption and attitudes towards nature and its constituents. Though the definition of culture has been long debated by anthropologists, 'culture' or "cultural diversity" is generally defined by the variety of religion, language, knowledge, food habits, values and philosophies in human societies (Maiero & Shen, 2004). Since time immemorial, culture has played a pivotal role behind nature conservation and sustainable use of wild species; including both extractive and non- extractive uses, and in general, shaped a symbiotic and harmonious relationship with nature. The concept of sacred groves, where a small patch of forest is worshipped, exists worldwide and possibly dates back to millennia (Alves, 2014; Negi, 2005). Traditional, resource-reliant communities engaged in an intimate relationship with nature, which is reflected in the multitude of myths, legends and lore linked to the flora and fauna surrounding them. In fact, indigenous knowledge and practices are considered to represent *'the oldest form of conservation known to mankind'* (Pretty *et al.*, 2009; Wild *et al.*, 2008). For example, places that are regarded as sacred by local indigenous people are protected as sanctified locations and species are protected through beliefs in totem or taboo species (e.g., Posey, 1999; Sheridan & Nyamweru, 2008; Verschuuren *et al.*, 2010). Similarly, human use of wild animals (e.g., totem species or tabooed species) for a variety of ethnic and religious purposes has been an integral part of many cultures and traditional societies (Alves, 2012). At the same time, pervasive animism is also practiced in many traditional societies, which, at times, resulted in unsustainable use of wild species.

The concept of biocultural diversity was originally proposed to denote this intimate link between nature and culture in relation to indigenous communities, especially those living in areas of high biodiversity (Maffi, 2005; Maffi & Woodley, 2012; Posey, 1999). Biocultural diversity recognizes "the interweave of biological and cultural diversity, people and places, and the continuing adaptation and co-evolution between landscapes and ways of life" (Laird *et al.*, 2011). In the broader sense, it encompasses coding for knowledge, values, norms and protocols. The concept has been used to successfully promote the value of local indigenous knowledge and to curb the loss of biodiversity and the decline of intergenerational transmission of traditional knowledge, practices, and languages (Rapport & Maffi, 2010). It further increased the understanding of how relationships with nature are informed by different worldviews (Descola, 1994, 2005; Mathez-Stiefel *et al.*, 2007; Posey, 1999) and how they contribute to a sense of personal and collective identity and heightened states of mental, physical and spiritual wellbeing (Pretty *et al.*, 2009; Russell *et al.*, 2013) and promote sustainable use and harmonious existence. Engagement in biocultural relations also elicit emotions of happiness, enjoyment, inspiration, love, belonging and connectedness, among others. Conversely, feelings of sadness, pain and loss are experienced when culturally relevant nature is no longer accessible (Cocks & Shackleton, 2020).

Many traditional practices, nonetheless, have faded in time and continue to erode under multiple pressures including globalization, human migration, urbanization, scholarization, changes in religion, and state control of land and resources. Still different elements of nature, including both biotic and abiotic components, continue to inspire and enrich people's cultural and ceremonial lives. They provide rich symbolic values and compassion for nature, and in a way, generate a positive affinity for nature and encourage sustainable use of wild species.

This section looks into the role of cultural drivers, including cultural diversity, religion and other belief systems, indigenous local knowledge and different customary values which contributed to the sustainable use of wild species, and how changes in these drivers have resulted in unsustainable and/or uncontrolled exploitation of wild species. The following four sub-sections are developed following systematic review methodology with specific search terms and engines specified in each sub-section.

4.2.5.1.1 Methodology

The following four sub-sections were developed following different types of literature review methodology. The sub-section on cultural diversity, religion and belief system is derived from the three specific Scopus database searches, i.e., understanding of the relationship with language diversity with sustainable use of wild species, the experts administered the search terms (TITLE-ABS-KEY (cultural AND diversity) AND TITLE-ABS-KEY (language AND diversity) AND TITLE-ABS-KEY (wild AND food) OR TITLE-ABS-KEY (hunting) OR TITLE-ABS-KEY (fishing) OR TITLE-ABS-KEY (logging)) in Scopus database. The search produced 22 articles, therefore, additional search for grey literature, including important reports and books were performed. For the section 4.2.5.1.2 on religious belief and sustainable use of wild species, the experts made a search using TITLE-ABS-KEY (religio) OR TITLE-ABS-KEY(belief) AND TITLE-ABS-KEY(species) AND TITLE-ABS-KEY(wild)). The search yielded a list of 195 articles, of which 55 articles were found relevant. The section on sacred groves was further developed based on an additional Scopus database search using the following search terms (TITLE-ABS-KEY (sacred AND groves) AND TITLE-ABS-KEY (hunting) OR TITLE-ABS-KEY (fishing) OR TITLE-ABS KEY (meditation) OR TITLE-ABS-KEY (gathering) OR TITLE-ABS-KEY (medicine) OR TITLE-ABS-KEY (healing) OR TITLE-ABS-KEY (tourism)). This search yielded 56 articles, out of which, 49 papers were considered appropriate. For the section 4.2.5.1.3. on the role of taboos and traditional belief systems on sustainable use of species, the experts used the publish and perish search engine. A total of 37 papers were considered for writing this sub-section.

Bibliographic search engines, cross-referencing keywords, are useful but the results are not perfectly satisfactory always, because they privilege 1) scientific articles from English-speaking journals, 2) recent publications, often pointed or targeted, to the detriment of reference and/or more synthetic publications, as the concepts and search terms change over time, and 3) do not sufficiently consider non-academic productions (grey literature, government reports, conference proceedings, indigenous and local knowledge productions or reports, indigenous and local knowledge dialogue workshops, media, etc.), which are nonetheless essential for taking into account local knowledge and cultural drivers.

To counterbalance these biases, the experts used other research methods for reviewing literature. The experts have mobilized partners and networks (students, colleagues, field workers), and have relied on diversified bibliographical resources, searching for relevant, synthetic or major references to the subject; some old, some not yet published (and graciously made available by the authors). The 54 cited references for the customary values section have been analysed and integrated in databases.

4.2.5.1.2 Gaps and limitations

Although biocultural diversity, indigenous and local knowledge, and customary values have been identified as a key component for the sustainable use of wild species, methods to document these and complement scientific studies, are not yet widely used and need to be further explored and implemented. There is still a clear dearth of quality documentation on the diverse indigenous and cultural use of wild species. For example, academic research has not understood well how languages changed certain practices and how they influenced their relationship with the sustainable use of wild species. Likewise, while the proportionate relationship between language and biodiversity is well-documented, underlying mechanisms remain unexplored. Similarly, academic efforts have focused on documenting the loss of systems knowledge indigenous systems and not on understanding the processes that drive those changes and their effects on society's capacity to generate, apply, and transmit knowledge to maintain living systems knowledge indigenous systems. There is a requirement to connect these dots via. qualitative analysis to understand the impact of cultural factors on the sustainable use of wild species. Besides, it will be crucial to understand the enabling conditions that contribute to the effective transmission of indigenous and local knowledge. This will entail a critical analysis of current educational curricula that minimize contact with local flora, fauna, and land, contributing to the erosion of local knowledge. By contrast, it will be essential to analyze the factors that support local cultural, political, educational, and economic institutions which lead to enduring connections to the land among youth, collectors, and citizens, even amid modernity. For use of wild species to truly be sustainable over time, analysis is required to understand how to stem the tide of rural abandonment, to raise the status of careers linked with wild harvest and natural resource management, and to attract youth to environmentally oriented vocations. while recognising/ valuing the existing knowledge of indigenous people and local communities.

4.2.5.2 Cultural diversity, religion and belief systems

4.2.5.2.1 Cultural diversity

The variety in religion, language, food habits and philosophies principally distinguish human societies from one another. Although biological and cultural dimensions of diversity have long been dealt with separately, there is an increasing recognition that cultural diversity plays a pivotal role in sustainable use of wild species and their conservation (Anthony *et al.*, 2011). For example, research conducted across countries and continents identified patterns of co-occurrence of linguistic and biological diversity (Gorenflo *et al.*, 2012; Harmon, 1996; Oviedo *et al.*, 2000). Evidence indicates that areas with high language diversity are strongly correlated with biodiversity, in particular high bird and mammal diversity (Frainer *et al.*, 2020; Gorenflo *et al.*, 2012; Sutherland, 2003). According to Gorenflo *et al.* (2012), a total of 3,202 languages, which accounts for nearly half of the existing 7000 languages, are found in the 35 global biodiversity hotspots. Languages encode non-transferable knowledge bases which serve as rich repositories of diverse uses of plant and animal species. Within these languages exist several thousand years of undocumented indigenous scientific knowledge of biodiversity inventory (e.g., folk taxonomy) and instructions (folklores, stories, proverbs). Languages often underpin the preference for species which are subjected to hunting or fishing *(established but incomplete)*. For example, in Senegal, "Essegnaille" refers to three commonly consumed species from the Carangidae taxonomic family, namely, *Caranx hippos, Caranx senegallus,* and *Hemicaranx bicolor*. The local fishers, however, do not have a name for *Chloroscombrus chrysurus* despite belonging to the same family. This is because it is usually rejected when caught (Frainer *et al.*, 2020). Folklores often prevent harming animals, foster positive environmental attitudes and teach harmonious coexistence. It symbolizes myths, tales, riddles, proverbs which are generally unwritten but passes through oral traditions. Historically, most indigenous folklores influenced the sustainable use of species, although with a few exceptions. Evidence indicates that folkloric or religious associations have particularly protected primates, predominantly in Asia and Africa, due to the physical and behavioral resemblances with human (Baker *et al.*, 2013; Riley, 2010; Waters *et al.*, 2018). In central Sulawesi, for instance, indigenous folklores prevented harming the macaques *(Macaca tonkeana)* despite the species' frequent crop-raiding behavior (Riley & Priston, 2010). However, folklores also contributed to unsustainable use and indiscriminate killing. In Portugal, indigenous folklores negatively portrayed the wolf's image as demon which resulted in strong apathy for the species (Ceríaco, 2013). As such, reptiles and amphibians are generally least appreciated in the indigenous folklores despite their high ecological and economic importance. Reptiles, in particular, epitomises many negative values within traditional folklores. Nonetheless, as cultures and languages are lost, precious information about species, their uses, as well as the philosophies' meanings are also lost. Of the estimated 7,000 languages, nearly half is already lost, while some studies predict up to 90% of the existing language may well disappear by the end of this century (Gorenflo *et al.*, 2012). Africa, in particular, is losing a great amount of linguistic diversity. It is estimated that one language gets extinct every 3.5 months (Rogers & Campbell, 2015). This poses an imminent threat to biocultural diversity, in particular, loss of traditional knowledge, including folklore, traditional music, literature and songs, etc. (see section on local practices and indigenous knowledge). There is, however, a dearth of quality documentation on how the annihilation of languages changed certain practices and their relationship with sustainable use of wild species. More so, while the proportionate relationship between language and biodiversity is well-documented, the underlying mechanism of sustainable use remain fairly unexplored.

4.2.5.2.2 Religion and belief systems

Human societies are governed by both formal and informal set of belief systems, including religious beliefs, principles and moral values such as kindness and compassion. Of these, religious belief is defined as a unified system of practices relative to sacred things, aiming to answer the quest and purpose of human life and beyond. Throughout history, every human society has followed certain religious narratives, symbols, and commitments in their public and personal life. Religious practices also include a significant part of ceremonial life, including different festivals, marriage and funeral. All major world religions, irrespective of their geographic occurrence, envision a symbiotic relationship between humans and nature (Negi, 2005). While some religions symbolize nature as 'God' or 'Godly', some believe nature as the creation of God, which deserves sympathy and respect. Today, nearly 80% of the world population follows a specific religion, which includes 2 billion Christians, about 1.34 billion Muslims, 950 million Hindus, and over 200 million Buddhists. In Africa, and Latin America, frequent syncretism occurs between ancient religion (animism) and revealed religion (Islam, Christianity), with ongoing engagement of ancient rites to preserve the heritage of the ancestors. In addition, there are more than 4000 religions, including animism, totemism with many believers belong to traditional indigenous communities.

According to (Berkes *et al.*, 2001), religious traditions, as such, have a fairly limited role in biodiversity. However, they provide critical values, worldviews, and beliefs, which determine how a society perceives it should interact with biodiversity(Negi, 2005). Religious beliefs can directly influence or mediate sustainable use in mainly two ways, firstly by providing effective protection to wild species in sacred natural sites, and secondly, by altering the attitude towards wild species by declaring it potentially sacred or important for ceremonial life (Pretty *et al.*, 2009). In fact, all traditional societies, to a meaningful extent, were able to conserve the functions of productive ecosystems, which were supported by various kinds of animism, rituals, magico-religious practices and taboos (Negi, 2005; Pretty *et al.*, 2009). Religious sanctions, in particular, played a significant role in conserving threatened species, while also reducing animosity towards wild species (McKay *et al.*, 2018). This is particularly prominent in the Asian sub-continent and in parts of Africa. Religious sanctions facilitated conservation in multiple ways, e.g., through the prohibition of entering certain areas or killing certain species and through instigating a fear of repercussions from doing dreadful things (Negi, 2005). For example, Islam prohibits the hunting and killing of wild animals for sports or for sale but permits hunting when meat is consumed as food. In this way, Islam prohibits unnecessary killings of animals (Negi, 2005). In Hinduism, several wild animals are considered sacred and the followers are generally not allowed to kill or harm those animals (Kandari *et al.*, 2014). In Hindu theology, God exists in every living being and every animal has the equal right to live. Likewise, in Buddhism, certain wild species, like elephants, enjoy special privilege and recognition. Other religions too, such as Jainism, promote the idea of *ahimsa* (nonviolence) toward human beings and all creations, and harming or hunting wild species is strictly prohibited.

There is strong evidence that religious beliefs and animism promoted sustainable use of wild resources by mainly controlling human practices of extractive use of wild species, especially hunting of animals even in the most unfavorable situations. For instance, according to the local belief, a giant crocodile formed the island of Timor in Timor-Leste, which restricts the killing of saltwater crocodile in the islands despite recurring attacks and crocodile hunting in near-by islands (Brackhane *et al.*, 2018). In Sumatra, despite hostile human-wild species conflicts, local communities do not kill or harm tigers as the communities consider tigers as spirit tigers or as an enforcer of moral rule (McKay *et al.*, 2018). In coastal Bangladesh, local religious beliefs have protected the Black Soft-shell Turtle, Mugger Crocodile, Rock Pigeon and Rhesus Macaque (Mukul *et al.*, 2012). In Ghana, local religious beliefs consider monkeys as 'untouchable children of God' and communities refrained from the killing of monkeys, while other species significantly declined (Attuquayefio & Gyampoh, 2010). In Golestan National Park, Iran, a sharp decline of mammals was reported due to illegal hunting. Only wild boar *(Sus scrofa)* showed a population increase because of religious sanctions not to hunt or eat those (Ghoddousi, 2019). Strong evidence is available that religious sanctions can prevent poaching and uncontrolled exploitation of wild species, and thus promote sustainable use. For instance, in 2014, Indonesian Islamic clerics issued a fatwa against the illegal hunting or harvesting of wild species, which immensely helped in the conservation of Asian Elephant. Broader religious efforts such as, Sacred Earth: Faiths for Conservation, engage religious leaders to collaborate in the protection of biodiversity. However, some religious beliefs can also drive unsustainable use of wild species. For example, a study in Singapore indicated that certain beliefs attached to traditional Chinese medicines facilitated unsustainable wild species trade for Saiga – a critically endangered antelope from Central Asia (Doughty *et al.*, 2019). Most of the Saiga users were characterized as middle-aged Buddhists and Taoists, who believed in miracle cures. Nonetheless, literature indicate a generally positive role of religion in promoting sustainable use of wild species.

The importance of religious beliefs in promoting sustainable use of wild species is incomplete without the mention of sacred groves. Sacred natural sites are identified as sites that protect nature and wild species by restricting anthropogenic disturbances due to religious sanctions. Sacred sites are religiously protected territories, the oldest form of conservation, which also find its mention in all the major religious scriptures, including the Holy Vedas and the Holy Quran. Consequently, a large number of self-imposed bio-divinity directives work in these sites. There is substantial evidence that religious beliefs associated with sacred sites halted deforestation of primary forests and in general, promoted non-extractive use of both flora and faunal species. Communities have traditionally attached great importance to sacred forests, and principally used these forests for religious tourism, watching, praying, meditation and healing purposes. Examples of sustainable use of sacred groves and its floral and faunal species can be found throughout the world, starting from Sub-Saharan Africa, parts of Europe, South America, South and Southeast Asia (Kandari *et al.*, 2014; Negi, 2005; Pungetti *et al.*, 2012). However, sacred groves are predominant in some countries, for example, in India, Ghana and Nigeria. Over 13,270 sacred groves have been reported from India alone, representing different faiths, including both traditional and temple forests (Ormsby & Bhagwat, 2010). Ghana, on the other hand, has more than 1900 sacred groves, along with a long history of cultural forests (Ormsby, 2012). Commensurate with these numbers, the number of peer-reviewed articles reporting multiple use of sacred groves from these countries are considerably high. As such, religious sanctions, beliefs, myths and taboos pertaining to the use of certain plants and hunting ban of animals, are the primary determinant behind sustainable use within the sacred groves. For instance, in

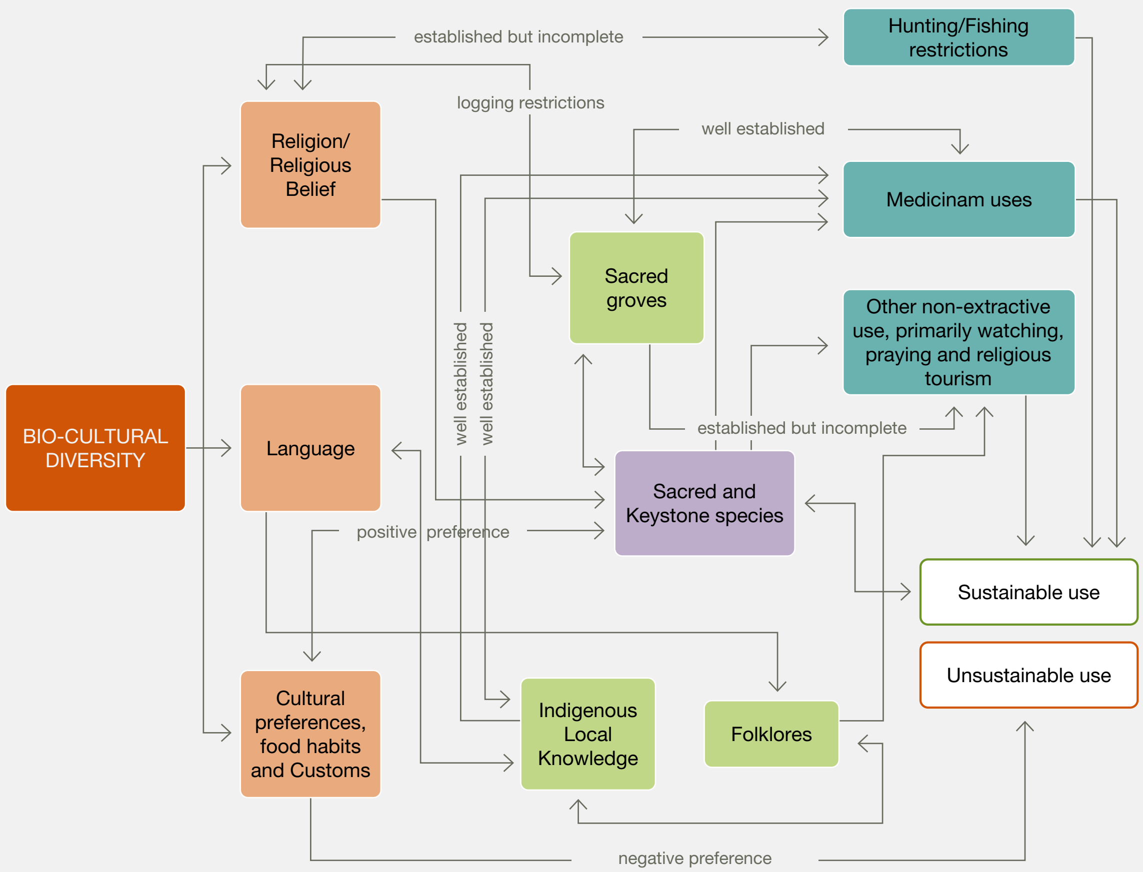


Figure 4 12 **The figure summarizes different feedback loops that emerge from the specific literature review conducted for section 4.2.5.2.2.**

It outlines the three pillars of bio-cultural diversity and how it promoted sustainable/unsustainable use of wild species. The darker lines signify strength of the relationship. Confidence levels are mentioned wherever possible.

Ethiopia, Orthodox Tewahido Church communities have ensured the protection of church forests over centuries despite widespread deforestation in adjacent forests (Aerts, 2016; Klepeis, 2016). Similarly, Bishnoi cult of western India protect sacred groves and its species, locally known as 'Orans', which are dedicated to the local deity (Kala & Sharma, 2010). In Ghana, sacred groves were used as the refuge for wild species breeding (Robinson & Sasu, 2013). It is evident that religious protection significantly enhanced biodiversity, in particular plants diversity within sacred groves as compared to adjacent forests and protected areas. Informal networks of sacred groves also played a critical role in maintaining plant diversity (Bhagwat *et al.*, 2005). For instance, the sacred natural site in Jaintia Hills in India gained widespread attention when just 0.5 ha of sacred grove was reported to have 82 tree species, out of which 54 are endemic species and 31 are rare species (Jamir & Pandey, 2003; Upadhyay *et al.*, 2019). Some floral species, however, are typically favoured for sacred groves. For instance, in India, banyan tree *(Ficus bengalensis)*, Peepul *(Ficus religiosa)*, wood apple *(Aegale marmelos)* and the neem tree *(Azardirachta indica)* are typically considered highly sacred and often used for ceremonial purposes. Felling of these trees are often considered amongst heinous religious crimes. In particular, large old trees are often considered keystone ecological entities within the sacred groves. Sacred groves have contributed to improve the quality of life for people not only in the traditional communities, but also many people used these areas as refuge from stressful urban life. Within the extractive use, sacred groves worldwide continue to serve as rich repositories for traditional medicines *(well established)*. Medicinal and therapeutic uses of sacred groves are particularly common in Asia and Africa, where several trees and their parts are used as traditional medicine. For the traditional societies, the need for traditional medicine is one of the primary causes of maintaining sacred groves (Adeniyi *et al.*, 2018). Apart from medicinal plants, these also serve as natural pesticides and sacred ingredients widely used in cultural and ceremonial activities. Yet, despite their bio-cultural significance, the spatial extent of sacred groves is rapidly shrinking. A number of factors, including rapid urbanization, globalization and transition to a market-based economy (e.g., rising land prices, land demand) have changed the core religious values and perceptions of local communities, eroding the emotional affinity and appreciation for wild species. Furthermore, current priorities supporting rapid economic development have conferred lesser importance to sacred sites (Xu *et al.*, 2006). In addition, many of the traditional religious practices are rapidly diminishing, due to conversion and changes in religion; religions with smaller number of followers are vanishing quickly. In fact, formal world religions are also experiencing losses of population share and this might have caused annihilation of several ethno-religious practices. There is also a frequent syncretism, for instance in Africa, between "ancient" religion (animism, totemism, etc.) and revealed religion (Islam, Christianity). If the maintenance of customary rites and preservation of the ancestors' heritage are guaranteed, the links to wild species could be reinforcing (Bassett & Cormier-Salem, 2007; Dugast, 2002). Information pertaining to these are not rigorously documented **(Figure 4.12)**, however, significant evidence suggests that religious beliefs are vanishing due to the materialistic transitions of human societies, while global mobility and technology has led to cultural homogenization of human societies.

4.2.5.2.3 Taboos and traditional belief systems

Taboos are usually social rules that are not written but regulate human behavior (Adler, 1998; Lévi-Strauss, 1962). Such limitations not only govern human social life, but also may affect, and sometimes even directly manage, many constituents of the local natural environment. Whatever the reason for such constraints, taboos, at least locally, play a major role in the protection of natural resources, species, and ecosystems (Begossi *et al.*, 2004; Gadgil, 1987; Gadgil *et al.*, 1993; Johannes, 1978, 1981, 1982, 1984). Taboos resemble mechanisms for the protection of species and habitats in present-day society, but they have other social rules and sanctions, rooted deep in traditional belief systems. In marine ecosystems, taboos are imposed on specific marine areas to prevent overexploitation of aquatic resources (Chapman, 1985; Johannes, 1978). Taboos are not always permanent in time and space but can be removed when food resources are plentiful. Taboos that directly result in management of natural resources are reportedly found among traditional groups from several parts of the world (Begossi & Souza Braga, 1992; Kwapena, 1984; Reichel-Dolmatoff, 1971; Sankhala, 1993; Sarkar, 1984). These regulations may have been the outcome of a trial–and–error process of resource management strategies like those of the contemporary practice of adaptive management (Holling, 1978; Walters, 1986). For example, Berkes (1997) argues that periods of mismanagement of North American caribou among the Cree in the 1900s resulted, in part, from a neglect of traditional hunting rules. After a change in Cree hunting behavior, the caribou population returned to previous levels. In the same manner, taboos may be employed as a social mechanism for the enforcement of ecologically adaptive behavior, even though different cultural contexts are attached to them. Taboos protect not only threatened and endemic species, but also keystone species (Colding & Folke, 1997).

A study conducted by Colding & Folke (1997) identified 70 species-specific taboos which included both flora and fauna throughout the world. They found that nearly 30% of the identified taboos ban any use of species listed as threatened by the International Union for Conservation of Nature. Of the species-specific taboos, 60% are directed at reptiles and mammals. In these two classes, nearly

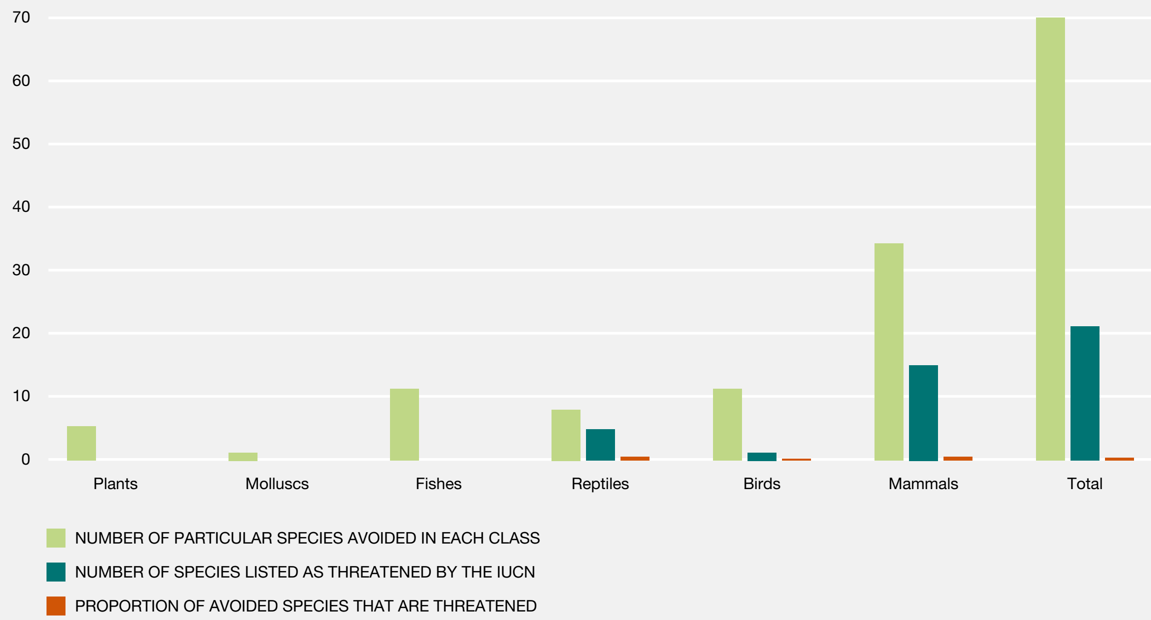


Figure 4 13 **Class distribution of avoided and threatened species.**

Source: adapted from Colding & Folke (1997).

Box 4 31 **The fading taboos.**

Bonobo *(Pan paniscus)*, endemic to the Democratic Republic of Congo (Zaire) (Badrian & Malenky, 1984; Thompson *et al.*, 2008) is an endangered species, included under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and is protected by the Democratic Republic of Cong government. Not hunting or and eating bonobo has been a traditional taboo held by the ethnic group (Bongando) that live in Wamba region of Democratic Republic of Cong. In Bongando folk taxonomy, bonobos are considered not as wild species, but as human beings. The resemblance of bonobo bodily characteristics and behaviors to those of humans is the key reason for this categorization and this similarity has helped to conserve this endangered species. Social and cultural interchanges with other ethnic groups are altering he tradition of “folk conservation.” Research indicates that although this taboo is persisting in older generations, some youth have begun to eat bonobo meat (Lingomo & Kimura, 2009). The taboo is weakening due to numerous influences including, economic incentives, foreigners who choose to eat bonobo meat, decrease in the availability of other game, and the influence of, and hardships caused by, the civil war. To avoid incurring the wrath of God and the ancestral spirits, people make food offerings in the hopes of obtaining game and other wild meat (Lingomo & Kimura, 2009; Tashiro, 1995).

50% of the species are threatened, representing all the threatened species in analysis, except for one bird species. Both endemic and keystone species that are important for ecosystem function are avoided by species-specific taboos **(Figure 4.13)**. These reviews indicate that species specific taboos have significant ecological ramifications for the protection of threatened and ecologically important populations of species (Colding & Folke, 1997).

4.2.5.2.4 Local practices and indigenous and local knowledge

Worldwide, indigenous people number over 370-500 million (UNESCO, 2021). They live in about 75 of the world’s 184 countries and are inhabitants of practically each main biome of the earth, with a remarkable overlap between indigenous territories and world’s remaining areas of high biodiversity. According to the United Nations, “indigenous peoples are inheritors and practitioners of unique cultures and ways of relating to people and the environment. They retain social, cultural, economic and political characteristics that are distinct from those of the dominant societies in which they live.” Despite their cultural differences, indigenous peoples of the world share common challenges and are among the most people in vulnerable situations in the world.

The term indigenous and local knowledge is broadly defined as the local knowledge held by indigenous peoples (Posey, 1999). Indigenous peoples with a historical continuity of resource-use practices often possess a broad information base of the workings of complex ecosystems in their own localities. This accumulated knowledge is passed from generation to generation and generally distilled through their world views, religious affiliations, and customary experiences with nature. Such observations can be of great value and complement the observations on which science is based. The discoveries and inventions of traditional science may not be fully understood by science and, as Lévi-Strauss (1962) suggests, traditional science may be able to perceive and anticipate the discoveries of science. As indigenous peoples have depended on the local environments for a long expanse of time for a variety of resources, they have developed a stake in conserving, and in many cases, enhancing biodiversity. Their practices for the preservation of biodiversity were grounded in a progression of general guidelines, which emerged through experimentation over a lengthy timespan (Lévi-Strauss, 1962). This implies that their knowledge base is specific, and their implementation involves an intimate relationship with their belief system.

Due to the influence of different world views and a belief system of cosmovision, such knowledge is often difficult to fit into the parameters of science. While modern hegemonic science is based in concepts, traditional science is based on perception. To realize sustainable use of wild species, it is critical however, that the value of the knowledge-practice-belief systems of indigenous people are recognized, respected and utilized in the design and implementation of land use and resource management systems. Some societies, such as the Peruvian Yagua, are considered cultural conservationists. Their ideology involves limited exploitation of natural resources, as human beings are perceived as sustainers of the equilibrium of the universe, including the natural and supernatural. Their values, interdictions on food and hunting, and institutional or supernatural sanctions, guide them to act according to their ideology (Cunha & Almeida, 2000).

Rituals and offerings are a way to establish communication and a relation of reciprocity with nature. When community members in the Yucatan region of Mexico prepare the land for cultivation, for example, they touch the soil and ask for permission to plant. They engage in rituals as a demonstration of respect for the earth. Their actions and prayers ensure that soil quality is maintained and that good relations are kept with the deities associated with the soil and land. Such rituals of reciprocity echo those of cultures worldwide and reflect a world view of being one with the earth, rather than separate from it. This is not a demonstration of dominion over the earth, as is common in western societies and agribusiness, but a sense of belonging to, and kinship with, the natural world. In this way, reciprocity and sustainable management practices are ensured. According to Barabas (2003) reciprocity occupies a range of behaviors from altruism to deferred exchange. A force in all aspects of indigenous life, reciprocity is central to a value system that envisions humans in relationship with both the tangible and intangible worlds.

4.2.5.2.5 Management and indigenous and local knowledge

Effective and sustainable management of populations of flora and fauna needs quantifiable information on rates of harvest, survival, and reproduction, as well as data on population size, habitat, and demographics to ensure that

Box 4 32 **Cosmovision, transformation and fallow – Milpa management in the Yucatan.**

Among the Mayans in the state of Yucatan in Mexico, specialized milpa production systems termed, the 'monte', are fallow areas where secondary vegetation grows. According to Maya cosmovision the vegetative growth undergoing regeneration is on its way to resurrection. Therefore, Maya campesinos do not abandon the milpa but instead return it to the owners. the *Yumilo'ob K'axo'ob*, the Lords of the Mountains. These powerful inhabitants ensure the continuity of life and supernatural force circulates through them, giving permanence to the milpa and the milperos. In the cosmovision of the native peoples, the phases which are not cultivated or intensively managed at the species and landscape level, are part of the transformation of the elements of nature and their symbolic forces (Quintanilla, 2000).

In the milpa, a wide variety of wild species are collected for food use, among them 20 species of wild sweet potato. These wild sweet potatoes have been crucial for survival during times of famine, even within the living memory of the elderly. Archeological evidence, and historical records show that since pre-Hispanic times, locusts *(Schistocerca piceifrons)*, have periodically caused plagues with widespread destruction and fatality. Having an underground source of food such as sweet potatoes, has been especially important during such disasters. The cultivated and wild sweet potatoes are key, as the tortilla mixed with ground sweet potatoes was the main food source.

The sweet potato is collected in the young or mature growth, which is left fallow after its use for the production of the milpa. The cultivated and wild sweet potatoes are key, the tortilla mixed with ground sweet potatoes was then the main food.

harvest does not endanger the survival of populations (Lebreton *et al.*, 1992; Ludwig *et al.*, 1993). For many populations of wild species, however, scientific information required to gauge sustainable management practices is lacking. Over the last few decades, there has been growing recognition by the research community, that traditional and local ecological knowledge (see Chapter 1) offers a valuable source of information to complement "western scientific approaches" to resource management (e.g., Berkes *et al.*, 2000; Chemilinsky, 1991). Because local ecological knowledge is typically derived from people who have lived with, hunted, and gathered wild species over decades, their role in resource management is analogous to "expert opinion" used in population modeling (e.g.,Walters & Holling, 1990; Zabel *et al.* 2002). Ecological knowledge has been applied to various scientific disciplines(Gadgil *et al.*, 1993; Johannes *et al.*, 2000; Krupnik & Jolly, 2002), and, in managing wild species, it may be primarily useful when managing populations that occur in isolated locations where widespread scientific studies may be impractical (Barsh, 1997). Despite the profound utility of local ecological knowledge, it has been received skeptically by some wild species managers and conservation biologists.

The coexistence of different forms of plant management and manipulation is particularly important in the case of edible plants. Multiple forms of management result in the persistence of diverse cultivars including those that combine superior flavor and better medicinal properties, with resistance to pests, floods, droughts, and the impacts of climate change (Mastretta-Yanes *et al.*, 2018). As (Maxted *et al.*, 2013) establishes that wild relatives have been found to have higher genetic diversity in terms of drought, pest, and disease resistance than their cultivated counterparts.

4.2.5.2.6 Indigenous and local knowledge and wild food plants

Food is central to the culture, health, and well-being of society. Maintaining traditional food systems is important to revitalization of indigenous peoples and conservation of local knowledge. Traditional use of wild plants, utilized as food or medicines is common to both rural and urban societies (Aziz *et al.*, 2018; Meragiaw, 2016). Ethnobotanical studies have documented medicinal and other traditional uses of wild plants, employed for human health, nutrition and veterinary use (Aziz *et al.*, 2018; Halmy, 2017; Heneidy *et al.*, 2017; Meragiaw, 2016). Nutritional values of wild foods and their key place in sustaining indigenous peoples and local communities' culture is important to be considered when designing sustainable use systems. Traditional practices of collection, preparation and consumption of wild plants are widely practiced in both rural and urban settings. Wild plants contribute to the nutritional wellbeing of families as well as offering a source of income generation. However, in situations of increased demand for a particular species, some traditional practices may become threatened by local populations, as well as by third parties (see **Box 4.33**), interested in generating income from increased exploitation of the natural resource (Chauhan *et al.*, 2018).

Great emphasis has been recently placed on the role of traditional food in human health and nutritional status. Many traditional foods, particularly wild variants, are nutrient dense, making a substantial contribution to daily nutritional intake, especially for marginalized social classes. Additionally, traditional food as well as condiments, constitute an essential aspect of cultural heritage. Since foodways are highly ingrained and part of the evolution of human behavior they are developed by the interaction between the ecological environment, cultural institutions,

Box 4 33 **Native maize: A protected cultural hertage.**

In the new Mexican political context, a set of conflicting public policies are emerging that may impact wild plant management and consumption. On the one hand, there is the April 13 agreement arrived at after a long negotiation between decision makers and collectives and rural communities with the goal of protecting local varieties of maize in Mexico. This Federal Law for the Development and Protection of the Native recognizes that the production, marketing, consumption, and diversity of native maize are cultural manifestations of Mexico. The preservation of native maize in all its variety places an implicit obligation on the State to guarantee a nutritious, sufficient and high-quality food free of genetically modified organisms. It is important to emphasize that even though maize has been domesticated since pre-Hispanic times, populations of the closest wild relatives of maize (*Zea mays* cultivated), known as teocintles (*Zea parviglumis, Zea diploperennis, Zea luxurians,* etc.) and *Tripsacum* species, continue to live together in the environments of the Mexican maize fields and contribute to enriching the genetic variability of native or creole maize cultivated via free pollination (Kato *et al.*, 2009). This law will favor the permanence of traditional milpa management practices, which include maintaining wild relatives of maize and other species with local uses.

At the same time, the national Plant Variety Law is under discussion. This law would prohibit the free exchange of seeds, which has been essential for the protection of biocultural wealth and food sovereignty in Mexico. In addition, it would allow companies and external agents to obtain the intellectual property rights for seeds from the rural towns and communities that have maintained the great diversity of native species of multiple use in the country.

and family dietary patterns (Contreras & Gracia, 2005). Studies in Mexico have found that an especially important set of condiment species with unique flavors and properties are found in wild populations and missing in cultivated populations. Wild collection of these species is the most common way of managing them. Notably, in recent years, as migrant populations from Mexico move to the United States of America, demand for these plants have increased in North America. Worldwide, the large number of immigrants with a significant amount of traditional communities' influences consumption in the countries where they settle. Demand for wild plant species by immigrants has strongly influenced local and national cuisines, increasing the marketing of imported wild products which are often transported by immigrants themselves.

The Ethnobotanical Database of Mexican Plants of the Botanical Garden of the National Autonomous University of Mexico, records 16,000 uses for a total of 4,000 plant species which corresponds to more than 50% of the total estimated useful plant species in Mexico. According to Caballero *et al.* (1998) two patterns of usage emerge. First, the majority of utilized plant species are wild, and second, the main uses are for food and medicine. Although the basic diet in rural populations consists of a set of cultivated and domesticated species, the diet is significantly supplemented by a large number of other plant resources, most of them wild or under "incipient management". These supplemental species provide essential vitamins, minerals, and other important nutrients. Although traditional food is being studied for nutritional composition and cultural food use, there is still a significant research gap (Heinrich, 2006), which could endanger food and health security as traditional knowledge erodes.

Local traditions rely on information being passed on from one generation to the next in one community or in a small region. Traditional food knowledge and traditional ecological knowledge (Heinrich, 2006) are strongly influenced by socioeconomic and cultural determinants, religion and history and their dissemination differs in local or national languages. However, transmission of indigenous and local knowledge is being interrupted in many communities. This trend represents a challenge to indigenous peoples and local communities and their traditional ways of living, including spiritual practices and relationships to land, waters, and other beings. Among the adverse consequences are a shift away from nutritious wild foods. The loss of a traditional languages is closely tied to the erosion of practices and uses related to wild species.

Traditional ecological knowledge is both cumulative and dynamic, building upon the experience of early generations and adapting to new technological and socioeconomic changes of the present. Although less attention has been paid to the situation of traditional ecological knowledge within Europe and highly industrialized countries, there are many cases of traditional use and consumption of species in specific and isolated regions (Heinrich, 2006), as well as in urban areas, which are important for biodiversity conservation, local cultures, and the maintenance of a healthy life for coming generations.

There are cases where despite difficult conditions, indigenous peoples and local communities are drawing on indigenous and local knowledge and customary rules and norms to revitalize traditional practices, restore disturbed environments, recover wild species populations, and reinvigorate more traditional ways of living, as in the case of the Xingu Seeds Network in Brazil (Antoniazzi, *et al.*, 2011).

Ethno-veterinary use of plants also remains very important, because many indigenous peoples depend on their livestock on a daily basis. Several animal diseases are treated through the use of indigenous knowledge on the use of parts of fruit trees and other herbaceous plants and trees (Cheikhyoussef & Embashu, 2013; Khan *et al.*, 2019; Maroyi, 2017). Conventional remedies for animal health care are inaccessible or unaffordable to indigenous people, incentivizing local communities to maintain traditional treatment practices.

Box 4 34 **Apatani's and their indigenous knowledge – A classic tale from Eastern Himalayas.**

The Apatani eco-cultural landscape in Ziro Valley of Eastern Himalyas represents as an excellent example of a uniquely distinct natural resource management practice which involves local and traditional knowledge systems. Apatani (earliest ancestors are termed as Abotani), is a small hill tribe that resides in the Eastern Himalayan region rich traditional knowledge. They have rich knowledge of medicinal plant use (45 species are listed) and some of these are nutrient-rich plant species supporting food security (Rai, 2005; Srivastava *et al.*, 2010). The Apatani practice a unique, advanced agricultural practice called, the paddy-cum-fish cultivation. The main advantage from the practice is that the land gives sustained yield year after year, unlike the Jhum system, that is under cropping only once in a few years of fallow interval, depending upon the Jhum cycle. The economic and energy efficiency of this agro-ecosystem is exceptionally high, and, after meeting local needs, rice is exported. Rain fed cultivation of millet and mixed cropping contributes toward meeting the diverse needs of the people. Mithun (*Bos frontalis* Lam.), Swine and poultry husbandry are an important link with agro-ecosystems (see Rai, 2005 for further reading). This indigenous knowledge system helps reduce the pressure and dependency on the surrounding biodiversity.

There is much evidence that traditional knowledge systems contribute significantly to wild species conservation globally (i.e., **Table 4.5** on practices and customary laws). Traditional knowledge systems are under stress in many parts of the world due to many factors associated with colonization, globalization (i.e., economic stress and socio-political marginalization (Gómez-Baggethun *et al.*, 2013). These broad patterns are compounded by land use change associated with industrialization and globalization forces and westernization (Harmon & Loh, 2010; Turner & Turner, 2008). Historically, academic efforts have focused on documenting the loss of traditional knowledge systems (e.g., salvage paradigm) and not in understanding the processes that drive those changes. Moreover, there is less focus on how to support and nurture traditional knowledge in ways that ensure its continued use and value in wild species stewardship (Gómez-Baggethun & Reyes-García, 2013).

However, during changing, challenging conditions, indigenous peoples and local communities can draw on indigenous and local knowledge and customary rules and norms to revitalize traditional practices, restore disturbed environments, recover populations of wild species, and reinvigorate more traditional ways of living, as in the Mapuche communities in northwest Patagonia of Argentina, where regional knowledge about fungi is an important aspect of their tradition but process of changes also responds to complex and dynamic socioeconomic and ecological contexts (Morales *et al.*, 2019). Other activities, such as gathering 'gum brea', an exudate of the *Cercidium praecox* tree in the Province of Salta, Argentina, despite not being traditional, can contribute to the generation of moments of cultural transmission, intergenerational learning and the strengthening of local identities and links between communities and territories (Olivera, 2018).

4.2.5.2.7 Customary values of wild species and policy-making challenge for sustainable use

The complex links, that bind indigenous peoples and local communities to wild species, are based on multiple values, uses and institutions, that change regarding the actors and the historical and geographical context. In this section, the purposes are to highlight first, in what way the customary values attached to wild species are (or not) a

Box 4 35 **Use of "chaguar" by Wichi women.**

In Argentina's dry Chaco eco-region, local communities depend on the integral use of the forest for terrestrial animal harvesting, and obtaining food, fiber, shelter, and medicine from timber and non-timber forest products. In the context of increasing deforestation, expanding agribusiness and the loss of communal lands, traditional territories and resources are rapidly diminishing with negative repercussions for rural families (Paolasso *et al.*, 2012). The Wichi people give special importance to the collection, processing, spinning, dyeing, and weaving of chaguar *(Bromelia hieronymi)*, an herbaceous plant with succulent leaves. Both the fiber of "chaguar" and the products derived from it are not considered as mere objects of use to be eventually discarded by the communities, but hold a strong symbolic meaning giving identity and character to local communities (Sastre-Merino *et al.*, 2013). The myth "The Advent of Women" conveys that the first women who descended from heaven into the world of men did so using braided ropes of chaguar. The plant has a prominent symbolic role in the female rite of initiation, in which women begin to spin and weave from adolescence. Beginning in childhood, girls accompany their mothers and female elders to the forest to collect chaguar, and learn the processes of spinning, coloring, and weaving that become central to their lives as adults. In the courtyards of their homes, grandmothers, mothers, and daughters come together to make textiles. These shared activities serve to transmit knowledge to new generations and integrate young women and girls into the community (Sastre-Merino *et al.*, 2013). Appropriation of land by the agribusiness sector and forest clearing and degradation have resulted in diminished access for women to the chaguarales, as well as other resources necessary for food, shelter, and medicine. In this way, women lose not only the material resources needed to sustain daily life, but their socio-cultural and economic role in contributing to the community economy. The disappearance of these activities also contributes to the loss of knowledge and symbologies that the Wichi peoples have developed for centuries. Therefore, it is important to encourage more sustainable forms of resource use, the addition of value to forest products through processing, and access to fair trade markets. In this context, the USUBI (Sustainable Use of Biodiversity) project, carried out by the Ministry of Environment and Sustainable Development of Argentina, works with Wichi women from the communities of Los Baldes, La Cortada, and Pozo El Chañar surveying chaguarales, promoting enrichment practices with chaguar in experimental plots, and hosting training workshops to improve artisanal products. These community-driven actions are aiming to generate locally derived, socially and environmentally sustainable solutions to prevent the loss of biodiversity and shore up centuries-old traditional knowledge.

There are a number of scientific-based evidence (or extensive literature) on the subject. Customary institutions, social practices, and cultural values participate, intentionally or not, in natural resource conservation (Dounias, 2007; IPBES, 2019b; Lizet & Millet, 2012; Ruddle *et al.*, 1992) indigenous peoples and local communities, by virtue of their proximity to natural resources, are the most capable of preserving them (Agrawal & Gibson, 2001; Bouamrane *et al.*, 2016; Dugast, 2002; Posey, 1999).

driver of sustainable use; second, to what extent changes in customs, positively or negatively, impact the use of wild species; third, to what extent policies consider customs and associated values for sustainable wild species governance.

Customary values of wild species as driver of sustainable use

The customary values of wild species encompass a set of anthropocentric values (Chan *et al.*, 2016; Maitre d'Hôtel & Pelegrin, 2012; Skubel *et al.*, 2019; Stålhammar & Thorén, 2019), either instrumental, either relational, either intrinsic, defined by a group. This group, at multiple scales (clans, lineages, villages, collectivity, community, associations), is the main player for the management and the governance of the species, which implies the set-up of local institutions or customary rules.

The close and deep relationships between a group and a species (or a space/ a site) are anchored in the local culture and the feeling of identity and/or dependence for the subsistence and the well-being (Borrini-Feyerabend, 2010; Garibaldi & Turner, 2004). Those relations are mediated by customary institutions, among others: totemic species, sacred sites, ancestral sites and meeting places, ancestral shrines (pioneer settlers/ land use in and around the shrine sites), animal taboos, spiritual practices and ceremonies (songs, dances, initiation), traditional calendar, village lands ("terroirs") and territories, etc. (Adler, 1998; Artaud, 2021; A. Begossi *et al.*, 2004; Lévi-Strauss, 1962). Indigenous peoples and local communities depend on those institutions for their livelihoods, with which they identify and which they control through ritual offices. These customary institutions are more or less formalized and recognized by official institutions (cf. chap 6) or combined with official systems of governance (positive law) in a context of legal and institutional pluralism. Therefore, custom systems (values, norms, institutions and rules) are recognized to play a major role in the development, management and control of wild species (Armitage *et al.*, 2017; Artaud & Surrallés, 2017; Bennett *et al.*, 2017; Cinner, 2009; Clark, 2011; Frangoudes & Gerrard, 2018; Hulme & Murphree, 2001; Johannes *et al.*, 2000; Pascual *et al.*, 2017).

From a vast literature review and critical analysis, three categories currently are identified, namely instrumental, relational and intrinsic **(Figure 4.14)**. These norms and values exclude or combine, succeed one another, or are superimposed on one another, mediated by institutions and customary rules, which regulate practices (hunting, fishing,

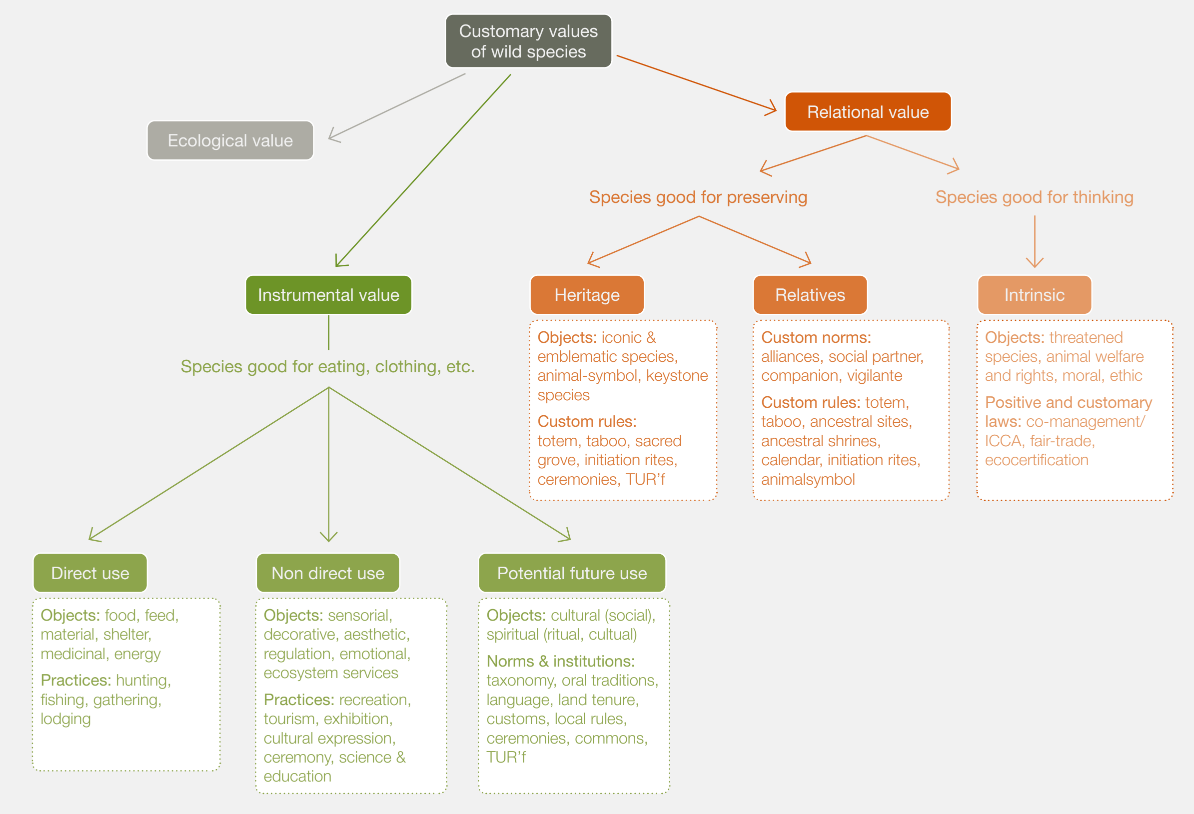


Figure 4 14 **Set of customary values of wild species.**

Source: adapted from Skubel *et al.* (2019) © 2019 under license CC BY.

gathering, etc.). As a matter of fact, the convergence of a species as "good for using (eating, clothing, healing, …)", "good for preserving" and "good for thinking" most often assure more efficient conservation of wild species.

Thus, the capture of an animal, its killing and the sharing of its body are subject to customary rules of respect, reciprocity, and sobriety. The indigenous and local knowledge report cites many examples of such customary rules including the relationship of Maasai with wild species.

Many indigenous peoples and local communities have rules for sharing the catch, with a special sin granted to the genitals of animals, endowed with aphrodisiac virtues and most often intended for the "big chief" or lineage elder (Agrawal & Gibson, 2001; Artaud, 2014; Benitez-Capistros & Couenberg, 2019; Johannes, 1981).

Moreover, the construction of wild species as iconic, and its transmission from generation to generation – is often deemed a tool for sustainable natural resource management and are susceptible to gaining heritage status (Bassett & Cormier-Salem, 2007).

The relations between people and wild species are complex and dynamic: they are complex, in so far as there are differential relations between species and what they reveal about the differential relations between social groups; one species can be considered by a group or certain members of that group (female or male initiated, priests, intercessors, etc.), at the same time and in the same place or according to the period and to the place, good for eating, preserving and/or thinking. The relations are dynamic in the same way that the social structures should adapt to the change. Human societies look to animal and plant species in their environment as a means to structure their social world (Lévi-Strauss, 1962). The reproduction of the social system (the establishment and maintenance of human interactions) requires a permanent reorganization of these relations between humans among themselves and between humans and nature regarding the links between tradition and innovation and resilience (Berkes *et al.*, 2003; Cinner & Barnes, 2019; Cosens, 2013; Matin *et al.*, 2018; Prado *et al.*, 2015; Yadav *et al.*, 2019; Young *et al.*, 2006).

The following sub-section will have two lenses: first on wild plants and medicinal values; second on wild fauna and animal symbolism.

Customary (traditional) medicinal values of wild plants

Medicinal values of wild species, especially wild plants have been extensively studied in recent years. For example, a study by (Shinwari & Qaiser, 2011) in Margalla hills National Park in Islamabad, Pakistan provides a list of wild plant species that are used by local people and *Hakims* (local practitioners) to treat several ailments. For instance, *Achyranthus aspera* is used for seasonal cough leaves of *Calendula arvensis* to heal wounds, leaves of *Achyranthus aspera* with the fruit of *Rubus fruiticosus* for eye diseases, *Chenopodium ambrosoides* for piles, etc. However, widespread recognition of such values, as well as population growth, promote overexploitation. The regeneration and propagation of the above-mentioned species are of concern in the region due to their unsustainable use, which includes

Box 4 36 **Generational transmission of ancient healing knowledge – Tibetan Amchis.**

Traditional Tibetan medical doctors and the traditional practitioners called Amchis, who use herbal remedies and analyze pulse, urine, and tongue to diagnose disease and are one of the oldest surviving medical traditions of the world. It has been popular throughout the central Asian regions of Mongolia, Bhutan, some parts of China (Tibet Autonomous Region), Nepal, the Himalayan regions of India, and a few areas of the former Soviet Union. In the trans-Himalayan district, Dolpa of Nepal, Amchi knowledge is passed down through dedicated apprenticeships under the tutelage of senior Amchi (Bhattarai *et al.*, 2009). In Dolpa – a northern and remote district of Nepal, more than 400 plant species were documented, and the area was found to be exceptionally rich in ethno-medicine and indigenous knowledge (Ghimire *et al.*, 1999, 2001), including use of caterpillar fungus *(Ophiocordyceps sinensis)* for the treatment of various diseases (Devkota, 2006). According to the Tibetan concept of illness, disease arises when the dynamic equilibrium between the three psycho-physiological conditions or 'humors' (nyepa-sum) translated as wing (lüng), bile (tripa) and phlem (beken) are disturbed (Khang, 1981; Lama *et al.*, 2001; McGehee, 2012). Amchis diagnose the disease without any sophisticated instruments by determining whether the nature of the disease is 'hot' (tsa) or 'cold' (dang) (Lama *et al.*, 2001). The basis of their diagnosis is analysis of pulse, urine, and tongue. The treatment of disease involves the use of herbal medicines as well as moxibustion and bloodletting (Ghimire *et al.*, 1999, 2001; Lama *et al.*, 2001). In Amchi medicine animal parts, and various minerals, stones, such as alum, calcium, camphor, copper, emerald, gold, granite, iron, lead, limonite, magnesium, mercury, sapphire, quartz, talcum, zinc, etc.(Khang, 1981), are also used for the preparation of medicine. However, Amchis face great difficulties in getting some of these products because of legal restrictions (Rokaya *et al.*, 2005). Training and less restrictive guidelines for the collection of medicinal resources, would assist local people in scaling up production, generating income, and preserving an age-old healing practice (Rokaya *et al.*, 2005).

untimely plucking of leaves, and flowers or uprooting the whole plant without considering its further propagation. Similarly, local communities living around Queen Elizabeth National Park, Maramagambo Central Forest Reserve and Ihimbo Central Forest Reserve in Southern Uganda identified nearly 302 medicinal plants, many which are used to treat several ailments including digestive disorders and allergy (Gumisiriza *et al.*, 2019). In addition to medicinal values, 47 wild plants species are also consumed as food, highlighting the nutraceutical value of the species. Out of 302 plant species identified, 91 were reported to be rare. In some cases, the use of roots, or several parts of the same plant for medicinal use results in killing the plant, thus destroying the chances of survival and propagation. In another study, 79 wild medicinal plant species were listed from Jordon (Al-Qura'n, 2009). Though the medicinal values of wild species are generally well-acknowledged, a lack of ethnobotanical, ecological, as well as ethno-pharmacological information on wild species often leave them vulnerable to overexploitation. In addition, indiscriminate and commercial use is also resulting in the loss of various wild plant species making them rarely available.

Communities value wild species not only for their medicinal or market values but also for a combination of criteria, including socio-cultural and environmental values. An ethnic group in Bénin, for instance, used a range of criteria including the plant's nutritive value, popularity, absence of taboos, its availability, and the energy input necessary for processing (N'Danikou *et al.*, 2015). The community also considered the perceived value of the species over their rarity for conservation. Wild species, especially wild edible plants, are considered important to maintain cultural identity (Schunko & Vogl, 2018; Seeland & Staniszewski, 2007), and spirituality (Hummer, 2013). Wild food is considered as a mark of local and regional traditions and is an irreplaceable expression of natural and cultural heritage (Pardo de Santayana *et al.*, 2012; Seeland & Staniszewski, 2007). For instance, wild foods have been part of traditional cuisines across the world, thus imparting cultural identities to various communities.

A study by Ali-Shtayeh *et al.* (2008) of 15 communities living under the Palestinian Authority, communities were found to gather nearly 100 wild edible plant species and to consume many of them cooked. For example, the leaves of *Rumex acetosa* are used as filling for a traditional pie called 'sambosek' or *Majorana syriaca* is used for preparing a traditional recipe that is popular in Palestinian communities called 'za'tar'. A few of these wild plants are mentioned in local folk songs and proverbs *(Malva sylvestris, Gundelia tournefortii, Salvia fruticosa)*. The study also highlighted how some wild plants are considered sacred as they are mentioned in holy books (e.g., *Majorana syriaca* in the bible), or blessed for being mentioned in legends linked with holy people (e.g., *Salvia fruticosa* and Virgin Mary). In Northern India, similar findings are reported (Chandra, 2013) where wild species of temperate Himalaya, like *Dioscorea belophylla* (locally known as Tairu) are used in traditional recipes to be consumed during winter, especially at festivals (Chandra, 2013).

Indigenous peoples and local communities in many regions depend on flora and fauna for food provisioning and cultural uses. In many cases, these uses are non-commercial (i.e., subsistence); in other cases, flora and fauna are shared through commercial markets (i.e., products sold commercially); in both instances, flora and fauna make important contributions to the health and welfare of communities (Cheikhyoussef & Embashu, 2013).

The contributions of flora and fauna to improved health outcomes are essential for many Indigenous Peoples and local communities. Clinically proven and perceived health benefits are also driving broader use of flora and fauna. In many countries common ailments, are treated at the household level, since diseases are considered to be connected with natural causes and hence their symptoms. This, in turn, can trigger unsustainable use. Moreover, large number of wild animals are consumed as ornaments, medicines, cosmetics, weapons, leather, and luxury lifestyle products (e.g., fur, wool, etc.). From large mammals to amphibians, unsustainable exploitation of wild species is often driven by social status and lifestyle, leading to uncontrolled exploitation of wild species. For instance, luxury seafood such as sharkfin soup, live reef food fish, etc. are often associated with traditional Chinese culture and medicine (Dell'Apa *et al.*, 2014; Fabinyi, 2012). Although in most cases such perceptions are misguided, the perceived benefits trigger high demand and consequently unsustainable exploitation of wild species.

4.2.5.2.8 Relational values of wild fauna

Nature occupies a privileged place in the symbolism produced by cultures around the world. Among all the elements of nature, animals are considered privileged communication partners in the processes of knowledge of humans. As expressed by (Dounias *et al.*, 2007), the animal symbol is the means by which man constantly strives to distinguish himself from or, on the contrary, to resemble, hoping to acquire its ability to liberate himself from certain human constraints. This animal is usually a real, tangible animal, and often a wild one. The species chosen differ from culture to culture and according to environmental, geographical, social, and historical contexts, as well as the psychological context, because all relations with animals call upon people's sensitivities and shared emotions. The formation (birth, with its reasons, choice modes, etc.), form (universe of signs, dialogue between concrete inventions, oral traditions, and writing), meaning (cosmogonies, myths, taxonomies), function (of mediator, unifier, pedagogue, socializer, …) of animal-symbol (Dounias *et al.*, 2007) illustrate the complex nature of the relationships between humans and wild species, the variability (sometimes of contradictions), multiplicity (of the layered levels of meaning), ambivalence, and also their constant reactivation or recreation.

The analysis of the local taxonomies is recognized as particularly efficient in documenting the place or the customary value that different species occupied for the indigenous peoples and local communities. The process of categorization is also considered as one of the most powerful solutions used by human to break up the world's complexity and there are a number of examples to illustrate this. A key finding from the indigenous and local knowledge workshop is that there can be sanctions or punishments for violating customary rules and norms designed to assure good relations with species and with nature.

4.2.5.2.9 Iconic species for indigenous peoples and local communities

Two major types of iconic species designation processes can be identified:

- **exogenous ones** that originate at the international scale: foreign actors, environmental lobbies, large non-governmental conservation organizations, and scientific experts. One only has to cite it in the International Union for Conservation of Nature red list or at the Appendices of the Convention on International Trade of Endangered Species. The history of these exogenous designations is well documented (Adams, 2006; Grove, 1996; Mackenzie, 1998; Neumann, 1998). They date from the late nineteenth century with the establishment during the colonial period of game reserves for hunting by foreigners and continue today in the creation of national parks by modern states (Rodary *et al.*, 2003). This history is replete with exactions made on the peoples living in or adjacent to the protected areas who have frequently been expelled, displaced and deprived of access to and use of their customary resources. It also provides many examples of imbalanced land-use patterns between protected areas that are little more than private reserves of a foreign elite engaged in trophy hunting or nature-based tourism and non-protected areas that are subject to intense demographic pressure and overuse of resources.

- **endogenous ones** (indigenous peoples and local communities and their organizations) that are more locally derived. In many instances, the two merge and thus become indistinguishable in origin (Fairhead & Leach, 2003; Luning, 2012). The Paris Convention, for example, takes into consideration the aesthetic, symbolic and historical value of retained sites.

4.2.5.2.10 Changes in customary values and status and effect on the use of wild species

Certain elements can lose their customary (or privileged) status while others might acquire it. The content of a custom is thus susceptible to alterations in the context of religious and political change, environmental transformations or diffusion of new ideas, products and peoples (through migration, for example). In Africa the erosion or transformation of ancestral cults by the spread of Islam and Christianity has turned sacred groves into profane places that are no longer protected from the axe (Dugast, 2002; Juhé-Beaulaton & Roussel, 2002). Thus, certain elements that were previously the object of implicit or explicit conservation measures have now lost their meaning and value and are no longer preserved. Such is the case with formerly taboo animals. Conversely, new natural elements can be invested with a patrimonial or identity dimension. For example, in Sub-Saharan Africa, indigenous peoples and local communities link land degradation to the erosion of customary institutions and knowledge, ritual neglect, and the diminished authority of land priests. While the Maane (Burkina Faso) recognize that demographic pressure has produced a demand for arable land on the Moose (Mossi) plateau, they ultimately interpret the disappearance of the bush as a consequence of a breakdown in their socio-cultural system Luning (2012). In Mauritania, Imraguen fisherfolk (Artaud, 2021): cultural values attached to 2 species (turtle and manatee): it's to-day loss of strength or its rebirth. While the manatee has lost its cultural relevance with the end of relations between herders and coastal communities, the importance of the turtle has doubled since the development of the National Park of Banc d'Arguin.

4.2.5.2.11 Iconic species and the policy-making challenge for sustainable use

The evolution of representations and their impact on the responsibilities and duties that indigenous peoples and local communities impose upon themselves as regards certain species, as well as their consequences, particularly in the domain of sustainable use and conservation are pretty well documented (Artaud, 2021; Dounias *et al.*, 2007). Besides, differences in wild species norms and values (cf. fig below with 3 categories of values): ecological, economical, anthropocentric, or customary, between stakeholders (indigenous peoples and local communities, non-governmental organizations, managers, decision-makers, etc.), locally, nationally and internationally, and even within local populations (between farmers and fisherfolk, herders and collectors, but also according to gender, origin, status, etc.) are at the root of environmental violence around the world, which have also given rise to many accounts (Neumann, 1998, 2015; Peluso, 1993; Peluso & Watts, 2001). The divergence of values regarding wild species (ecological *versus* anthropocentric, economical *versus* socio-cultural) most often are at the root of inefficient policies, environmental injustice, and unsustainable use **(Figure 4.15)**.

Box 4 37 The changing status of shark.

From the (artisanal) fisherfolk knowledge, the shark is neither a predator nor a prey, but rather a social partner, with various protective, vigilante or even totemic status for certain lineages in Pacific islands (Bataille-Benguigui, 1988) or in Africa (M.-C. Cormier-Salem, 2006). The shark only became a target species with the removal of fins, which has resulted in many social and spatial changes on tropical coasts (Africa, Madagascar, Asia)

Regarding the customary values of the shark within West African communities, three main relations can be schematically identified:

1. In some communities, estuarine, lagoon and island, the shark is game, the capture of which gives rise to collective hunting and meat is a delicacy. Smoked or salted-dried shark flesh constitutes an essential source of protein for certain forest and Sahelian populations; in certain coastal communities, it is a sought-after dish, and even locally, with a strong identity burden as among the Aïzi Ivorian lagoons (Verdeaux, 1981).

2. In others, on the contrary, among peasant-fisherfolk, it is an iconic animal, which gives rise to many myths and rites (see below initiation rituals of Bijjogo people, Bissau Guinea). Among the Bijagos, in Guinea Bissau, sharks are an emblematic species, as evidenced by the sumptuous prows of the Bijagos canoes bearing the image of this animal, ritual dances with masks dominated by shark (or rather fish) saws. Sharks are also involved in the initiation of rites as young boys, to reach adulthood, should capture a shark and present its liver to the elders. These rites are very similar to that practiced among the Maasai populations of Kenya, which the writer J. Kessel helped to magnify: the Morane is considered by the tribe a man capable of marrying a woman when he kills a lion with a knife and a javelin. For this hunt, he is adorned with hair similar to the lion's mane. This parallelism between the lion and the shark is also noted in certain coastal communities: in Wolof (Senegal), the generic name for the shark is gainde gej, that is to say literally "lion of the sea. Like the lion, who owes his power, his strength and his majesty, to be the king of the jungle, the shark, sea monster, is the king of fish, or more precisely the king of marine fauna. We don't fish it, but we hunt it like all great predators. The liver sample is not surprising because, with the heart, it is the most valued part of the body.

   In the animistic pantheon of Diola de Casamance, marine animals are widely represented. Sharks, alongside manatees, dolphins and caimans, often have the status of totem animals. The origin myths of certain clans, for example in Kabrousse, clearly refer to the sea and a sea monster, cousin of the shark. In addition to its symbolic and cultural value, it should also be emphasized its nutritional and utilitarian importance. Investigations carried out in Casamance in the 1980s (M.-C. Cormier-Salem, 1992) showed that incidental catches of sharks were "traditionally" remarkably valued: both the flesh (consumed smoked, in sauce, with rice) and the fat (processed in oil, soap, cosmetics and pharmaceuticals 15, etc.), the skin (flaking and tanned like leather), teeth and bones (various tools, such as hooks, jewelry, weapons) were used.

3. In most of the artisanal fisherfolk, the professional of the sea, who have knowledge of the sea, the shark has a privileged status, like all sea monsters, the consumption of which is prohibited. Shark is considered as an avenger, protector and repairer. In Senegal, among the migratory fisherfolk (Guet-Ndariens, Wolof, Lebu, Serer), the tradition recognizes various categories within sea creatures, distinguishing in particular good-luck or bad-luck fish. The shark capture is avoided. Its flesh, red and bloody, is poorly valued (this ban also affects tuna). If a fisherman is wounded by a shark, it is considered as the fair punishment for his fault. The "victim" has transgressed a prohibition, justifying the manifestation of the sea monster and the necessary intercession of the priest, whose incantatory formulas will make it possible to be reconciled with the sea and its creatures.

The shark's status has changed from that of a respected, feared, and avoided social partner to that of a target species with the globalization of the market and the arrival of new actors in the fisheries sector. The fining is a fishing system that targets the capture of selacians for their fins and has developed considerably since the 1980s in all coastal countries of the world to meet the demand of the Southeast Asian market. Shark fins are the basis of a Chinese soup appreciated for its gastronomic and healing properties. In West Africa, the specialization of certain fisherfolk in the "fining" is first of all due to the "old" shark fishermen, such as the Ghanaians (Fanti and Ahena) who, from the 1970s, controlled the salt-dried shark meat sector. Nowadays, they constitute important communities of migrants in Ivory Coast, but also in Senegal, Gambia, Guinea-Bissau, Republic of Guinea, playing a major role at all stages of the sector (fisherman, processor, trader). On their model, other actors, originating from the circles of fisherfolk – guet-ndarien, lebu, serer, niominka – specialize in fining. Finally, this sector is attracting a growing number of actors from the interior regions, foreign to the sector, farmers, and breeders, who convert to fishing but are above all very present in the marketing and processing of sharks. With the development of fining, from the 1980s, the shark became a target species with high market value, and consequently, some species of shark would have disappeared, others would have become rare. This is the case with sawfish *(Pristis pristis)*, represented on all the coins. The main socio-cultural drivers of the unsustainable uses are the attractivity of this sector for new actors, coming from the hinterland with their uses and knowledge, the loss of traditions, a dysfunction of the customary institutions and of the old systems of control over the coast and its resources, a questioning of the knowledge and powers of the elders. Islamisation, the marginalisation of former customary chiefs, the loss of control of the elders over fishing grounds, non-compliance with prohibitions lead also to unsustainable practices.

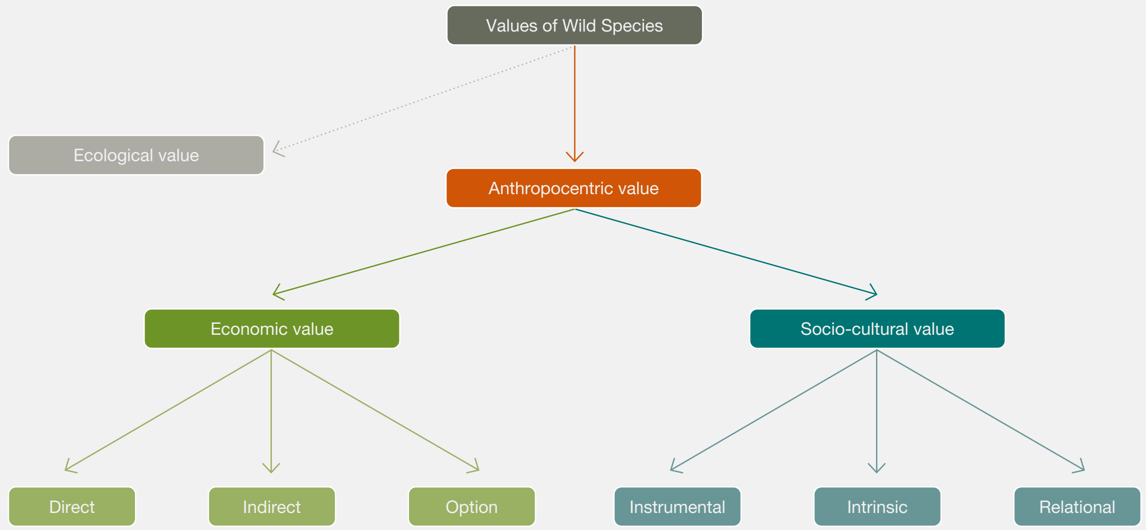


Figure 4 15 **Values of wild species**

These conflicts accompanied the colonization of the Southern part of the globe (colonial imperialism), then from the end of the 19th century onwards, what some call "green imperialism" with the rise of environmental lobbies (Grove, 1996), and finally the neoliberalism and the commodification of nature (Fletcher *et al.*, 2015). The debates are always vehement (cf. in France regarding the reintroduction of large predators, wolves, lynx, bears, etc.).

There are examples and counter-examples of sustainable and unsustainable use of iconic species (or customary lands), notably due to the changes in policymaking regarding land tenure or the enclosure of the commons during the colonial period. Customary claims on land within national park boundaries are pointed out by Neumann and others. Heritage claims in Africa often serve to mediate territorial and identity claims (Berry, 1993; M.-C. Cormier-Salem *et al.*, 2005; Zerner, 2000). The changes in governance from customary laws to formal laws contributed to the decline of the traditional chief, and the appearance of new elites (Agrawal & Gibson, 2001a; Bassett & Cormier-Salem, 2007).

As highlighted above, the convergence of a species as "good for eating", "good for thinking" and "good for preserving" most often assure more efficient conservation of wild species. Nevertheless, there are counter-examples of "false convergence" with a risk of freezing the tradition, which can actually lead to weakening conservation attempts. Artaud (2021) highlights the limits of these "hybrid" models, which wish to integrate the cultural values attributed to a species, but which do so only partially, without considering the complexities and the dynamics (studied case: Fish co-management in two marine protected areas in Guadeloupe and in Mauritania).

Although the existence of indigenous conservation territories and areas conserved by indigenous peoples and local communities is as old and widespread as human civilization itself, they have emerged only recently as a major phenomenon in formal conservation circles. International policies and programmes, notably those of the International Union for the Conservation of Nature and the Convention on Biological Diversity, encourage today all countries to recognize and support indigenous peoples and local communities as examples of "effective governance of bio-cultural diversity". It is clear, however, that such recognition and support need to be carefully tailored, and cannot be improvised (Borrini-Feyerabend, 2010).

Changes: shifting or porous frontiers between human and animal

Recently, the divide between humanity and animality has started to be less radical, new horizons are opening to philosophical and anthropological thoughts (Dounias *et al.*, 2007). For example, whale (Kalland, 2009) metonymic relationship to nature (i.e., whales represent nature at large) and, at the same time, a metaphoric relationship to society (i.e., whales symbolize human relations.). In the case of the chimpanzee, the biological relationship with humans is closer. Scientific research and the observation of language, but also aesthetic sensitivity and cognitive anthropology lead to a blurring of the frontiers, making them more labile (Dounias *et al.*, 2007; Leblan, 2017). In the case of the Landouma people in Republic of Guinea, they can hunt chimpanzees but not for consumption. There is no competition between them; they can coexist and therefore there is no reason to separate humans and animals by creating protected areas (Leblan, 2017).

A growing challenge facing science-based policymaking on sustainable use is the growth in dominance of intrinsic (and ecological) values and morals opposing the sustainable use, particularly of iconic species such as elephants, lions, and rhino (Bauer *et al.*, 2018; Biggs *et al.*, 2017; Di Minin *et al.*, 2016; Lindsey *et al.*, 2016). In particular, there has been a growth in mutualist orientations toward wild species (Manfredo *et al.*, 2017), which dictate that wild species should be treated in the same way as people and should have the same rights (Maris & Bechet, 2010). Therefore, sustainable use of wild species is perceived as immoral (Biggs *et al.*, 2017). Examples of policies on sustainable use and real impacts on human livelihoods and wild species can be seen in the outbursts in response to the hunting of Cecil the Lion (Lindsey *et al.*, 2016) and the restrictions on transporting wild species trophies by numerous airlines. These developments point to a main challenge for science-based decision-making regrading sustainable use. Underlying this challenge are the different values that individuals and groups hold over the moral acceptability of sustainable use of iconic species as a source of conservation revenue (Biggs *et al.*, 2017). Drawing on experience and evidence from other areas of conflict resolution, Biggs and others propose a structured iterative process that incorporates differences in values together with scientific evidence (Biggs *et al.*, 2017).

4.2.6 Scientific and technological innovation and education

Key messages:

- Rapid transformations in the life sciences and modern biology have changed the way the natural world is studied and understood, with enormous implications for the management of wild species and conservation across all sectors and practices including fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices like observing. Genomic technologies and bioinformatics have generated an enormous amount of data and analysis, and the trend is a continued and accelerated expansion of scientific understanding *(well established)* {4.2.6.2}.

- Advances in science and technology can both contribute to, and undermine, the sustainable use of wild species. Positive contributions include an enormous expansion of invaluable scientific understanding and knowledge directly useful for the sustainable use and conservation of species, including new ways to identify, characterize, manage, and monitor species, and set priorities for conservation. This knowledge and resulting tools are employed across practices including fishing, gathering, terrestrial animal harvesting, and logging, as illustrated in hundreds of studies in recent years *(well established)* {4.2.6.2}.

- Positive contributions of advances in science and technology also include information/knowledge and technical support for the implementation of policies and laws that regulate the use and trade of wild species. Conservation and sustainable use laws based on a deep understanding of species, populations, and ecosystems have proven to be more effective, as documented in numerous studies and policy evaluations. The indirect and direct negative impacts of destructive laws and policies are also illustrated by advanced scientific research *(established but incomplete)* {4.2.6.2}.

- Fishing, gathering, terrestrial animal harvesting, logging and non-extractive uses all take place within the context of broader ecosystems, the health of which impacts sustainable use of species and populations. Advances in science and technology also have direct impacts on sustainable use by impacting ecosystems from which species are harvested, including erosion and degradation of ecosystems, and nature's contributions to people, resulting from feedstocks for new 'biological factories', as well as the positive impact of bioremediation *(established but incomplete)* {4.2.6.2}.

- Science and technology create conditions that support or undermine sustainable use and local livelihoods, indirectly or directly. Biotechnology and 'biological factories', for example, can provide substitutes for unsustainably harvested plants, animals, and marine species, -thereby taking pressure off wild populations, but they can also negatively impact small-scale producers and harvesters who depend on those species to make a living in a range country *(established but incomplete)* {4.2.6.2}.

- Information and communication technologies improve managers' decision-making processes through improving their ability to acquire timely and relevant data related to the population movement, scale, and management of wild species *(established but incomplete)* {4.2.6.3}.

- Information and communication technologies support managers and decision-makers' ability to collaboratively analyze, access, and share data, and to work in partnership in these processes with colleagues, peers, decision-makers, and members of the public *(well established)* {4.2.6.3}.

- It is well established that technology and urbanization contribute to decreased contact with biodiversity, leading to a decline in biodiversity-related knowledge and lack of awareness of its loss, unsustainable use, and importance in the lives of humans *(well established)* {4.2.6.4}.

- Global trends toward standardization of education are resulting in decreasing attention to, and understanding of, local biodiversity, and a decline in community resilience *(well established)* {4.2.6.4}.

- Research and practice demonstrate that indigenous, place-based, and experiential learning build bonds between community members and their ecosystems, leading to a stronger environmental ethic *(established but incomplete)* {4.2.6.4}.

- Institutional disincentives within academic and research organizations discourage the communication of relevant research results about biodiversity to broad audiences. Reform of academic incentive structures is needed that reward on-the-ground engagement with local groups and in biologically and culturally diverse regions, and broader communication of findings beyond the scientific community *(established but incomplete)* {4.2.6.4}.

- Initiatives such as communication for social change, social learning, citizen science, and health-related sciences demonstrating links between human health and biodiversity can serve as a model; these fields are building bridges between science and the public, and their methods could improve understanding of the value of biodiversity and promote sustainable use of wild species *(well established)* {4.2.6.4}.

- Many local and indigenous groups are calling for systemic changes in educational systems to respect the traditions, knowledge, languages, values, history, and identities of their cultures. Formal recognition by national educational systems of cross-generational knowledge transmission and a wider range of approaches to learning would support local stewardship and sustainable use of wild species *(established but incomplete)* {4.2.6.4}.

- Biodiversity education and communication can nurture a conservation consciousness which is fundamental to supporting sustainable use of wild species. There is an emerging consensus that effective education programs respect local cultures, languages, and land, involve women, elders, and youth, and promote inter-generational transmission of knowledge *(established but incomplete)* {4.2.6.4}.

4.2.6.1 Overview

This section addresses scientific and technological innovations in the life sciences, and information and communication technology, with direct and indirect impacts on the sustainable use of wild species, as well as the critical role that education and awareness can play in changing behavior and practices. These elements are combined into a single section because they contribute to shifting paradigms, and to solutions. All are drivers of change at the levels of both specific sustainability challenges (e.g., over-harvesting, hunting, grazing, etc.), as well as broader, transformative social, economic, and ecological change.

Scientific and technological innovations, characterized by new ideas, creative thoughts, and imagination in the form of a device or method, can have both positive and negative impacts on sustainability, and this section addresses both the challenges and opportunities they present. Recent scientific and technological advances have transformed how people interact with, and learn about, the natural world. The understanding of biodiversity has expanded through scientific advances, as at the same time, human-nature interactions, among vast proportions of the world's population, have drastically diminished. Information and communication technologies have also revolutionized education, as has the rise of citizen science across the globe. This section will explore the positive contributions education and awareness-raising can contribute to sustainability of wild species use, as well as the challenges to enacting appropriate education and outreach, including institutional disincentives for researchers, governments, and others to incorporate education and awareness-raising into their work.

Developments in the life sciences, modern biology, and information technologies have both contributed to, and undermined, the sustainable use of wild species. Benefits include improved identification, characterization, management and monitoring of species, and technical support for the implementation of policies and laws that regulate sustainability and trade of wild species. Information and communication technologies play a central role in influencing and shaping the public's perception of the value, management, and use of wild species. Information and communication technologies and global trends towards homogenization and standardization of education, have also contributed to a decline in direct contact with, and knowledge of, biodiversity. There is emerging consensus that effective education programs respect local cultures, languages, and land, involve women, elders, and youth, and promote place-based learning and inter-generational transmission of knowledge.

Evidence-based knowledge from academic literature has been searched extensively using unique and cross-referencing keywords to find information relating to the main questions of this sub-chapter (science, information and communication technologies, and education) regarding sustainable utilization of wild species in local, regional, and global scenarios. In addition to scientific findings, from bibliographic search engines, non-academic publications (grey literature, reports, working papers, government documents, white papers, and evaluations) were similarly reviewed. Furthermore, to broaden the range of information on indigenous and local knowledge, the experts conferred with individuals with decades of experience living in and working with, rural and indigenous communities. Critical evaluation of the state of knowledge was performed by independent team members to ensure the legitimacy, relevance, and credibility of the presented evidence.

4.2.6.2 Developments in the life sciences and modern biology with a bearing on the sustainable use and management of wild species

Rapid transformations in the life sciences and modern biology have changed the way people study and understand the natural world, with enormous implications for the management of wild species and conservation across all sectors and uses – including hunting, fishing, wild plant gathering, logging, and non-extractive uses like recreation and tourism. Genomic technologies and bioinformatics have generated an enormous amount of data and analysis, and the trend is a continued and accelerated expansion of scientific understanding including quantifications of three genetic indicators in the context of international policy and regulation related to the sustainable use of biodiversity (Hoban *et al.*, 2020).

Almost every branch of the life sciences and modern biology today are undergoing rapid change. Genetic, or DNA, sequencing techniques have become faster, cheaper and more accurate in recent years, helping us to understand the molecular basis of life, and transforming scientific practices and understanding (Heather & Chain, 2016). Linked to genomic technologies is the parallel development of the field of bioinformatics. Genomic technologies used to study genes and their functions generate an unprecedented amount of information, and require bioinformatics to manage the collection, classification, storage and analysis of vast and complex biological data (National Academy of Sciences, Engineering and Medicine, 2017).

Advances in genomics and bioinformatics have in turn spawned metagenomics, also known as environmental genomics, in which researchers sequence and analyze genetic material found in environmental samples, usually from soil or water. Thousands of microorganism species might be represented in a single sample. This technique has vastly increased the knowledge of genetic and biological diversity (Escalante *et al.*, 2014). In another advance, DNA barcoding focuses on the 'genetic fingerprint' of a species, allowing for the identification of species from short fragments (standardized region between 400 and 800 base pairs) of DNA (Schindel *et al.*, 2015).

4.2.6.2.1 Advances in science and technology can both contribute to, and undermine, the sustainable use of wild species

Positive contributions include an enormous expansion of invaluable scientific understanding and knowledge directly useful for the sustainable use and conservation of species, including new ways to identify, characterize, manage, and monitor species, and set priorities for conservation. This knowledge and resulting tools are employed across sectors including terrestrial animal harvesting, fishing, wild plant gathering, and logging, as illustrated in hundreds of studies in recent years.

Advances in science and technology can both contribute to, and undermine, the sustainable use of wild species (IUCN, 2019; Laird & Wynberg, 2018). Positive contributions include the indirect, but extremely important bedrock of scientific understanding that supports sustainable use and conservation of wild species, including providing invaluable information and understanding to conservation planning and management. Scientific advances have transformed the understanding of the natural world in recent years, providing researchers and conservationists with important tools and approaches to management and policy, which continue to advance with time (Supple & Shapiro, 2018).

Examples of conservation understanding and management gains from advances in science and technology include, for example: a discovery of additional components of lichenicolous fungi together with mycobiont and photobiont symbionts (Lawrey & Diederich, 2003; Millanes *et al.*, 2016; Spribille *et al.*, 2016) new ways to identify and characterize biodiversity (Mosa *et al.*, 2019; Palomares & Adrados, 2014); better understand genetic variability in populations of highly abundant or rare wild species (Ayala-Burbano, 2020; Drury *et al.*, 2016; Xue, 2015) and the critical role of pollinators (Lopez-Maldonado & Berkes, 2017); monitor environmental change (Thomsen & Willerslev, 2015); manage invasive species (Hand *et al.*, 2015); sequence and taxonomically identify understudied taxa like lichens (Mark *et al.*, 2016) and edible/poisonous wild mushrooms (Khaund & Joshi, 2014; Parnmen *et al.*, 2016) and set priorities for *ex situ* (Castañeda-Álvarez *et al.*, 2016) and *in situ* (Kell *et al.*, 2012) conservation. A range of technologies – including miniaturized satellite tags deployed onto animals, smartphone apps, camera and audio traps, and drones – as well as the work of citizen scientists, have considerably increased the ability to collect huge volumes of new data, which people can now analyze with news analytical methods, allowing a much better understanding of wildlife and plant behavior and population dynamics, and the consequences of their exploitation.

Some groups are working to sequence genomes and catalogue species, to build libraries and datasets to support sustainable use and conservation of species. For example, the Earth BioGenome Project is working to sequence, catalog, and characterize the genomes of all of Earth's eukaryotic biodiversity over a period of 10 years (Lewin *et al.*, 2018). (Mosa *et al.*, 2019) report on global efforts to generate DNA barcode libraries for vascular plants, and the contribution of herbaria specimens – preserved and already identified – as a complement to wild samples as groups develop reference DNA barcode libraries for plants from different regions. (Marthinsen *et al.*, 2019) describe the OLICH Project, an authoritative reference library of DNA barcode sequences of Nordic lichens.

4.2.6.2.2 Positive contributions of advances in science and technology also include information/knowledge and technical support for implementation of policies and laws that regulate sustainability and trade of wild species

Conservation and sustainable use laws based on a deep understanding of populations, species, and ecosystems have proven to be more effective, as documented in numerous studies and policy evaluations. The indirect and direct negative impacts of destructive laws and policies are also illustrated by advanced scientific research. In addition to expanding the understanding of populations, ecology and conservation status of useful species, new technologies also support the sustainable use of wild species more directly by assisting with the implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora and national laws intended to regulate trade in wild species (Ghorbani *et al.*, 2017; Subedi *et al.*, 2013). This includes tracking illegally harvested and traded species, and identifying those intentionally mislabeled (Feitosa *et al.*, 2018). DNA sequence markers make it possible to distinguish between wild and cultivated species, geographic origin, and assist with the Convention on International Trade in Endangered Species of Wild Fauna and Flora enforcement (Hassold *et al.*, 2016). Enforcement is clearly an essential part of compliance, and of ensuring sustainable use of wild species, and increasingly this involves scientific analytic techniques and DNA profiling and barcoding. The key areas this is done to support the Convention on International Trade in Endangered Species of Wild Fauna and Flora compliance include: *species identifications*, including using DNA markers when wild species samples are heavily processed or multiple species are mixed as in traditional medicines; *matching a DNA sample to an individual plant or animal* using DNA profiling that relies on reference databases; *verifying captive breeding origins* and parentage; and *identifying geographic origins of samples*, assigning them to genetic populations of origin, which also requires comprehensive data profiles from possible source populations; and *forensic scientific standards* to prosecute the Convention on International Trade in Endangered Species of Wild Fauna and Flora offenses (UNEP-WCMC, 2013).

Chang *et al.* (2018) used DNA barcoding based on government-seized Chelonian (turtle and tortoise) specimens deposited at Taipei Zoo as a shortcut to traditional morphological identification and found that a "fast and accurate method to authenticate seized samples could assist law enforcement agencies to prosecute criminals and restrict illegal exploitation of wild chelonian resources." DNA barcoding approaches would make applying the Convention on International Trade in Endangered Species of Wild Fauna and Flora more practical and accessible. Aubriot *et al.* (2013) used DNA barcoding for the genus Euphorbia in Madagascar, with 170 native species almost all endemic and threatened by habitat loss and illegal collection of wild plants. Almost all Malagasy Euphorbia are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendices I and II, but an absence of reliable taxonomic information means that these species are difficult to identify, even when fertile with flowers and fruits, and this makes implementation of the Convention on International Trade in Endangered Species of Wild Fauna and Flora difficult. DNA barcoding can also be used in border security programs to intercept potential invasive species at ports-of-entry and is particularly useful because identification of immature arthropods is challenging when identification characters are based on adult morphology and reproductive structures (Madden *et al.*, 2019).

Johri *et al.* (2019) report on recent innovations to increase the affordability, accessibility, accuracy, speed and breadth of ecological investigations of threatened Chondrichthyes – sharks, rays, skates and chimeras – through genome sequencing. Global markets for these species have resulted in unsustainable fishing practices, which are facilitated by a lack of regulations and ecological data required for conservation. Using a Next Generation Sequencing (non-Sanger-based high-throughput DNA sequencing technologies) method, MinION, a hand-held portable sequencing device, allows more widespread and accurate identification of shark species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendices, and produces invaluable ecological data.

4.2.6.2.3 Terrestrial animal harvesting, fishing, gathering, logging and non-extractive uses all take place within the context of broader ecosystems, the health of which impacts sustainable use of species and populations

Advances in science and technology also have direct impacts on sustainable use by impacting ecosystems from which species are harvested, including erosion and degradation of ecosystems, and ecosystem services, resulting from feedstocks for new 'biological factories', – that use biotechnology to produce biofuels, biochemicals, bioplastics and other products, as well as the positive impact of bioremediation.

In addition to the contributions of science and technology to species conservation and management, commercial applications of knowledge and technologies also have positive and negative direct impacts on the sustainable use of wild species through the ecosystems of which they are a part. This impact is increasing, as science and technology rapidly advance, and one area with direct impacts on the sustainable use of wild species is synthetic biology, and biotechnology or biological factories.

Using 'synthetic biology' – the design and construction of new biological parts, devices, and systems, and the redesign of existing, natural biological systems for useful purposes – researchers now design cells to replicate products or compounds found in nature, or new chemicals, drugs, biofuels, food and flavorings, and a myriad of other products (Eisenstein, 2016) Synthetic biology is a departure from earlier science because of the focus on design and construction of core components (parts of enzymes, genetic circuits, metabolic pathways, etc.) that are modelled and tuned to meet specific performance criteria (https://ebrc.org/synberc). Synthetic biology was defined by the Convention on Biological Diversity *ad hoc* technical expert on synthetic biology, as "a further development and new dimension of modern biotechnology that combines science, technology, and engineering to facilitate and accelerate the understanding, design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems" (UNEP/CBD/SBSTTA/20/8, March 2016).

One implication of these new technologies for wild species is that production and manufacturing have been 'decoupled' from finite, non-renewable resource consumption. Some argue that this is a positive development for sustainability since biological factories – that use biological systems to produce commercial materials – can replace petroleum-based products and those over-harvested from the wild and are cleaner and more efficient manufacturing processes that pollute less and reduce waste (Piaggio *et al.*, 2017; D. Scott *et al.*, 2015). The commercial growth of *Cordyceps militaris* a caterpillar fungus as a substitute of highly priced and well demanded *Ophiocordyceps sinensis* is also an important outcome of technological enhancement (Lin *et al.*, 2018).

Others are concerned that the supply of feedstocks – raw materials used to produce sugar for the biological factories – is itself unsustainable. Feedstock crops can replace food crops, and forests, and 'marginal' or 'degraded' areas are cleared to grow agricultural feedstocks, in some cases through land grabbing and the violation of the rights of indigenous peoples and local communities (Bagley, 2017; Scott *et al.*, 2015; Webb & Coates, 2012). Many of these so-called "marginal" and 'degraded' areas might contain wild species of value to local communities, or regional or global markets, and might also be biologically diverse and important habitats.

Positive contributions of advances in science and technology to ecosystem health include bioremediation. Bioremediation uses decomposers or their enzymes – mainly microorganisms, plants, and microbial or plant enzymes – to clean pollution, and remove or neutralize contaminants in the soil, ocean, and other environments.

4.2.6.2.4 Science and technology create conditions that support or undermine sustainable use and local livelihoods, indirectly or directly

Biotechnology and 'biological factories', for example, can provide substitutes for unsustainably harvested plant, animals, and marine species –- thereby taking pressure off wild populations, but they can also negatively impact small-scale producers and harvesters who depend on this income. This is liable to reduce local motivation to conserve the ecosystems on which those species depend.

For species currently overharvested in the wild, the production of substitute chemicals and products in biological factories could provide a non-destructive alternative. For cultivated raw materials insufficient to supply the demand of markets, with resulting unstable markets producing shortages or wide price fluctuations, biological factories – which use synthetic biology methods and biological systems to produce useful commercial biomaterials or biomolecules – can help address supply challenges (Kung, 2018; Paddon *et al.*, 2013). This includes medicines like artemisinin, an important life-saving drug used to treat malaria. However, for species that are grown sustainably in small-scale agriculture, products produced in biological factories and labelled 'natural" – like vanilla, saffron, stevia – could displace the products of small farmers, damaging local livelihoods (Bagley, 2017; Laird & Wynberg, 2018), although a wide range of factors contribute to supporting or undermining community livelihoods tied to commodity sales of bulk raw materials.

4.2.6.3 Developments in the information and communication technologies with a bearing on the sustainable use and management of wild species

Rapid development and increasing access to information and communication technologies are changing how policymakers, managers, local communities, and organizations communicate about, collaborate and administer the sustainable use and management of wild species.

Information and communication technologies refer to all digital communication tools including the internet, wireless networks, mobile phones, computers, software, instant messaging, video-conferencing, social networking, and other media applications and services that enable users to access, retrieve, store, transmit, and manipulate information in a digital form. Progresses in mathematics, computer science (big data) and other kinds of technology (e.g., miniaturized satellite tags deployed onto animals) have considerably increased the ability to collect and analyze huge volumes of new data, allowing a much better understanding of wildlife and plant behavior and population dynamics, and the consequences of their exploitation Globally people now live in an increasingly 'networked society' where there is 'growing convergence of specific technologies into a highly integrated system, within which old, separate technological trajectories become literally indistinguishable' (Castells, 2011).

The importance of information and communication technologies in the sustainable use and management of wild species cannot be overstated. They are changing nature conservation and the understanding of biodiversity in both novel and profound ways (Arts *et al.*, 2015). Information and communication technologies directly shape the public's perception of the management and use of wild species; improve managers' decision-making processes through improving their capacity to collaborate with peers and to access timely and state-of-the-art information related to wild species; support decision-makers ability to create and disseminate effective and contemporary policy; as well as promote collaboration between decision makers, researchers, and members of the public through citizen science data collection and knowledge dissemination projects. Information and communication technologies are vital tools in achieving the global long-term sustainability of critical wild species. However, people need to recognize that their diffusion remains starkly uneven across different generations, scales, and geographies.

However, not all examples of information and communication technologies usage are positive. Information and communication technologies are a fundamental tool in maximizing resource extraction efficiencies and cost-effectiveness and can lead to predatory extraction. For example, Geographic Information Systems (GIS) are integral to predicting the location of precious materials for mining exploitation, often degrading landscapes with irreversible consequences for traditional communities. Yet, they are also used to secure land rights for indigenous communities. It is not that information and communication technologies are inherently destructive or negative, rather it is the purpose to which they are put. Similarly, poachers use GPS locality data taken from wildlife photography, including camera traps, and other sources to locate populations of rare and local species. Many descriptions of new species in recent years have had to exclude precise locality data for the same reason (Choo *et al.*, 2020).

Drones are increasingly used to monitor terrestrial animals and plants. In another example, researchers have effectively used drones to gather data on schooling juvenile Atlantic bluefin tuna in the Gulf of Maine. Very little is known about the movement and foraging of the fish, so this data is an important resource to better understand, and thus sustainably manage the species (Fisheries, 2021). Furthermore, drones are increasingly being used as a surveillance tool to collect spatially referenced data on the location of fishing vessels and gears to eradicate illegal, unreported and unregulated fishing activity (Toonen & Bush, 2020). Yet drones have also been used to turn aquatic refuges into popular fishing spots and to lead to overfishing in these areas.

4.2.6.3.1 Because of their growing global uptake, information and communication technologies play a central role in influencing and shaping the public's perception of the value, management and use of wild species

The internet is the overarching technology that permits the access, sharing and storage of digital data. Broadening bandwidth, lowering prices, and general public acceptance are fueling the near global access to information and communication technologies. Individuals, organizations, governments and communities increasingly communicate using 'horizontal networks of communication' that are built around peoples' shared interests, initiatives and needs (Castells, 2011). People progressively seek out and share information (for example the cost of products at the market, access to services or weather forecasts), skills (for example how-to videos or brochure information required for completing tasks) and news (thus stimulating the decrease in accessing traditional media such as newspapers) using web-dependent social media and associated technologies.

Because of this growing reliance on information and communication technologies to mediate, augment, and inform the understanding of the world, they assume a growing role in shaping the way that people perceive, understand and articulate their own, as well as other peoples', relationship to wild species and their use and management (Kahn *et al.*, 2009). New visual technologies are increasingly being employed by wild species conservation-related organizations in their science communication and public engagement efforts (Cox, 2013). They can sensitize the public's perception of conservation initiatives as well as help generate an emotional response perceived as being necessary for motivating a sense of caring about wild species (Verma *et al.*, 2015). Similarly, social networking platforms allow stakeholders from around the world to remain in contact and communicate about different aspects of the natural world, unfettered by their geography, the time of day or their native language. Furthermore, there are a growing number of examples that suggest that information and communication technologies not only play an important role in fighting against deforestation, but that they also actively help decrease deforestation through increasing management efficiencies, monitoring risks, preventing illegal activities and amplifying the voice of indigenous peoples land rights (Yilmaz & Koyuncu, 2019).

Despite the importance of information and communication technologies ability to influence public perceptions of the natural world, it is necessary to recognize that many communities, and especially those living within or beside areas rich in wild species, are still limited by the partial penetration of information and communication technologies and the concomitant benefits they bring. Inadequate access to the appropriate communication technology for the dissemination of knowledge and information is believed to be an important cause of poverty and also the pushing factor for natural resources degradation in the remote mountains of the Hindu Kush Himalayan region (Maikhuri *et al.*, 2011). For example, the lack of access to suitable information and communication technologies among wild species collectors, harvesters, local brokers, retailers and traders have led to those involved in the trade being deprived of getting a fair price for their products (Olsen & Larsen, 2003).

4.2.6.3.2 Information and communication technologies improve managers decision-making processes through improving their ability to acquire timely and relevant data related to the population movement, scale, and management of wild species

It is well supported that the regular monitoring of animal populations and natural habitats should be implemented to ensure wild species protection, especially when pressure on animals is high (Linchant *et al.*, 2015). A central contribution of information and communication technologies to the sustainable use and management of wild species are their ability to acquire data, to transform this data into information, which in turn becomes central in informing decision-making processes. Legacy information and communication technologies such as satellite imagery acquisition and Geographic Information Systems continue to play an important role in spatial decision-making processes and wild species management. However, they are increasingly augmented with data captured using automated, miniaturized, low-cost and readily available hardware sensors that are capable of measuring heat, temperature speed, pressure sensor (e.g., to study diving depth in penguins etc.), and location. This includes the growing use of radio frequency identification tags and camera traps to record the movement of birds, fish and animals, the use of unmanned aerial vehicles, or drones, as well as the increasingly prominent role of mobile devices to support citizen monitoring and reporting on wild species.

Radio frequency identification is a wireless communication technology that permits computers to read the identity of inexpensive electronic tags from a distance without requiring a battery (Nath *et al.*, 2006). This allows users to identify, track and monitor the objects attached with tags globally, automatically, and in real-time (Jia *et al.*, 2012). This relationship between physical technologies (such as the radio frequency identification tags) and computer automation is now commonly referred to as the Internet of Things. Radio frequency identification tags have already been used for some time in commercial livestock identification and tracking (Ruiz-Garcia & Lunadei, 2011), even for monitoring cattle rustling activities in Eastern Africa (Siror *et al.*, 2009). Increasingly they are being used to monitor wild species. One example is the use of radio frequency identifications, to better understand how bird feeders in urban environments in the US impact the survival, range extension and species conservation of hummingbirds (Bandivadekar *et al.*, 2018; Choo *et al.*, 2020).

Camera traps have become a 'preferred tool' for monitoring and sampling animal populations; this in turn has greatly improved science's understanding of ecological relationships and population dynamics (O'Connell *et al.*, 2010).

Unmanned aerial vehicles can be remotely controlled or fly autonomously through software-controlled flight plans that work in conjunction with their onboard sensors and GPS. These vehicles provide a safe, inexpensive, user-friendly, and statistically robust option for a variety of wild species survey applications (Jones *et al.*, 2006). Unmanned aerial vehicle technology continues to develop rapidly and dropping prices and their ability to synchronize with mobile device applications are making them more and more prevalent in civilian markets. The future role of unmanned aerial vehicles for monitoring will include the growing number of semi-autonomous robots.

Globally, thousands of research projects are engaging millions of individuals—many of whom are not trained as scientists in the collection, categorization, transcription and analysis of scientific data (Bonney *et al.*, 2014). This contemporary trend in science is referred to as Citizen Science and is being used to support a broad range of projects that require vast quantities of data to better understand large-scale patterns in nature (Bonney *et al.*, 2009). These projects range from supporting the Christmas bird count (Silvertown, 2009) to studying new galaxies (Raddick *et al.*, 2013). Information and communication technologies play a central role in supporting Citizen Science projects, which tend to focus on enabling members of the public to capture data in the field using specialized mobile device apps, camera and audio traps, which can now be explored more in-depth by new analytical methods (deep learning, advanced mathematical models, etc.).

4.2.6.3.3 Information and communication technologies support managers and decision-makers ability to collaboratively analyze, access and share data, and to work in partnership in these processes with colleagues, peers, decision makers and members of the public

Data is a vital commodity in the sustainable use and management of wild species. How managers access, disseminate and share data is vitally important in supporting effective decision-making. Fifteen years ago, there was little sharing of data. Today governments, organizations and businesses are more prepared to see the value of sharing data in order to enable making the best decisions. The ability to share data is supported by the rapid transformation of cloud computing, access to big data and a willingness to share through open data classifications and agreements.

Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the data centers that provide those services (Armbrust *et al.*, 2010). Cloud computing gives the appearance of infinite computing resources available on demand, and it enables organizations to no longer invest in hardware or software – they pay for it as they use these resources. As research in wild species management increasingly relies on quantitative population modelling, cloud computing is playing an increasingly important role in providing managers the tools to analyze large datasets on demand, but also to provide a means for members of the public to interact with and access large and complex datasets to simplified user interfaces that are no longer software dependent (Chapron, 2015).

The past twenty years has witnessed an explosion of digital data. The term big data is used to describe the enormous, often unstructured, datasets that have emerged through cloud computing, the internet of things and other devices that capture data. This explosion is represented by an increase in the volume of data, the velocity to which it is created, as well as the variety of data (McAfee & Brynjolfsson, 2012). These datasets provide a huge opportunity for understanding complex values and behaviors that in the past have remained invisible, and for improving to decision-making ed about the sustainable management and use of wild species. In addition to an increase in the volume of data, it should also be stated that the ability to analyze the data in depth has considerably improved thanks to progress in mathematics and biostatistics. Knowledge and science in this field are also more readily accessible nowadays (e.g., most scientists now rely on the R software for statistical analyses, which is a collaborative, open source and free system constantly being improved by the users themselves; https://www.r-project.org/).

The information society changes the conditions and resources which are involved in environmental management and governance: old modes and concepts are increasingly being replaced by new, informational ones (Mol, 2008). Information and communication technologies in their essence are involved with the communication of information, in the realm of environmental governance; they can play a significant role in making environmental decision-making transparent, and in doing so. Furthermore, scholarship in global environmental politics increasingly recognizes the role of "information as influence" whereby it creates the conditions under which informational governance may stimulate environmental reform (Gupta, 2008).

The MapBiomas initiative, which originated in Brazil in 2015, provides an important example of the collaborative use of technologies to improve the monitoring and management of changes in land cover. This project has developed innovative and low-cost methods using Landsat imagery of 30-meter resolution and machine learning supported by Google Earth Engine to generate annual maps showing land cover change over time. For Brazil and much of South America, MapBiomas has produced annual land cover maps for the period, 1985–2020, and these are made publicly available on a user-friendly web-based platform. In Brazil, project partners have also incorporated high resolution satellite imagery to create a system of alerts to detect deforestation in near-real time. Images are then rapidly validated and shared with government law enforcement agencies to hold landowners accountable for illegal deforestation. MapBiomas has been pioneered by a collaborative network of non-governmental organizations, universities, and technology companies, enabling the initiative to harness local knowledge and to building capacity among national scientists and civil society organizations. The project has trained collaborators throughout Latin America and is currently bringing this innovative use of technologies to environmental and social movement organizations in Indonesia and other parts of the tropics.

A wide range of political, social, cultural, ecological and economic factors determine the way new innovative technologies are developed and used (Trace, 2016). It is not always possible to anticipate trends into the future for science and technology since unintended consequences or unanticipated gains, are often difficult to determine in advance. It is important that global policy processes monitor and regulate dramatic scientific and technological advances to ensure that they support sustainable use of wild species, and the conservation of biodiversity.

4.2.6.4 Education and awareness tools and approaches with a bearing on the sustainable use and management of wild species

It is well-established that direct contact with, and knowledge of, biodiversity has been declining among populations worldwide (Gadgil *et al.*, 1993). Major factors contributing to this decline include technology and urbanization, leading to less interaction with, and understanding of, wild species (Cox & Gaston, 2018). In the face of unprecedented levels of declining biodiversity coupled with a lack of human contact with nature, it is important to understand the role education plays in supporting sustainable use of biodiversity, and the elements of education, both formal and informal, that support and drive sustainable or unsustainable use.

According to a global survey carried out on behalf of the Secretariat of the Convention on Biodiversity, efforts to communicate the importance of biodiversity have not made clear the value and relevance of nature to citizens' daily lives (Airbus, 2010; J. R. Miller, 2005). Survey results from across 10 countries sampling 10,000 children between the ages of five and eighteen indicate that 40% ranked watching TV or playing computer games as a priority, compared to 4% who considered the environment to come first (CBD, 2010). Results highlight the need for increasing efforts to inform future generations about the importance of biodiversity conservation and sustainable use of species (Airbus, 2010).

This section explores three questions: 1) How are educational systems addressing biodiversity in the face of urbanization and the expansion of technology, alongside biodiversity loss? 2) What barriers exist to effective education and awareness-raising about biodiversity and the sustainable use of wild species? 3) What are common elements of effective biodiversity education and communication programs?

4.2.6.4.1 The impact of technology and urbanization on biodiversity education and awareness

It is well-established that technology and urbanization contribute to decreased contact with biodiversity, leading to a decline in biodiversity-related knowledge and the lack of awareness of its loss, unsustainable use, and importance in human lives.

The United Nations projects that by 2050, 68% of the world's population will be urban, with diminished contact with nature, resulting in a significant loss of associated health benefits (United Nations, 2019). It is well established that due to demographic shifts, the number of people with first-hand experience of biodiversity diminishes each year (Orr, 2004). Limited transmission of knowledge regarding wild species brings to light the paucity of daily human interaction with plant species.

Studies illustrate the erosion of children's knowledge not only of plant names, but where to find and how to prepare

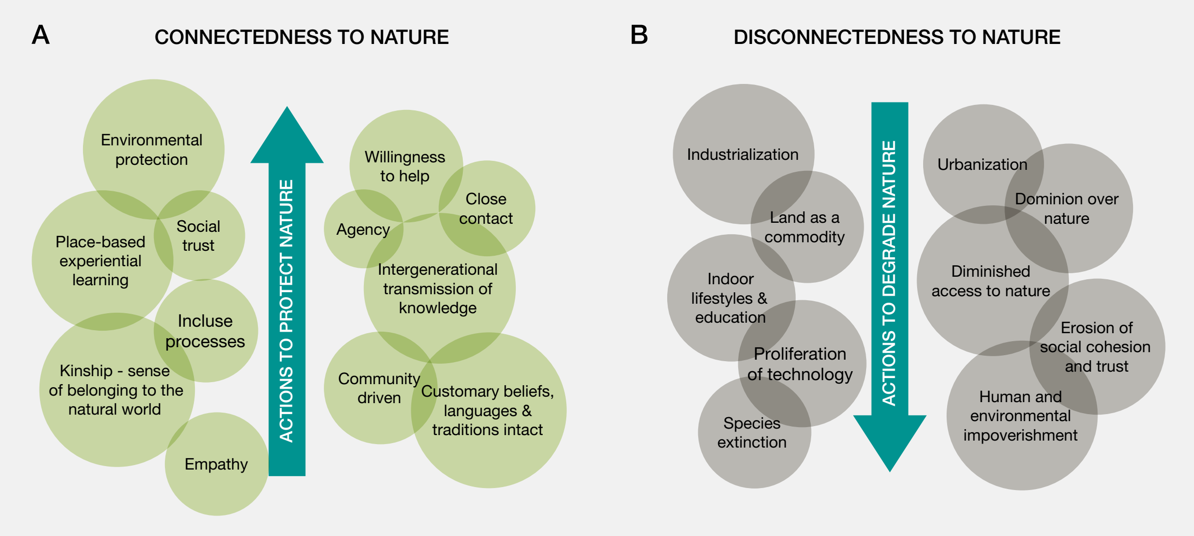


Figure 4 16 **Effects of connectedness and disconnectedness to nature.**

Source: Shanley & Lopez, (2009) © 2009 by The Association for Tropical Biology and Conservation. License CC-BY.

them, highlighting how children's knowledge is detached from hands-on knowledge and practice (Setalaphruk & Price, 2007). Children from rural areas who migrate to cities no longer take part in helping their parents in farm fields and forests (Barreau *et al.*, 2016). As a Mapuche woman reflected, "How can we teach our children if we cannot access the forest?" This sentiment underscores how critical forests are for intergenerational environmental learning as for centuries they have been a place for children to gain ecological knowledge (Barreau *et al.*, 2016).

Increasing urbanization leads to a break in the transmission of local knowledge regarding seasons, geography, botany, ecology, and culture needed to gather wild species sustainably. Today, within the educational, socio-economic, and political systems in which urban and suburban populations live, biodiversity "is considered expendable and the ecological processes which sustain us are hidden from view" (Miller, 2008).

Research across the globe also demonstrates that many youths currently spend from 2 to more than 7 hours a day on technological devices, with a negative association between screen time and psychological well-being (Aitken, 2001; Twenge & Campbell, 2018), and a corresponding decline in time spent in nature and in contact with biodiversity (S. Adams & Savahl, 2017). The result of diminishing contact with biodiversity, and time outdoors, that result from urbanization and technology, has been shown to lead to a lack of knowledge and/or interest in nature. As Pyle (2002) states, "Collective ignorance inexorably leads to collective indifference, and from there it is not many more steps to ecological depreciation and collapse." Decades of studies on the impact of nature on health clearly demonstrate that detachment from nature also leads to a decline in mental and physical health. Conversely, time spent in nature is not only central to improving human health and well-being but can also motivate people to make more informed decisions and take actions to protect the environment (Capaldi *et al.*, 2015; Dasgupta, 2021).

4.2.6.4.2 The role of formal educational systems

Global trends toward standardization of education are resulting in decreasing attention to, and understanding of, local biodiversity, and a decline in community resilience.

Currently, over 50% of *Homo sapiens* live in urban centers, and the majority lack basic knowledge regarding flora, fauna, water, and weather (Orr, 2004). Scholars describe the current chasm between people and nature as the "extinction of experience" (Miller, 2005; Pyle, 1979). Concern about the sharp decline in nature-based knowledge, coupled with intensifying environmental degradation, has led to the development of global biodiversity educational initiatives that seek to counter the effect of these trends.

For example, the United Nations called for a Decade of Education for Sustainable Development (2004–2014), focusing on the interconnectedness of nature, culture, society, and economics. The biodiversity education goals of the United Nations Environment Program (UNEP) encourage individual and collective work to maintain and enhance biodiversity at local, regional, and global levels. The United Nations Education Science and Cultural Organization (UNESCO) is a lead agency promoting the inclusion of sustainability and conservation in national education systems. Furthermore, in 2015, Pope Francis released an encyclical entitled "On care for our common home". Lamenting environmental degradation and loss of biodiversity, he calls for people worldwide to take, "swift and unified global action" (Cathlic Church & McDonagh, 2016).

Despite efforts by leading international figures and agencies to intensify biodiversity education, over the last few decades a divergent trend has gained momentum – globalized and nationalized educational systems – which work against the uniquely local and endemic and undermine connection to biological and cultural diversity. These widely used systems are characterized by homogenization, consolidation, corporatization, institutionalization, testing, and competition in the global economic sphere (Spring, 2015). Critics describe the internationalization of education as being founded upon vestiges of colonial structures intended to eradicate indigenous cultures, land-based knowledge, and languages (Anderson-Levitt, 2008; Sloan, 2008).

The International Council of Science established that universal education programs, characterized by standardization and testing, and divorced from local cultural and environmental conditions, weaken the transmission of traditional knowledge, contributing to an erosion of both indigenous knowledge and languages (ICSU, 2002). In the Australian context, (Ditchburn, 2012) notes there has been, "swift and unquestioning acceptance of the National curriculum, with long term implications." Within such homogenized curriculum, students may graduate with literacy in mathematics and language, but without knowledge of their ancestry, culture, land, plants, and animals. School regimes are cited as causal in children's lack of knowledge of and interest in wild plants (Barreau *et al.*, 2016; Dounias & Aumeeruddy-Thomas, 2018; Saynes-Vasquez *et al.*, 2013). Studies indicate that children's knowledge of wild plants decreases with their age and that forest-based knowledge, suffers the greatest rate of loss as compared to gathering in other types of locations (e.g., (Caniago., 1998; Setalaphruk & Price, 2007).

In the past, many children attended local schools during their first 12 years of life. Today, many children leave rural communities at a young age, becoming disconnected from traditional practices and land, and experience a gradual transformation in their values, attitudes and food habits. The trend toward consumption of processed foods is substantially altering outlooks and tastes worldwide and has been termed, "gustatory subversion" whereby the introduction of industrialized foods undermines local cuisine, eroding nutrition and resulting in economic dependence (Dounias & Aumeeruddy-Thomas, 2018; Garcia, 2006; Ladio & Lozada, 2004; Lewis, 1998). As populations of, and access to, forest plants diminish, knowledge erodes more readily (Cruz-Garcia *et al.*, 2018). Such profound erosion of knowledge regarding wild plant gathering among youth can have a significant impact on the resiliency of communities to absorb and buffer changes (Begossi *et al.*, 2002; Berkes & Folke, 1998).

In addition to schooling that distances children from contact with nature, international child rights laws insist on both access to formal education and a ban of child labor, reinforcing the notion that children should not be involved in agroecological activities (Dounias & Aumeeruddy-Thomas, 2018). Such a global perspective discounts local realities in rural villages where children's participation in subsistence economies contributes to the resilience of local knowledge and where the well-being of children is tightly woven into community practices.

Subsequently, as rural children finish school and embark upon careers, their interests are increasingly geared toward jobs in urban centers, with youth less interested in studying biology, ecology, and whole organisms. Furthermore, within the biological sciences, there is a tendency to choose lucrative careers in biotechnology and related areas, rather than the environmental sciences. In response to the wave of rootless and globalized education and work prospects, there is a growing trend in alternative schools and programs to restore educational initiatives which draw from local and indigenous cultures, traditional knowledge, and environmental and social justice.

4.2.6.4.3 Place-based education: Indigenous, outdoor, environmental, and experiential learning

Research and practice demonstrate that indigenous, place-based, and experiential learning build bonds between community members and their ecosystems, leading to a stronger environmental ethic.

For 99% of the time *Homo sapiens* have inhabited the earth, they accumulated relevant knowledge and learned complex skills and expertise related to geography, astronomy, biology, ecology, and other aspects of the natural world when engaged in outdoor activities such as fishing, hunting, and gathering. Children learned less through direct "teaching" and more through individual observation, imitation, stalking, games, stories, practice, and time accompanying a parent, friend, or relative (Lew-Levy *et al.*, 2017). By age ten, "children in hunting and gathering communities identify, locate, and know about the behavior of many plants and animals in their environment" (McDonald, 2007).

Until recently, such a deep, multi-faceted understanding of biodiversity for the provision of food, water, shelter, and medicine has been fundamental to human survival. The environmental movement of the 1970's – a response to rapid and alarming environmental damage – renewed interest in outdoor and environmental education in which learning is based on a combination of experiences in nature, community, and/or culture (Gruenewald & Smith, 2008). Current educational movements also include indigenous, and place-based education centering around stories, ecologies, languages, histories, and politics embedded in place (Bartlett *et al.*, 2012; Cajete, 2010; Orr, 2004).

4.2.6.4.4 Research and academic incentive structures

Institutional disincentives within academic and research organizations discourage the communication of relevant research results about biodiversity to broad audiences. Reform of academic incentive structures is needed that reward on-the-ground engagement with local groups and in biologically and culturally diverse regions, and broader communication of findings beyond the scientific community.

In addition to the standardization of education, another significant barrier to successful education and awareness raising about biodiversity and sustainable use of species includes entrenched institutional disincentives within academia (Edwards & Roy, 2017); infusion of corporate funding into research (Nestle, 2016); and a flawed peer review process leading to impoverishment of science (Smith, 2006). Over the last 30 years, excessive performance measurement, based narrowly on the quantity rather than the substance of publications, has led to an increase in conformity and superficiality, reducing the motivation of researchers to engage in original thinking (Gendron, 2007). These trends have resulted in what is being termed, "blind science" in which positive feedback loops within research institutions, reinforce self-promoting forms of science as opposed to contextualized, impact-oriented research (Morin, 2005).

Prioritizing the production of peer-review journal articles has also discouraged applied research, and activities such as public education, outreach, and extension. Successful educational tools such as plain language communication, the synthesis and application of knowledge to address problems, partnerships with civil society organizations, and artistic expressions, are generally not accepted as legitimate forms of academic communication (Jacobson *et al.*, 2004). Knowledge generation is instead occurring at the periphery, where multiple voices, diverse lenses and languages converge (Gendron, 2007).

In a survey of 3,748 members of the American Association for the Advancement of Science (AAAS), 77% indicated that it is not important for career advancement to promote their findings on social media (M.O.R.I./Wellcome Trust, 2001). In a Center for International Forestry Research (CIFOR) study of 268 researchers in the field of conservation biology from 29 countries, less than 5% of respondents engaged with the media, produced training and educational materials, or popular publications (Shanley & Lopez, 2009). Respondents considered local initiatives and training likely to lead to success in conservation but, due to institutional disincentives, few invested in these activities. The result is inadequate communication, which in turn means that governments and the public rarely understand the value of, and threats to, biodiversity, and the urgent need for action.

To improve biodiversity research and communication, changes in academic incentive structures and resource allocation are needed that reward communication and action (Bawa *et al.*, 2004; Edwards & Roy, 2017) as well as participatory research processes that include local communities in the co-production of knowledge and share its benefits (Grasser *et al.*, 2016). Research and academic institutions need to recognize public education and outreach as important professional endeavors, and such efforts should be considered positive in merit evaluations (Hampton *et al.*, 2010).

4.2.6.4.5 Equitable trends in communication and education: Social learning, two-eyed seeing and citizen science

Initiatives such as communication for social change, social learning, citizen science, and health-related sciences demonstrating links between human health and biodiversity can serve as a model; these fields are building bridges between science and the public, and their methods could improve understanding of the value of biodiversity and promote sustainable use of wild species.

Communicating with and for marginalized people reflects a movement that has been led largely by social scientists. The Brazilian educator Paulo Freire and his colleagues (Freire & Macedo, 1987) conceived of communication for social change as participation for the purpose of empowering the voiceless and strengthening cultural identity. Understanding through dialogue creates a cyclical model of social and environmental transformation that is built on relationships and mutual change (Figueroa *et al.*, 2002; Pretty & Smith, 2004).

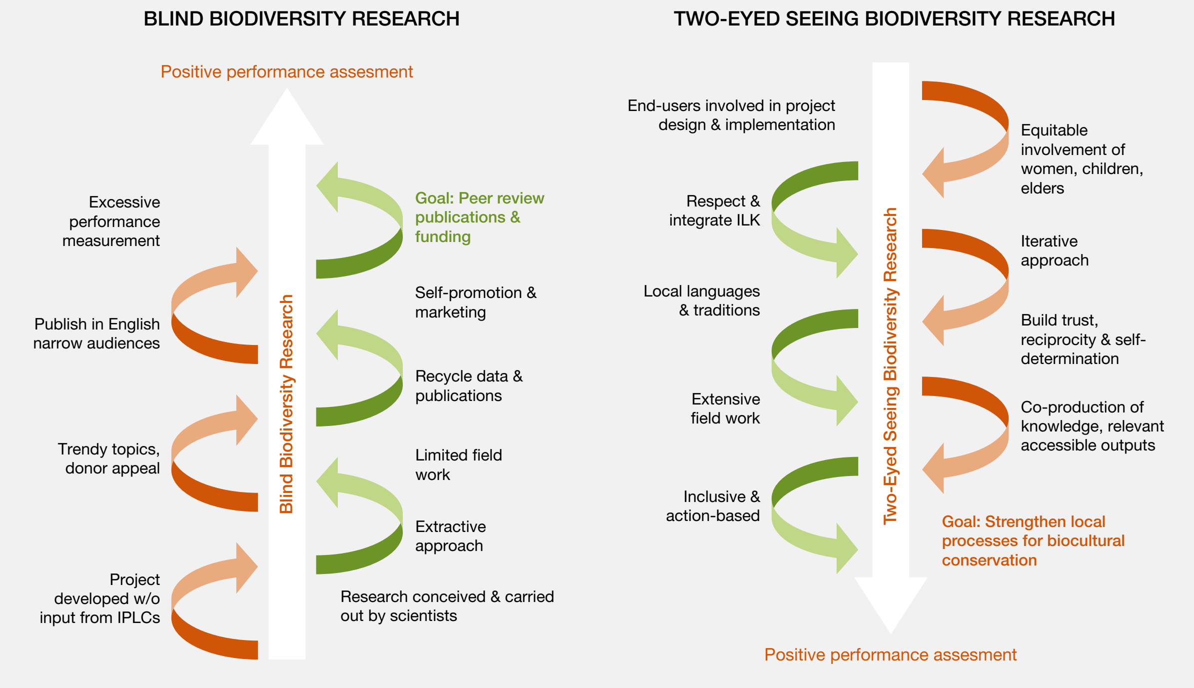


Figure 4 17 **Blind *vs* two-eyed seeing biodiversity research and education.**

Source: Shanley & Lopez, (2009)

Behavioral psychology, communication for social change, social learning, and the health-related sciences have developed methodologies to link science and public understanding, and these methods can inform sustainability initiatives by building bridges between knowledge and action (Garzón-Galvis *et al.*, 2019). To varying degrees, participatory processes and inclusive communication are present in biocultural research and development, such as sustainability science (Cash *et al.*, 2003), knowledge systems, integrated natural resource management (INRM; Sayer & Campbell, 2003), and adaptive collaborative management (ACM; Colfer, (2008). INRM and ACM are attempts to include end users in all stages of research and to move from a scientist-dominated research focus to action research that includes social learning and adaptive processes (Shackleton *et al.*, 2009). An extensive recent study analyzing the impacts of environmental education concludes that inclusive, creative, hands-on, action-based projects which address local community needs through collaborative processes can be highly effective in achieving education and conservation outcomes (Ardoin *et al.*, 2019).

Two-eyed seeing and collaborative research also strive to take an equitable approach to research and communication (Cajete, 2010). Two-Eyed seeing entails methods whereby indigenous and western scientific ways of viewing the world are respected and woven together for the benefit of all (Wright *et al.*, 2019). In methodologies, implementation, and outputs, collaborative approaches and Two-Eyed Seeing contrast starkly with, 'blind science', in which the process rarely includes input from local communities or end-users, and primarily produces peer-review publications (Morin, 2005) **(Figure 4.17)**.

A recent initiative establishing a bridge between the public and the world of research and education is citizen science, in which members of the public collect substantial quantities of data at unprecedented spatial and temporal scales that would otherwise not be possible or affordable (Dickinson & Bonney, 2012). Citizen science authenticates place-based nature experiences while enhancing understanding of and support for sustainable stewardship (Shirk *et al.*, 2012). As contributors become engaged in resource management issues that impact their lives, participation can initiate democratization of the research process (Dickinson & Bonney, 2012). Furthermore, the inclusive nature of working with diverse collaborators more readily sparks innovation (Woolley *et al.*, 2010).

4.2.6.4.6 Movements toward indigenous, culturally inclusive, and place-based education

Many local and indigenous groups are calling for systemic changes in educational systems to respect the traditions, knowledge, languages, values, history, and identities of their cultures. Formal recognition by national educational systems of cross-generational knowledge transmission and a wider range of approaches to learning would support local stewardship and sustainable use of wild species.

Examples of case studies highlighting trends in education and awareness-raising which support sustainable use of wild species are described below.

The Philippines, the Negritos: An example of a systemic change in formal education, policy and resource conservation has occurred among the Negritos in the Philippines. Over 70 Negrito communities are currently using culture, education, and awareness-raising as effective tools to change public perception of indigenous peoples and promote conservation. Once denigrated, the Negritos now host cultural revival festivals, boosting their societal status, as well as improving relationships with policymakers. Wild plant foods, crafts, herbs, songs, and dances are shared to celebrate biodiversity and the knowledge of the elders in managing forests sustainably. The revivals have helped lead to a reform of elementary and secondary education whereby traditional ecological knowledge, values, and skills are integrated into school curricula and bi-lingual learning materials (Quierrez & Beer, 2014). School credit is being granted to youth for time spent outside with elders learning about nature first-hand. To expose urban families to the Negrito lifeways, the National Museum of the Philippines has created a permanent exhibit and programs, which along with newspaper and television broadcasts, highlight the positive contributions of Negritos to the nation. Negritos are currently engaging with government agencies in multi-stakeholder symposiums to conserve biodiversity and enact policies favorable to rural livelihoods (Beer, 2014; Jenne, 2011).

In Sulawesi, Indonesia, an extensive awareness programme to promote biodiversity protection at the Nantu Wild species Sanctuary has been carried out over the last three decades by the Adudu-Nantu Conservation Foundation ("YANI"). This has included the construction of a Biodiversity Field Training Center, conservation workshops for all sectors of local society, and the creation and distribution of 5,000 copies of a children's storybook about the endangered Babirusa, an endemic mammal in Sulawesi. In addition, live "Conservation Concerts" by local entertainers, Nantu Forest scholarships providing secondary school education to local children, and the development of a Biodiversity Curriculum Materials Manual (Kartikasari & Clayton, 2015) have helped to conserve 62,000 hectares of the threatened rainforest at one of Southeast Asia's five most significant sites for biodiversity (Clayton *et al.*, 2007).

In Mexico, at the State University of Veracruz, indigenous villagers can enroll in a certified diploma course covering themes such as community development, silviculture, and multiple-use management. Experiential, Box 4 38 **Case Study: Key drivers of wild resource use and how interactions amongst them can dramatically change outcomes.**

Source: Murali Chatakonda and Ganesan Balachander; Compiled from publicly available information and as reported by Mr. Phanteo Kittan, Secretary, Amur Falcon Roosting area Union, Pangti village.

The Amur Falcon is a fascinating migratory raptor. Every year, the small, resilient birds make the voyage from breeding grounds in Russia, Mongolia, and northern China to winter in southern Africa. Because of the long journey, approximately 22,000 km, the longest sea crossing of any raptor, stopover sites are important to stock up on food for the ensuing journey. It feeds on dragonflies, grasshoppers, locusts, and termites. Pangti is a small village in Nagaland, northeastern India. Nagaland is rich in natural resources, but the hilly terrain, landlocked location and poor infrastructure are key reasons for underdevelopment, and poverty. Until 2012, hunting of the Amur falcon used to provide meat as well as cash income for large numbers of local people. In 2012 an estimated 120,000 to 140,000 birds were trapped in nets and killed while passing through Pangti. Video images of the slaughter resulted in a national outcry. The Government of India and the State of Nagaland imposed bans on hunting. However, the role of non-governmental organizations working with the local indigenous community was key in ensuring compliance. Local adults were trained in natural history education and employed as teachers, strengthening local capacity and indigenous pride in managing the resources. Eco-clubs and engaging the local youth further motivated them to stop hunting. After the initiative was taken to conserve the falcon, local communities also benefited economically with homestay lodges opening up for visitors to the *"amur falcon capital of the world".* Locals were trained as tourist guides, the youth recruited by the forest department for patrolling and monitoring the roosting areas. The actions taken were not top-down and prescriptive, but the spectacular change was possible through the empowerment of local communities, and recognition of indigenous knowledge as well as skill development for alternative income generation.

peer-to-peer, field-based learning leads to individual and collective transformation, building resilience and sustainable means of facing land use challenges. The project has led to retaining tree diversity, production of native dyes, management and consumption of indigenous foods, curriculum reform, and hands-on teaching methods. It has also led to the protection and consolidation of the socio-ecological system underlying traditional weavers, which serves as a cornerstone of community-based landscape management (Binnqüist *et al.*, 2017). As an original, transdisciplinary approach to solving complex problems, indigenous education holds the profound potential to address the array of sustainability challenges facing the planet (Cajete, 2010).

In the Brazilian Amazon as part of a decades-long initiative, over one hundred Brazilian researchers shared relevant ecological and economic data on 30 fruit, medicinal and wild species-attracting tree species with a wide distribution throughout Amazonia, and integrated these with traditional knowledge, recipes, stories, songs, and management tips from scores of local people. The resulting illustrated book in Portuguese, *Fruit Trees of the Forest in the Lives of Amazonians*, has been translated into English and Spanish, and has served as a template to share local and scientific knowledge for community benefit. Throughout the Amazon Basin the information has been used to enhance the management of medicinal plants and fruit trees, increase women's participation in decision-making, create forest reserves, and train foresters. Radio programs, a film, and workshops complement the manual and have resulted in improved forest practices and policies, and more sustainable use of wild species (Shanley & Medina, 2006).

4.2.6.4.7 Elements of effective biodiversity education and awareness initiatives – mediating factors

Biodiversity education and communication can nurture a conservation consciousness which is fundamental to supporting sustainable use of wild species. There is an emerging consensus that effective education programs respect local cultures, languages, and land, include women, elders, and youth, and promote inter-generational transmission of knowledge.

The relationship between education of various kinds and behavioral change is complex (Liu *et al.*, 2016). Interests and motivations are impacted by socioeconomic variables such as income, gender, religion, age group, schooling, and place of residence (de Oliveira *et al.*, 2019). However, in the examples above some commonalities can be identified. First, these examples focus on issues related to wild species of direct relevance to local populations. Second, the challenges are approached respectfully, taking into consideration local traditions, customs, and intergenerational world views. Third, in these cases, the action was not prescriptive, but through education, empowerment, and skill development for alternative management practices and/or income generation. In addition, change was instilled through a cyclical, collaborative process whereby perspectives of local and regional people and policymakers were considered. Furthermore, in each case, unique aspects of local and regional flora, fauna, and culture were celebrated, engendering in villagers, urban residents, and policymakers, a feeling of pride, and a connection to species other than themselves. Finally, these case studies reveal a renewed sensitivity to the plight and perspectives of birds, mammals, and trees, which led to systemic changes in education, policy, and practice.

These elements of biodiversity education highlight components of effective local initiatives less frequently recognized or documented by scientists -- appreciation of people's cultural, emotional, and spiritual connections to nature. Understanding the emotional connection to, and cultural importance of, biodiversity is essential to developing collectively acceptable forest management and restoration strategies (Posey, 1999; Wehi & Lord, 2017). Additionally, the extent to which a person feels a part of nature is vital to how they act towards nature. Such values and belief systems are reflected in linguistic and cultural identities which convey respect for nature and which constitute a strong foundation for the sustainable use of wild species (Cocks & Shackleton, 2020).

Case studies indicate that education and communication leading to sustainable use of biodiversity are characterized by some of the following features:

- Support cultural inclusion and linguistic identity
- Foster intergenerational transmission of knowledge
- Include elders and youth
- Promote gender equity
- Advance place-based initiatives
- Recognize parents and community as primary teachers
- Uphold respectful communication and interactions
- Employ experiential learning techniques
- Advocate creative use of technologies when appropriate
- Stimulate cross-sectoral initiatives
- Reflect the input of local people

4.3 INTERACTIONS AMONG DRIVERS

Key messages:

- In most, if not all instances of resource use, there is interaction amongst drivers leading to either synergistic or antagonistic effects. Interactions among the various drivers make use of a species sustainable or unsustainable and are common. The level of interaction is often case-specific and depends on whether:
  - use is restricted to a single jurisdiction *versus* being regional or transboundary.
  - technology is relatively simple and stable *versus* highly mechanized and frequently innovated.
  - alternative sources of food or livelihoods are of limited or ample availability.
  - governance processes are robust or contested.
  - there are multiple competing uses, or
  - little is known about the species.
- Whether a practice of using wild species is sustainable or not is highly complex and may be influenced by how drivers (i.e., environmental, social, economic, cultural, political, and science and technology and education) interact, which is often also influenced by mediating factors such as species ecology, value systems, indigenous and local knowledge and context *(well established)* {4.3.2, 4.3.4}.
- The sustainability of fishing and fisheries is widely driven by the complexity of the web of interactions among environmental, social, economic and technology drivers, where species biology, ecosystem and multi-species interactions also matter significantly *(well established)* {4.3.2.1}.
- The economic trade driver interacts with environmental, cultural, and social drivers to have an effect on the sustainability of gathering and collection of wild species. Such effects may be mediated by the use of technology and tools to further impact the collection of wild resources *(well established)* {4.3.2.2}.
- Cultural and social drivers often interact with economic drivers which are further mediated by factors such as species biology to shape the sustainability outcome of hunting, with the bulk of the studies coming from the tropics *(well established)* {4.3.2.3}.

- Political and economic trade drivers and mediating factors such as species management interact to determine if logging practices are sustainable, but regional differences are apparent *(well established)* {4.3.2.4}.

- Compared to other practices, the non-extractive use of wild species is relatively sustainable, though not as widely studied. Multiple drivers have been documented to interact to affect the sustainable management of species *(established but incomplete)* {4.3.2.5}.

- The ecological settings, species rarity, and the resilience of ecosystems can influence the sustainability of the practices. Understanding species biology and ecology and how they interact with drivers can affect the management and sustainability outcome of the practice *(established but incomplete)* {4.3.3}

- Long-term, spatially explicit studies are important for the assessment of the sustainability of the use of wild species. The interactions of drivers change with time and conditions, particularly when subjected to external shocks (e.g., economic or environmental) and perturbations, which may impact the sustainable use of a species in the future *(established but incomplete)* {4.3.4}.

4.3.1 Overview

The section addresses the relationships among different primary drivers (e.g., environmental *vs* social) and the synergies among the different combinations of drivers. In the previous sections, the experts recognized a total of six key drivers namely environmental, social, political, economic, value systems, customs and beliefs, scientific and technology innovation and education. Within each primary driver, secondary drivers often interact leading to unintended wild species use outcomes (see each driver section for examples). In many instances, different drivers interact to give unexpected hunting, extraction and harvest outcomes. Three possible ecological outcomes that may change dynamically over time upon further interactions. Wild species sustainable use may either be positive (+), negative (-) or no net change (=).

In this section, the focus is on inter-driver interaction and how they influence the ecological outcomes. This section highlights cases with different combinations of drivers under a variety of ecological context and settings, species rarity, and resilience of ecosystems. Temporal and spatial scale issues may also influence the interactions among drivers, providing a mapping of these relationships and identifying possible indicators of each driver (or group of drivers). This section draws on examples to illustrate the nature of the

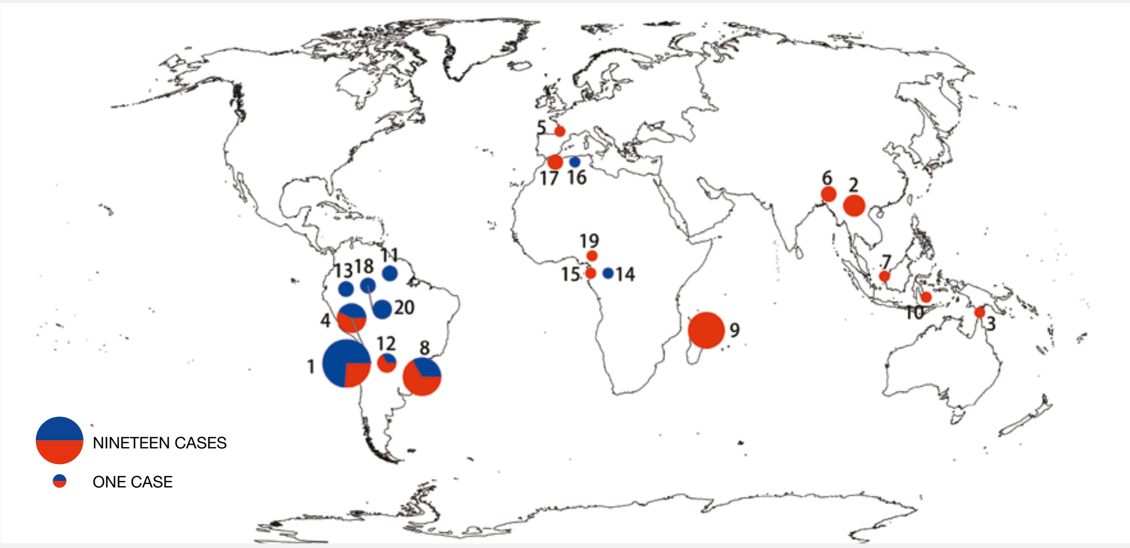


Figure 4 18 **The global geographical locations of selected 20 studies (a subset of available literature) comprising 74 cases on the sustainable use of wild species based on hunting.**

Author-assessed sustainable and unsustainable use of wild species represented in blue and orange, respectively. The size (not to scale) of the circle represents the number of cases per study. The proportion of cases that are sustainable or not is indicated for each study. An orange circle means that all cases are unsustainable for the study.
See data management at https://doi.org/10.5281/zenodo.6453169

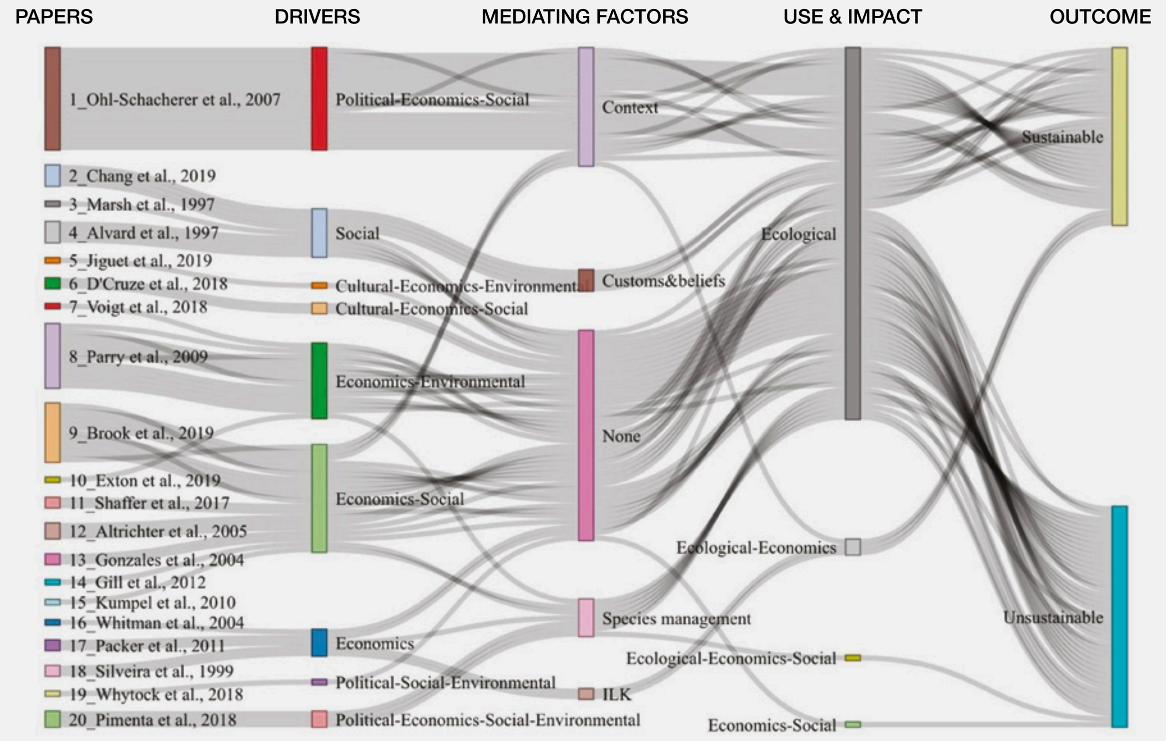


Figure 4 19 **Preliminary analysis of the factors driving the sustainable use of wild species based on hunting as a practice (number of cases = 74; from 20 papers).**

The data is presented in the form of a Sankey diagram. The leftmost column shows the paper, the second from the left column shows the combination of five main drivers, the third from the left the mediating factors, the fourth from the left column provides the identified impact measures (i.e., ecological, social, economics, or combinations), and the rightmost column indicates if a certain driver leads to a sustainable or unsustainable use based on the authors' evaluation.
See data management report at https://doi.org/10.5281/zenodo.6453184

interactions among drivers and how the sustainable use of wild species can change.

Methodology

Chapter 4 has compiled a database of relevant papers partitioned into the five different practices and their drivers for in-depth analyses. The interactions among the drivers for a practice (i.e., terrestrial animal harvesting) will be quantified and elucidated during this process. The Sankey diagram below illustrates the complexity and interactions among the five key drivers in producing sustainability outcomes of the use of wild species throughout the world for selected key papers associated with the hunting practice. In addition, this section delves into details for each practice to look at interactions within and across drivers separately.

Analysis of literature and cases on sustainable use of wild species

As a first pass analysis in understanding the influence of drivers, mediating factors on the sustainable use of wild species focusing on the published literature related to the hunting practice. From the selected 20 studies based on a pre-determined set of criteria, the 74 sets of drivers and mediating factors and associated outcomes were identified, as well as the concluded author-assessed use. In many cases, they have listed multiple and interactive drivers and mediating factors when evaluating whether a hunting practice is sustainable or not. The listed drivers and mediating factors were categorized based on the proposed structure set shown in **Figure 4.18**.

From **Figure 4.19**, when it comes to hunting, all five types of drivers are listed, with the economic and social drivers being the most common solo ones (first column). While interactive and combination of drivers are recorded frequently, many cases only considered two to three drivers (e.g., Economic-Social). Similarly, while mediating factors are seen in many cases, over half of them has none. The most frequently seen mediating factors include species management and context. In addition, the most dominant use and impact measure is related to a single ecological dimension, although other combinations of outcome measures (combinations of ecological, social, and economic) have been found. Economic-related and combination drivers are more commonly observed than others in driving outcomes in hunting. Context matters in influencing the sustainability outcome of the use of wild species. Overall, based on the first pass analysis, the author-assessed evaluation of sustainable use is slightly skewed towards unsustainable use, although sustainable use cases have been reported.

4.3.2 Interactions between drivers across different practices

4.3.2.1 Interactions between key drivers for fishing

Complex ecological (e.g., interspecies interaction), economic and technology drivers interact to influence if fishing levels are sustainable or not (Aura *et al.*, 2019; Bertocci *et al.*, 2018; Biggs *et al.*, 2016; Campos-Silva *et al.*, 2020; Filous *et al.*, 2019; Gianelli *et al.*, 2019; Irvine *et al.*, 2019; Kluger *et al.*, 2019; Lee & Perry, 2019; Maravelias *et al.*, 2018; Muallil *et al.*, 2019; Paesch *et al.*, 2014; M. N. Peterson & Nelson, 2017; Puente-Rodríguez *et al.*, 2015; Stephenson *et al.*, 2018). In Galicia (Northeast Spain), cetacean depredation on catches and damage to fishing gear can cause substantial economic loss for fishers, while cetacean bycatch raises conservation concerns. Fishers report that economic loss can result from common bottlenose dolphins *(Tursiops truncatus)* damaging coastal gillnets and from short-beaked common dolphins *(Delphinus delphis)* scattering fish in purse-seine fisheries. The main problem, however, was that cetacean bycatch mortality was reported to be highest for trawls and set gillnets, and likely exceeds sustainable levels for local dolphin populations. To minimize cetacean fishery interactions, there is a need to implement case-specific management strategies with the active participation from fishers. For set gillnet and purse-seine fisheries, the use of acoustic deterrent devices (e.g., pingers) may stop cetaceans from going near and getting trapped in the nets. For trawl fisheries, where bycatch appears to be particularly high at night in water depths of 100-300 m, possible solutions include the implementation of time/area closures and the relocation of some fishing effort to deeper waters (Goetz *et al.*, 2014). Improvising the use of technology and considering the species behavior will reduce the cetacean by-catch mortality which will make the harvesting more sustainable.

Social, economic, and ecological drivers often interact in the sustainability of fishing and fisheries. There is a need to understand the fishing process to understand and manage fisheries. A quantitative, mechanistic understanding of the opportunities fishers encounter, the constraints they face, and how they make decisions within the context of opportunities and constraints will enhance the design of fisheries management strategies to meet linked ecological and social objectives and will improve scientific capacity to predict impacts of different strategies. Spearfishing in a Caribbean coral reef fishery was examined. There are differences among taxa in this multispecies fishery, as some taxa are known to be ecologically or economically more valuable than others. Parrotfish are ecologically indispensable for healthy coral reefs, and they were encountered and captured more frequently than any other taxon. Fishers made decisions about which fish to target based on a fish's market value, proximity to the fisher, and taxon. The information uncovered on fishers' opportunities, constraints, and decision making has implications for managing this fishery and others sustainably (Pavlowich & Kapuscinski, 2017).

4.3.2.2 Interactions between key drivers for gathering

Economic trade driver may interact with environmental and biological, and/or cultural and social drivers to have an effect on the sustainability of gathering and collection of wild species (Brooks & Tshering, 2010; Gaoue & Ticktin, 2009; Huber *et al.*, 2010; Jensen & Meilby, 2010). Humans compete directly with native dispersers/predators (e.g., agouti) for *Bertholletia excelsa* seeds traded internationally as Brazil nut, and hence timing and intensity of harvests following fruit-fall determine the availability of this resource for dispersers. Research has revealed that agouti is particularly important for *B. excelsa*, because it disperses and often buries seeds into spatially scattered caches, facilitating seed germination and early seedling establishment. By tracking and monitoring the timing of the rodents' dispersal behavior and human harvesting behavior, local people could safely collect, and dispersers would have periods of unlimited resource access. Considering the collective understanding of the dynamic Bertholletia-Dasyprocta-Homo sapiens interactions, properly timed harvests across the sites in the region could boost rural people incomes and probably not threaten Brazil nut recruitment or maintenance of agouti populations (Wadt *et al.*, 2018).

Commercial gathering of selected medicinal plant species in the Himalayas to meet increasing national and international demand can lead to overexploitation. Sustainable management of medicinal plants requires a clear understanding of the respective roles, responsibilities and viewpoints of the various stakeholders involved, which could be drastically contrasting. Perceptions on market availability and threat status of medicinal plants differed between representatives from the district and national organizations and local people. Nevertheless, both stakeholder groups agreed that key threat drivers are over-harvesting, habitat loss due to land-use change and deforestation, and livestock over-grazing which could undermine the sustainable use of important plant resources (Uprety *et al.*, 2011).

Cultural and social factors may interact with technology use to impact the collection of wild species resources. Cultural and socio-economic factors influence the collection practice and resource use of indigenous wood carvers in the Maningrida region of central Arnhem Land, Darwin, Australia. Local woodcarvers use a small amount of carving timbers from two species but many cultural differences in harvest practice exist with artists from a different (i.e., Kuninjku/Kunibeidji) language community, where they harvest a greater number of tree species, larger quantities per harvest trip and thinner stems. Artists owning a vehicle are known to acquire more stems than those who did not. Not surprisingly, such influences on harvest practice can have significant implications for the ecological sustainability of logging in the region, highlighting the need to examine localized factors when assessing the sustainability of indigenous wild species harvests (Koenig *et al.*, 2011).

Social and economic factors may interact to determine if communities can sustainably gather wild species resources. Surveys of actual resources suggest that for poorer resource-dependent communities without access to markets, plants, algae and fungi can only be a safety-net activity and a supplementary income source. Resource availability, in terms of the diversity and productivity of the forest, has been argued to be key in contributing to well-being. Data from an area of tropical rainforest in Peru show that non-timber forest products provide only a relatively small portion of income and that only a small proportion of available products are in fact commercialized, even when markets are available. The observed low rates of commercialization can also be explained by unequal access capital assets used for extraction, to natural resources themselves, and to product markets, as well as due to the concentration of capital-poor households on subsistence gathering activities. As a result, unsustainable and destructive uses of forests (e.g., logging), generate more returns than those from plants, algae, and fungi. While plants, algae and fungi may have the potential to be an important livelihood source for poorer communities, market integration and commercialization, two critical enablers, may not be omnipresent (Pyhälä *et al.*, 2006).

4.3.2.3 Interactions between key drivers for terrestrial animal harvesting

For political drivers to be effective in making the use of wild species sustainable, it is crucial to consider the circumstances of local communities, be complementary and coordinated with other secondary drivers, and be well implemented. Furthermore, people may consider the impacts and interaction of political drivers with other drivers such as those economic in nature. For example, effective programs to manage wild species trade sustainably should be instituted not just at source populations but also at the point of sale and consumption (Nasi *et al.*, 2008). This is in addition to considering other economic and livelihood activities such as agriculture and market trends (Hakimzumwami, 2000), coupled with economic incentives (Abensperg-Traun, 2009). Similarly, political drivers need to be considered at different scales. For example, developing institutions at local levels to promote sustainable use of species need to be supported by other institutions and across different levels (such as devolution of land ownership or use rights) (Abensperg-Traun, 2009), also considering impacts policies at the international level can have at the local level. For instance, what are the impacts of trade barriers on local prices of wild species (Giller *et al.*, 2008). Sustainable use is thus conditional on a wide range of political, economic, environmental, and other drivers, and with a full understanding of the interaction of these drivers across multiple levels.

Cultural, social, and other drivers interact and are mediated by other factors to influence the sustainability of hunting (Brook *et al.*, 2009; Brooks *et al.*, 2007; Etnier, 2007; Golden, 2009; McAllister *et al.*, 2009; Naranjo & Bodmer, 2007; Ohl-Schacherer *et al.*, 2007; Zapata-Ríos *et al.*, 2009). In Latin America, campesino hunters are identified as peasants-cultureless, uneducated, and uncaring toward wild species sustainability, but knowledge from this largest group of hunters is underrepresented in the literature. Existing studies spanned 17 countries, 7 ecosystems, and >75 indigenous and nonindigenous demographics in 30 research contexts, where the focus is on nonindigenous campesinos for species-specific conservation and protected area management in tropical broadleaf forests of Mexico, Peru, and Colombia. The synthesis revealed that factors subsistence, income, ethics, regulations, and crop or livestock protection and their interactions shaped whether these hunters hunt nearly 800 species, most of which are the International Union for Conservation of Nature least concern species, and if they do so sustainably (Petriello & Stronza, 2020).

Economic and social drivers may interact to affect wild meat hunting sustainability. In the Democratic Republic of Congo, artisanal and small-scale mining is a source of livelihood for up to million people and is one of the main threats to large mammal species and their habitats, including forest elephants and great apes. Wild meat hunting is a consequence of mining. Minerals exploited at the sites included cassiterite, gold, coltan and wolframite, and most mines were controlled by armed groups. On average, miners earned significantly higher revenue than non-miners. Because mining was seen as a short-term activity, most miners were in favour of leaving the sector for better jobs. Almost all respondents consumed wild meat regularly due to the lack of alternatives and they believed that wild meat hunting had caused declines and local extinctions of some large mammal populations, including great apes. Nevertheless, the respondents indicated that they would reduce their consumption of wild meat provided that domestic meats became more available. To remove the threat of unsustainable hunting by miners, access to sustainable meat sources should be made, micro-financing mechanisms should be established to help miners leave the mining sector, and de-militarizing the mining sites should be prioritized to facilitate law enforcement (Spira *et al.*, 2019).

4.3.2.4 Interactions between key drivers for logging

Political and economic trade drivers and other mediating factors interact to determine if logging practices are sustainable (Houehanou *et al.*, 2011; Medjibe *et al.*, 2013; Robiglio *et al.*, 2013; Scabin *et al.*, 2012). Illegal timber trade is a global issue, with highly prized rosewoods from Madagascar providing an example. Corruption and political instability facilitated illegal rosewood exploitation in recent decades. At present, there exists no non-detriment findings (where the exporting State ensures that a proposed action will not be detrimental to the survival of a species) to enable the sustainable use of standing populations. The Malagasy government, with support from the World Bank, is promoting the sale of stocks of confiscated precious woods. Such sales could encourage further illegal harvest because tools to identify, control and monitor standing trees and cut timber are lacking. Taxonomic confusion and substantial knowledge gaps regarding species limits and population sizes may also increase the difficulty of detecting and addressing unsustainable levels of the harvest of rosewoods (Waeber *et al.*, 2019).

Social drivers interact with species management to mediate the sustainability of logging. Implementation of forestry best management practices protects water quality during and after logging operations. Effective best management practices are site or region specific and address the full course of logging operations from planning and site preparation to felling and removal of trees, to the closure of logged sites. Throughout logging, sediment control and road construction and maintenance are especially important to assure water quality. In the United States of America, over 50 years of research in three regions of the United States of America demonstrate that well-designed forestry best management practices can reduce erosion and sedimentation of surface waters. However, their effectiveness is dependent upon the quality of their implementation (Richard Cristan *et al.*, 2016). In the case of logging on private forest lands, loggers, landowners and professional foresters each play a role in the implementation of forestry best management practices. With their differing interests in the logging process and its outcomes, as well as variable levels of knowledge about forest ecology and management, implementation of best management practices can be enhanced by training programs for young loggers, educational programs for landowners, and discussion platforms for all stakeholders (Tumpach *et al.*, 2018).

Legacies of past logging practices and climate change may interact to influence the behavior of rural communities in harvesting forest timber products. Rural households in southern Africa need fuelwood to meet daily domestic energy requirements. Unsustainable fuelwood harvesting arising from the increasing demand due to growing human populations may lead to environmental degradation. The impacts of fuelwood harvesting from 1992–2009 on the woodland structure and species composition surrounding two rural villages, with similar socioeconomic characteristics, located within the Kruger to Canyons Biosphere Reserve (Mpumalanga Province, South Africa) were assessed. The total wood stock in the communal woodlands of both villages declined overall, with adverse changes in woodland structure and diversity of species commonly harvested for fuelwood in one village. The latter site became degraded, and no longer produced fuelwood of preferred species and stem size in sufficient quantity or quality. More sustainable harvesting regimes probably existed at the other site because of the lower human population and lower fuelwood extraction pressure. However, both communities harvested from neighbouring unoccupied private land in a social response to fuelwood scarcity due to either degradation or drought periods (Matsika *et al.*, 2013).

4.3.2.5 Interactions between key drivers for non-extractive use

Multiple drivers may interact to affect the sustainable management of iconic species, particularly for those of non-extractive (e.g., cultural) and economic use. The Murray crayfish *(Euastacus armatus)* is a freshwater species valued by the Aboriginal Owners and threatened by landowners, tourism businesses, scientific researchers, non-governmental organizations, and government agencies across southeast Australia (Noble *et al.*, 2018). Research showed that *E. armatus* is a culturally significant species, targeted for fishing, but is also highly valued for a range of non-extractive reasons that support social-ecological linkages between local people and freshwater ecosystems. Regarded as an iconic species by most stakeholders in SE Australia, there was general support for *E. armatus* to be used as a flagship species for conserving a spectrum of social-ecological values (e.g., Aboriginal Traditional Owner totem species) in local freshwater ecosystems. General calls for increased public education, co-management with non-government stakeholders, federal government coordination, and spatial protection of critical areas could feature for more equitable conservation and management strategies.

Wild edible mushrooms offer us a system that illustrates how economic, cultural, and social drivers may interact to produce potentially sustainable forest production and management. The diverse use of mycological resources may include tourism, where recreational and non-extractive activity is largely based on knowledge, identification, gathering, and tasting of mushrooms. By productively restructuring the forest spaces in Mexico, for example, developing mycological tourism could aid in generating income and social transformation of rural communities and provide incentives for optimal resource management and spatial planning (Jimenez-Ruiz *et al.*, 2017).

4.3.3 Effect of ecological settings, rarity & resilience of ecosystem

Wild species hunting and harvesting is often unsustainable in the tropics. This is in part due to a burgeoning human population and shrinking forests, and weak enforcement and regulation of protected areas and protected species, respectively (Bennett & Rao, 2002; Brodie *et al.*, 2015; Corlett, 2007; Harrison *et al.*, 2016; Kamp *et al.*, 2015; Lavery & Fasi, 2019; Milner-Gulland & Bennett, 2003; Nasi *et al.*, 2008; Ripple, Abernethy, *et al.*, 2016). Drivers of recent overhunting include deforestation, improved access, including road infrastructure, to forests and markets, improved hunting technology, and their interactions and escalating demand for wild meat, and wild species-derived medicinal products (Corlett, 2007; Harrison *et al.*, 2016; Lima Constantino, 2016).

For example, there is a need to understand the complex and dynamic relationships between the hunting ground, its resources, the stakeholders, and the different exogenous drivers of change that affect the components of the system at different scales. Using the resilience theory in the context of wild meat hunting people may considering shifting from the need to assess stocks with imprecise measures to the incorporation of the uncertainty and stochasticity inherent to complex systems in participatory and adaptive management

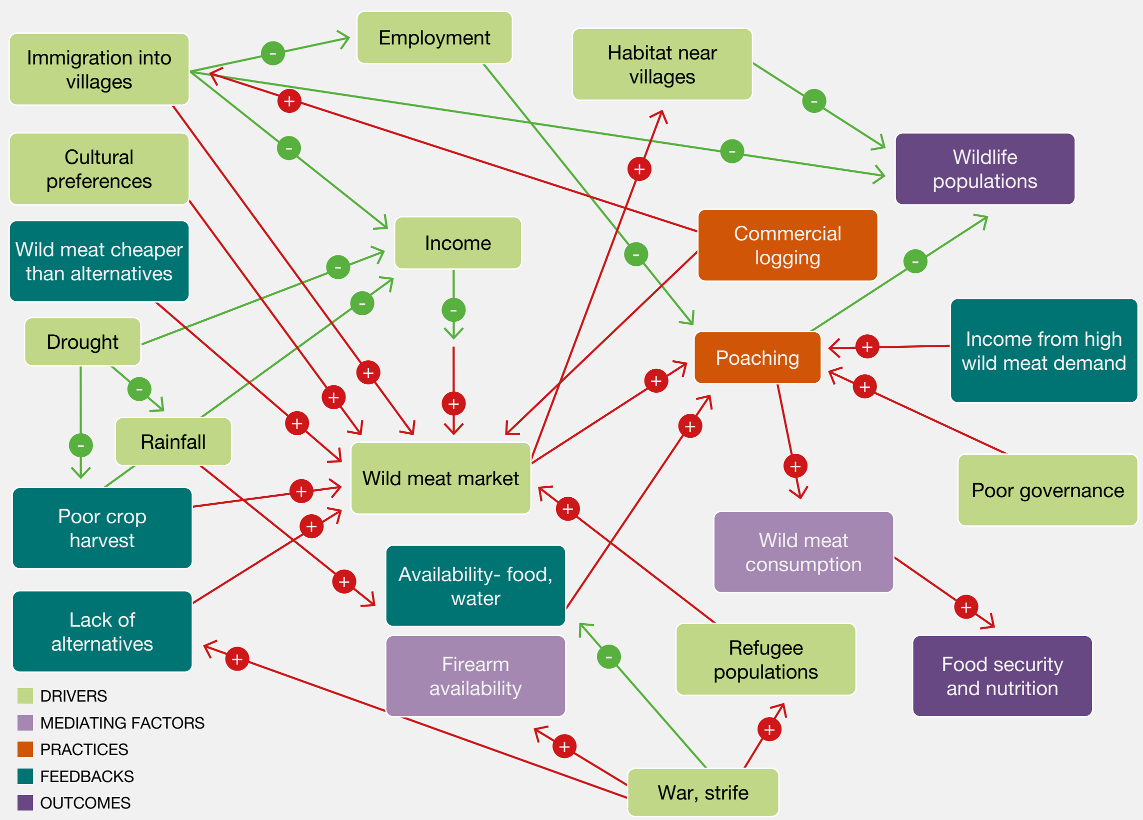


Figure 4 20 **Inter-related and interacting drivers contributing to rising wild meat demand, for example, and consequent resource overexploitation (arrows with + signs denote positive relationships between drivers; arrows with – signs denote negative relationships between drivers).**

Each node is also classified as either a driver, a mediating factor, a practice, a feedback, or an outcome). Source: adapted from Cawthorn & Hoffman, (2015) © 2015 Elsevier Ltd. License number 5300701475716.

processes. Such an approach can provide an opportunity for the sustainable use of wild meat and allows the identification of strategies to strengthen resilience when the system is found to be close to a given threshold (van Vliet, Quiceno, *et al.*, 2015).

Conservation and management design of threatened aquatic species, such as Murray crayfish in SE Australia, should include their entire range of cultural, economic, and ecological values using more stakeholder-led approaches (including from locals, non-governmental organizations, and tour operators). In doing so, broader stakeholder engagement and co-management could increase the capacity and confidence of managers to implement strategies that bolster both the social and ecological resilience of aquatic ecosystems (Noble *et al.*, 2018).

The non-extractive value of certain marine species may have important impact on the economic viability of marine protected areas that are highly dependent on marine-oriented nature tourism. Some marine protected areas in the Turks and Caicos Islands have recorded increases in spiny lobster *(Panulirus argus)* size and abundance leading to more sustainable fisheries. While these economic benefits of these changes have been linked to the effects of emigration of adult lobster to adjacent fishing grounds and/or increased larval export to downstream nurseries, non-extractive economic value resulting from viewing wild species from recreational divers may also have an important impact on the overall economic viability of Marine Protected Areas (Rudd, 2001).

Looking at a sample of 27,600 vertebrate species assessed by the International Union for Conservation of Nature Red List, slightly over 30% of them are decreasing in terms of both population size and range (IUCN, 2017). In the last one hundred years, vertebrate species have been lost at 100 times the normal background rate. Specifically, of the 177 evaluated mammal species, all have lost over 30% of their range since the year 1900, while >40% have experienced severe population declines (i.e., over 80% range shrinkage) during the same time (Ceballos *et al.*, 2017). The Living Planet Index estimates that the global wild species abundance has dropped by up to nearly 60% between 1970–2012 (WWF, 2018). Species with larger body sizes are suffering the worst declines (Dirzo *et al.*, 2014; Ripple *et al.*, 2014, 2015), indicating the influence of ecological traits (body size), which may be related to rarity. Because wild meat harvesting can contribute directly to wild species losses, particularly for large mammals (Ripple, Chapron, *et al.*, 2016), understanding of the myriad of interacting factors that drive such unsustainable harvests to better tailor interventions to curtail such losses.

As depicted in **Figure 4.20**, the reasons for wild meat overexploitation or unsustainable harvesting are many and these often vary significantly between regions (i.e., spatial variation). Take for instance, how escalating human populations via new immigrants (transmigration) and refugees (due to war and conflict) in villages, coupled with drought conditions and widespread economic and social inequalities could lead to ongoing decimation of wild species populations. **Figure 4.20** illustrates the tangled web of some of these inter-driver interactions that typically catalyze wild species overexploitation. For example, **Figure 4.20** shows how the extensive and complex interactions among many of the primary drivers such as environmental, social, economic and political drivers can critically affect the sustainable harvesting of wild meat.

4.3.4 Pattern of interaction among drivers across time and space

Hunting may also be indiscriminate, with offtake determined largely by relative abundance rather than intrinsic preference or legislation. As such, specific management and policy options include the need to monitor the hunting impacts on vulnerable species, the delineation of no-take areas, and modification of the legal framework for wild species conservation over time (Rao *et al.*, 2005).

Long-term, spatially explicit studies are important for the assessment of the sustainability of the wild species trade, as they provide the potential for disentangling the influences of market dynamics from population declines and contribute to interpreting changes in prices and quantities on sale in end-markets, for example (Milner-Gulland & Clayton, 2002).

When drivers interact and progress over time, the (un) sustainable use of a species may change in the future. Sea trout is one such species. It is a key species in both freshwater and marine ecosystems, providing important demand-driven ecological provisioning and socio-cultural services. As a salmonid species, the sea trout is sensitive to negative environmental conditions in both freshwater and marine coastal areas and is in general decline. Historically, the sea trout professional and subsistence fishery was important but unsustainable. However, in recent times recreational fishing for sea trout in the near shore coastal areas and rivers became more popular and accessible activity and that helped generate primarily socio-cultural services. The progressive growth of the recreational fishery may contribute to local cultural heritage, its folkways and lore, to the development and transfer of local ecological knowledge and fishing experience to the young and to human well-being, which may pave the way for more sustainable management (Liu *et al.*, 2019).

How environmental drivers and species management interact to affect practices over time remains data limited. Selective logging, a prominent land use in tropical forests, harvests a

Box 4 39 **Multiple-use system and sustainability.**

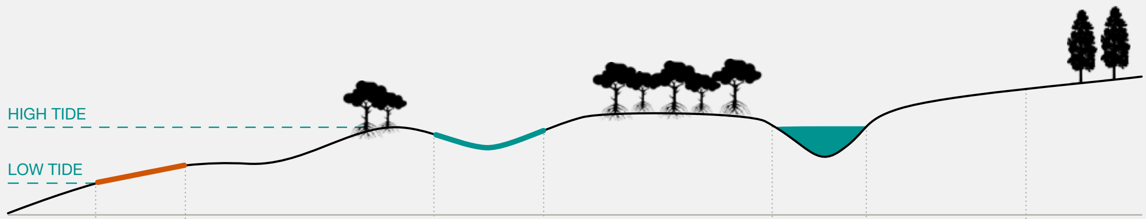
The diversity of wild species used, the complementarity in space and time of diversified practices, the fair regulation of access to resources – and notably the gender equity – are all elements that contribute to the co-viability of ecological and social systems, that means their adaptability to the global change and their sustainability (Armitage *et al.*, 2017; Berkes *et al.*, 2003; Cinner & Barnes, 2019; Cruz-Torres & McElwee, 2017; Gillon *et al.*, 2000; Matin *et al.*, 2018; Prado *et al.*, 2015). Mangrove (socio-ecosystem) is a good example for illustrating in what way a multiple-use system is more sustainable than a single-use system (Sarr *et al.*, 2011) **(Table 4.7)**. Forest in the sea, mangrove combines diverse facets of seascape and landscape – from hinterland to open sea, from tidal channels to backwaters and barren land or tanne areas. Depending on the seasons, the places/sites of uses and the labor forces mobilized (women/men, senior/junior, resident/migrant, etc.), various practices are associated: fishing (fish, crustaceans, shellfish), wood cutting, logging, salt gathering, bee hunting, rice growing, etc.).

Along West African coast, from Senegal to Sierra Leone, the communities of peasant-fishermen, used all the facets of the mangrove, that is not only a resource support or a source of income, on which they depend for their livelihood, but even a more collective heritage. (**Figure 4.21**: transect of mangrove -zones, species, uses and actors). That means the mangrove socio-ecosystem, with the biological and cultural diversity associated, is inherited from the ancestors, managed thanks to diversified technical systems, controlled over time by means of traditional rules, in such a way that it can be passed on to the next generations. This traditional multiple-use system, which prevailed until the 1960s, has been profoundly affected by a set of interacting factors, including climate change (severe Sahelian drought of the 1970-80s, rain variability since the 1990s), rural exodus (notably inked to urbanization and schooling), globalization of market and also insecurity, political instability and civil war. Local communities cope with these drastic changes in re-arranging the interactions between species/places/uses and actors. Also, the reorganization of the mangrove multiple-use system is based on 3 main trends: the abandonment of mangrove rice fields, the revalorization of traditional uses, the conversion of peasant-fishermen to sea fishing. Long been considered as a secondary or marginal practice, in comparison with rice cultivation, the oysters gathering, under the hands of the women, have become a major resource to face the crisis of the farming system; that means a key source of animal protein for the household consumption, but beyond, a major source of income, through their smoking and long-distance selling on the urban markets. The women gatherers, thanks to the oyster value-chain they control, now cover the essential need of the household (provision of rice, food, medical and education expenses) and have gained new (economic and social) power. This recombination of practices, the rearrangement of uses within the system (included the gender balance within the household and in the whole society), ensures its long-term maintenance. The resilience of the mangrove socio-ecosystem largely is due to the diversity of its components, at all levels, genetic (several varieties of rice), population (several groups of exploited wild species), sea/landscape (from the plateau to the sea). The complementarity between species/practices/actors, with their strategies and institutions, is a key driver of flexibility and adaptability to the changes. On the opposite, when a single use is privileged, whether it is oriented towards production (such as the shrimp aquaculture) or protection/restoration (reforestation with a single species of *Rhizophora* for carbon sequestration), when a component or a facet of the mangrove is overvalued (e.g., the mangrove trees to the detriment of the aquatic component), there is a high risk of biodiversity loss and unsustainability (M.-C. Cormier-Salem, 2017a). Clearly, multiple-use systems in the hands of local communities based on the sustainable management of multiple resources and their redistribution for the benefit of all community members are opposed on the one hand to specialized systems, assigning a use to a space and aiming to intensify production, increase yields and maximize private profits, and on the other hand to protected areas, spaces under severe constraints. These models of environmental management are based on radically different practices, knowledge and relationship to place.

limited number of trees, but the impact on forest structure, composition and aboveground biomass can be significant. While these impacts are well noted, the extent to which selective logging practice affects tree floristic composition and its recovery process is poorly known. Data from the effect of logging on long-term recovery trends of species composition in a tropical forest with yearly measurements were taken over 25 years. In the first years, post- logging, floristic composition differed widely between intact and selectively logged forests, with exploited areas diverging from pre-logged composition. Gradually, exploited areas shifted towards the original composition, with clearer changes in this trend after 13 years. Shifts in floristic composition were caused by a significant increase in light-demanding fast-growing pioneer species and their subsequent continuous high mortality rates after 13 years of the recovery process. In contrast, the control permanent plots showed similar shifts in composition over time, suggesting that external factors such as long-term climate changes may be driving these shifts. After 25 years, floristic composition tends to recover closer to the pre-logged status if the forest had undergone selective logging. Without additional human disturbances, experimental selectively logged forests in low-to-moderate intensities may be favorable for biodiversity conservation, at least during the first harvesting cycle. Reconciling conservation strategies with the recovery of stocks of commercial timber species could lead to more sustainable forest management plans (Gaui *et al.*, 2019).

Table 4 7 **Mangrove services.**

Services	Services from mangroves	Main functions (examples)
Regulation	Erosion control	Stabilization of shorelines, trapping of sediments by mangrove roots
	Protection against storms	Dam consisting of mangrove forests against storms, cyclones and tidal waves, damping of the waves
	Flow regulation	Circulation and water exchange through tidal, the river systems, coastal currents
	Waste treatment	Waste assimilation by the plant biomass, wastewater
Self-production or support	Air and water purification	Carbone export or sequestration by mangrove (carbon sink or source depending on the year)
	Water purification	Processing and storage of energy via biomass; sequestration of metal contaminants from the soil
	Constitution of the soil	Reclamation and colonization of soft substrate and low oxygen by the root system
	Nutrient cycling	Processing and storage of energy and materials (e.g., photosynthesis biomass of mangrove trees, bioturbation and landfill litter by crabs burrowing, litter mineralization by the benthic macrofauna)
	Enrichment of coastal waters	Direct transfer of the productivity of mangrove forests to coastal waters via tidal channels and flood; decomposition and mineralization of detrital organic matter, mixed continental water – ocean water; export of materials by migration of macrofauna
	Nutrient cycling and Biodiversity	Refuge habitat for birds
		Nursery for fish fauna (retention area, feeding and growth for aquatic life)
		Spawning ground for many species (fish, shrimp)
		Refuge from predators with shade trees, tangle of mangrove roots, turbidity
		Habitat of grazing gastropods (*Littorina* sp. and *Pachymelania Terebralia*), and of filter-feeding bivalves such as oysters, arches and *Cardium* sp.
Provision	Food	Mangrove forests, tidal channels and associated ecosystems, agro-silvopastoral resource support, fisheries and food (rice, salt, honey, fish, shellfish, etc.).
	Drinks and alcohol	Wood, flower, leaf and fruit fermented beverage, alcohol, vinegar, tea
	Wood fuel	Firewood and charcoal (fish smoking, heating the brine to manufacture salt)
	Health	Leaves and fruits at medicinal and cosmetics uses
	Material	Timber: poles, wood for house (piles), boat, farm tools (round, plow, dam), fishing gear (dam fence, trap and scoop nets); kitchen (mortar and pestle), tannin and dye (bark), lime shells, sticks
	Trade	Commercial and small-scale fishing, coastal and estuarine (fish – mullet, captain, carp and shrimp); collection of crabs, clams, oysters; aquaculture
	Livestock feeding	Forage and grazing herds of cattle, goats and other, salt cure
Culture	Spiritual	Sacred sites, totemic species: shell middens as tumulus in Saloum
	Recreation	Tourism and nature-based tourism (boat ride, wild species viewing); fishing, etc.); terrestrial animal harvesting
	Aesthetic	Oral traditions (myths, songs and poems), directed by the mangrove



Habitat	Mudflats	Mangrove Forest	Barren land	Mangrove Forest	Bolon	Lowlands	Sacred Forest
Practices	Fishing	Fishing	Gathering Grazing	Gathering	Fishing	Fishing Ponds cultivating	Gathering No use
Species	Seafish Shellfish	Oysters	Salt-fodder	Honey, wood	Tilapia Shrimp		
Actors	Men Women	Men Women	Men Women	Men (Women)	Men	Men Women	Men

Figure 4 21 **Transect of mangrove – zones, species, uses and actors.**

Environmental changes over time and the impact of rare events (such as droughts) may interact with extractive and management practice to influence if the harvest of wild species is sustainable or not. Over 20 years in Paragominas, Para, Brazil, previously unlogged forest was experimentally subjected to three different logging practices: conventional logging; reduced-impact logging; and unlogged control. Above-ground biomass and bole volumes of commercial species were tracked based on ten inventories (between 1993 and 2014). One year after logging, biomass, compared to pre- logging numbers, was reduced 14% by reduced-impact logging and 24% by conventional logging with corresponding merchantable species volume reductions of 21% and 31%. By 2014, biomass and bole volumes of commercial species had recovered 95% and 98% of their pre- logging stocks in the reduced-impact logging plot but only 76% and 72% in the conventional logging, plot, respectively; timber volumes from large trees (>= 50 cm diameter at breast height) were only recovered to 81% in the reduced-impact logging plot and 53% in the conventional logging plot. Twenty years after logging, average volume increments from commercial species were substantially higher in the reduced impact logging plot than in the conventional logging plot. The probable impact from the 2010 extreme drought temporarily reversed the biomass and timber volumes between 2009 and 2014 because of a 3-5.5-fold increase in annual mortality rates across the plots. This research shows that logging practices can interact with extreme events to affect the recovery of forests and hence the sustainable harvest of timber species (Vidal *et al.*, 2016).

Multiple drivers (e.g., cultural, social, technology) and mediating factors interact in a complex manner to determine if hunting is sustainable. Hunting in villages of northeast Gabon is practiced for both local consumption and cash income to cover basic family expenses. Cultural and socioeconomic factors could explain the temporal and spatial variation in hunting activities. Hunting increases in the dry season during circumcision ceremonies at > 10 km from villages and decreases during the rainy season because hunters are engaged in other economic activities. Degraded forest accounts for 20% of the animals killed and the greatest diversity of species nearest to villages. Mature forest supplies the species with the greatest commercial value, e.g., red river hog *(Potamochoerus porcus)*, and is the preferred source of meat for traditional ceremonies. In the last 15 years, hunting patterns have evolved rapidly, mainly because of the use of gun, which had serious implications for the sustainability of offtakes. However, hunting resilient species such as blue duiker *(Cephalophus monticola)* should be possible, but not sensitive species such as red river hog and small diurnal monkeys. As such, specific management systems are needed to identify possible solutions to sustain the population levels of the critical species (Van Vliet & Nasi, 2008).

4.4 CONCLUSIONS AND OPTIONS

Given the multiplicity of drivers and the contexts in which they operate through the human agency, achieving sustainable use of wild resources may appear to be a tall order and classified as a “wicked problem”. Wicked problems are difficult to solve. They require multidimensional and adaptive responses involving governments, the private sector, civil society, and indigenous peoples and local communities to address drivers and find solutions that are appropriate in the local context.

Various demographic and social factors influence the sustainable (or unsustainable) use of wild species: migration and urbanization, social organization and reproduction, empowerment, effective participation and accountability, poverty and process of marginalization, gender equity and, rural development (roads, infrastructure, access to material assets and immaterial goods-market, credit, internet). Population growth, aging populations in some countries and youth bulges in others is affecting patterns of use of wild species, the greatest of which is an increasing demand for wild species as food resources as well as expanding use of wild species habitats.

Increasing urbanization has led to perverse values of wild species that privilege some uses such as tourism – (e.g., polar bear viewing) over rural and indigenous uses (e.g., bear harvest), which is creating unintended consequences (e.g., polar bears are becoming acclimatized to human interaction with tourists and creating risks/safety, human-wild species conflicts for Inuit communities; other examples in east-Africa /China).

Economic forces are considered among the most critical in addressing rapid declines in biodiversity including the use of wild species; economic systems directly impact species but also shape perceptions and norms about the importance of particular species and their value within society. Global markets and consumer behavior patterns (particularly in the Americas) are drivers of demand for wild species and unsustainable uses (e.g., wild salmon harvest).

Rights of access to and use of common property wild resources by local communities along with social capital, participation in governance mechanisms and accountability greatly influence the sustainability of wild resources. Equitable distribution of benefits from the sustainable use of wild species is a stated goal of many governance and institutional frameworks. However, the implementation of these goals is often flawed. This has a direct impact on sustainability, creates incentives to over-harvest species, undermines long-term management of species, and can support unsustainable commercial extraction. Equal rights of access and use of resources on one side, social alliances and solidarity on the other side are recognized as key drivers for sustainable use.

Indigenous people and local communities are often at the front line of where the problems (unsustainable use) occur as they live close to wild resource-rich areas, though the ultimate causes of the change may lie far away in board rooms, government policies and, imperfect markets. So, it is imperative that if equitable solutions are to be found that indigenous communities and their local knowledge honed over centuries of resource use, are recognized and used judiciously.

Understanding of wild species as relatives, with whom humans should have a relationship of respect and reciprocity is common across cultures, continents, and oceans. Good relationships with wild species (the relationship between people and wild animals and plants) is understood as akin to a family relationship. All actions should assure the long-term wellbeing of that family and community.

Inequality and poverty are major drivers of unsustainable use of wild species. Eradicating poverty requires a multidimensional approach. Policies that maintain access to resources and opportunities for those marginalized and/or living in poverty (especially Indigenous Peoples and local communities) are key to sustainable use of wild species. Given that poverty is multidimensional, eradicating it requires a multidimensional approach. Access to food, shelter, education, employment, and healthcare can lift people out of poverty and make them less dependent on unsustainable use of wild species. The subsistence uses of wild species by women and Indigenous Peoples, are under-recognized and poorly protected. Such lack of recognition creates and aggravates problems of food insecurity and poor health for vulnerable populations (e.g., poor nutrition) and increases dependency on commercially produced food resources.

There is progress, however, in understanding the outcomes of single drivers (cause and effect) and in some instances, multiple drivers on wild species uses and outcomes, including synergistic, or antagonistic effects. Accounting for the interactions among the multiple drivers can ensure sustainable use.

4.5 GAPS AND CHALLENGES

One of the main challenges faced by the authors of the current chapter was in accessing the information presented by sources written in languages other than English. Also, there was difficulty in accessing non-academic sources of information such as the grey literature, government reports, and conference proceedings. Authors struggled to achieve balance between the conventional scientific knowledge and the knowledge of indigenous peoples and local communities. To be able to overcome these biases, authors engaged with reports from indigenous and local knowledge dialogue workshops, and contacted experts working closely with indigenous peoples and local communities; some authors reached out directly to members of indigenous peoples and local communities. Authors aimed to present a diversity of bibliographical resources; in some cases, this involved searching for information by directly contacting experts and those involved in fieldwork.

The following list reflects some of the main gaps in knowledge identified in this chapter:

Environmental drivers

- There is insufficient information on how climate change will affect wild species use through gathering and non-extractive practices.
- The assessment revealed that there is a significant gap in knowledge on the ecological impact of invasive species in the marine ecosystem globally.
- A more elaborate assessment of the contribution of air pollution and climate change to the global decline of insects, especially pollinators, is needed for effective intervention. This is important in view of its huge implications for horticulture and agriculture sectors that comprise the backbone of economies of the global south.
- There is a lack of focused in-depth studies on the impacts of pollution on keystone wild species (their biology, ecology, and conservation in the context of growing pollution), especially in the global south.
- There is a paucity of in-depth studies assessing the interactions among states, indigenous peoples and local communities, different forms of conservation bodies (international non-governmental organizations, non-governmental organizations, community-based organizations, and other stakeholders) particularly as it relates to minimizing causes and threats posed by pollution on wild species. This is particularly problematic in the global south.
- Acts and regulations are often inadequate or poorly addressed in terms of local impacts and evaluation methods (e.g., environmental assessment).
- Regulations in managing the impacts of pollution on wild species are poorly understood.
- More understanding of pollution-induced changes in wild species dynamics is needed.
- There are gaps in information about effective implementation of regulations.
- More information is needed about building capacity and awareness

Social drivers

- Urbanization tends to lead to decreased consumption of wild species, however there are some gaps in the assessment of how the influence of urbanization may differ particularly in lower-income countries where there are strong drivers for the consumption of wild species.
- Social systems, like many aspects of ecosystems, are highly complex and there are many factors, which affect sustainable use that are not well-documented.
- There are gaps in literature related to governance of gathering and non-extractive practices (including viewing) when compared to the extractive practices of terrestrial animal harvesting, fishing, and logging.
- Regional gaps exist concerning social norms, perceptions, and gendered dimensions of sustainable use in most parts of the globe, particularly for Latin America, and Asia, especially regarding informal institutions and governance systems of indigenous peoples and local communities.

Economic drivers

- There were some challenges regarding the availability of data, whether due to insufficient official trade statistics (that trace the status of threatened species) or due to the inconsistencies in the official statistics and trade surveys for wild species. The lack of systematic collection of data was another challenge, which curbs the quality and quantity of evidence concerning the sustainability outcomes.
- There is no clear definition of 'economic sustainability' and a lack of quantitative measures that can be used to evaluate which outcomes would be considered sustainable, which may change over time, and which specific drivers cause changes in outcomes over time.

- There are no guidelines for assessing economic sustainability, including tools to facilitate comparison among different regions/cases.

- There is insufficient quantitative data that can be compared across geographic regions regarding subsistence and indigenous economies, especially in relation to economic impacts and drivers of cultural, spiritual, and social uses of wild species.

- There are significant gaps in the availability of documented Indigenous and local knowledge related to economic drivers at all scales and in relation to all species.

- There is regional disparity in respect of understanding the economic drivers of sustainable use issues.

Cultural drivers

- Methods to document Indigenous and local knowledge, and customary values are not yet widely used and need to be further explored and implemented.

- There is a clear dearth of quality documentation on the diverse indigenous and cultural use of wild species. Documentation of the importance of languages in changing certain practices and that influenced the sustainable use of wild species is also limited.

- The underlying mechanisms that control the relationship between language and biodiversity remain unexplored.

- While academics have concentrated their efforts on documenting the loss of [Indigenous Knowledge systems, they overlooked studying the processes and the factors that drive this loss and the effect that has on society's capability to produce, employ, and transfer knowledge to sustain traditional ecological knowledge systems.

Interaction among drivers

- Lack of in-depth studies on ecosystem resilience and how it relates to non-fishing practices.

- Long-term temporal and spatial studies are few, particularly for non-fishing practices.

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Chapter **5**

FUTURE SCENARIOS OF SUSTAINABLE USE OF WILD SPECIES[1]

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FUTURE SCENARIOS OF SUSTAINABLE USE OF WILD SPECIES

EXECUTIVE SUMMARY

Changes in economic development, population growth, societal values and demands, as well as environmental and climate change, make the sustainable use of wild species a challenging and dynamic process that requires adaptive management and that will benefit from the use of scenarios.

1 Scenarios depict plausible futures for indirect and direct drivers, alternative policies and human development strategies that may affect the sustainability of wild species use. Options for sustainable use can be conceptualized as multiple pathways and trajectories {5.2} which depend on social, technological, economic, environmental, political, and cultural factors. This chapter performs a systematic review and assessment {5.3} of the sustainable use of wild species scenario literature for individual practices {5.4} and considers the integration of indigenous peoples and local communities and indigenous and local knowledge in scenarios {5.5}. Based on the review, it then evaluates the literature in the context of scenario frameworks and other relevant conceptual lenses, including archetypal scenarios {5.6}, the nature futures framework {5.7}, transformative change and leverage points {5.8}, and inequality issues {5.9}. Finally, knowledge gaps arising from the synthesis are identified {5.10}.

2 Scenario analyses indicate that climate change poses a challenge to sustainable use across all practices *(well established)* {5.4}. Impacts can include changes in species distributions and ecology, increased uncertainty around both biological change and management outcomes into the future, and an increase in extreme events. Scenario analyses also indicate that for many practices, demand is linked to demographic trends and consumption rates, and thus indicate increasing pressure into the future as the human population increases. In some cases, however, this can be moderated by effective governance, policy, and institutional performance, and through changing social or cultural norms *(well established)* {5.4}.

3 Technological advances are likely to make many extractive practices more efficient and may contribute to overexploitation; however, they are also likely to contribute to an enhanced ability to conduct monitoring, surveillance, and enforcement, in addition to, in some instances, reducing environmental impacts *(well established)* {5.4}.

4 Fishing: production is expected to remain at high levels, global fish demand and consumption is expected to increase, against a backdrop of climate change impacting catch potential and food-security for fisheries-dependent communities in some regions (e.g., more substantially in the tropics) *(well established)* {5.4}. Effective management measures, such as harvest control rules and recovery plans, may also help to buffer against some climate change impacts, though climate hazards are likely to pose threats to nutritional, social, economic, and environmental incomes worldwide, especially for wild-capture fisheries in the Global South. Small-scale fisheries will likely play an important role in those regions. Demand will also be affected by the balance of global food production between agriculture, aquaculture, and wild capture fisheries.

5 Gathering: scenarios and projections for wild gathered products are relatively limited *(well established)* {5.4}. A lack of baseline data in many cases makes it difficult to determine trends, although sustainability under exploitation depends greatly on the individual species and context *(well established)*. Long-term unsustainable harvesting can negatively affect livelihoods of local people with low socio-economic status *(established but incomplete)*. Climate change is likely to affect many of the conditions that affect sustainability of gathering into the future, including impacts on species distributions and wildfires *(well established)*. Changes in land-use and land-cover will also have an important impact *(well established)*. Policies that support gathering as a contribution to food security and the well-being of communities will be of benefit to both people and conservation, as will identifying and correcting regulations that mis-match current or future conditions *(well established)*. Gathering has and will continue to play an important cultural role for many peoples, including indigenous and local peoples, with their knowledge playing an important role in the sustainability of practices *(well established)*. Localized models and scenarios, as well as monitoring and assessment, can help to inform policy and practice *(well established)*.

6 Terrestrial animal harvesting: scenarios and projections around sustainable use for terrestrial

animal harvesting are limited, but key factors affecting sustainable use include legislation and regulation, values, illegal hunting and poaching, institutions, technological drivers, and climate change *(well established)* {5.4}. The limited presence of scenario/projection studies in hunting is a clear knowledge gap; most studies are around drivers *per se* rather than scenarios. Attitudes towards terrestrial animal harvesting are evolving, including those around the social acceptability of hunting, legislation and hunting bans, and poaching. Technological drivers are also likely to continue to evolve, with improved technology both for hunting but also for surveillance and detection of illegal hunting *(established but incomplete)* {5.4}. Climate change has implications for both hunting practices and underlying population dynamics (e.g., changing sea ice conditions). The demand for wild meat products shows differing regional trends with projected increases in some areas but declines in others due to changing cultural norms, social acceptability, values, and preferences.

7 **Logging: future changes in food production and agricultural practices, population increases in rural areas, and climate change are all likely to affect forest cover *(well established)* {5.4}.** There is a continuing reduction in global forest cover, despite increasing forest restoration, suggesting a trend of net forest loss and fragmentation. In the future, land conversion and deforestation rates will be affected by changes in agricultural practices and rural population densities. Furthermore, the demand for wood-based bioenergy continues to increase. Forest plantations may meet some of this growing demand. Scenario studies suggest that climate change may increase tree mortality and change forest composition but that integrated management including sustainable practices, multi-use forests, and food systems transformation can help to support sustainable use *(well established)* {5.4}. There are likely to be trade-offs between intensified logging, such as for bioenergy, and reduced logging to preserve biodiversity. Technological innovations that enhance efficiency and reduce waste may help with sustainable use, as may economic and political initiatives; however, customary and tenure rights, as well as land-use rights for local communities, also need to be integrated.

8 **Non-extractive practices: there is very limited exploration of sustainable use with specific regard to non-extractive practices in the scenario literature, leading to considerable uncertainty, particularly around generalizations *(well established)* {5.4}.** While scenarios exist of sustainable tourism more broadly, those that directly and specifically incorporate the sustainable use of wild species in non-extractive practices are much rarer. However, there is an expectation that the non-extractive use of wild species will continue to grow and rebound from the COVID-19 pandemic. This expectation is based on global trends including economic growth, media impacts, increasing environmental awareness, and the feasibility of travel *(established but incomplete)* {5.4}. The demand for both connectedness to nature and for visiting natural areas is affected by socio-cultural trends such as increasing urbanization. Technological changes in information and communication technologies have the potential to help enable sustainable non-extractive wild species use, such as through virtual wild species viewing. Wild species tourism represents an important source of income for many communities and regions, and may generate funds for conservation. However, nature-based tourism itself can contribute to negative environmental trends. Thus, projections of increasing tourism suggest that significant additional efforts will be necessary to mitigate negative impacts *(well established)*. Climate-driven impacts on wild species and ecosystems may also affect tourism potential in many regions.

9 **Scenarios from indigenous peoples and local communities, currently still scarce, will play a significant role in exploring sustainable futures for wild species use at the local and regional levels, promoting collective and participatory co-creation of sustainable futures rooted in local cultures *(well established)* {5.5}.**

10 **Linking the literature review for each practice to a set of archetype scenarios suggests there may be multiple pathways and solutions that can lead to more sustainable use of wild species, but that this understanding is limited due to the substantial knowledge gaps that remain in the exploration of archetypes focusing on sustainable use *(well established)* {5.6}.** The mechanisms by which sustainable use can be reached are very different for different practices, but generally include sustainable solutions that appear to benefit from market or policy support, even when solutions are bottom-up or technological in nature, and empowering local communities to help moving towards sustainable use irrespective of the practice. There is limited exploration of transformative change and radically different futures around sustainable use. In general, it is easier to link fishing and logging practices to archetypes due to their greater prevalence in the relevant scenarios' literature. Non-extractive practices have distinctively different example solutions in relation to extractive practices.

11 **The decision to follow specific management strategies at any time is complex and must be regularly reviewed and updated as environmental and socioeconomic conditions evolve.** That is where scenarios represent important contributions to envision outcomes *(well established)* {5.2.3}.

12 **Regardless of the future trajectory of society, archetypical scenario exploration indicates that some actions can be taken to contribute towards the sustainable use of wild species *(well established)* {5.6}.**

13 **Transformative change in the sustainable use of wild species may also be feasible through identifying and acting on multiple leverage points, identifying an outcome-based vision for nature and people, political prioritization of nature, aligning incentives, and changing social norms, among other approaches *(established but incomplete)* {5.8}.** These approaches must be effected within the context of clearly understanding cost-benefit trade-offs, particularly in terms of who benefits and who pays, and how interventions can enhance or exacerbate these trade-offs. They must also integrate transparent, participatory processes and adaptive management to help enhance transformative change. Consideration of a plurality of values, especially from indigenous peoples and local communities, is also needed.

14 **The nature futures framework can be applied to the sustainable use of wild species to help envisage positive futures centered around human-nature relationships and multiple values.** By promoting participatory and inclusive approaches to scenario development through co-creating narratives and frameworks with stakeholders, the nature futures framework can help facilitate and enable transformative change *(established but incomplete)* {5.7}.

15 **Critical reflection on social equity issues is crucial for the interpretation and evaluation of scenarios exploring the future of wild species use, and potential trajectories towards sustainability *(well established)* {5.9}.** Issues around social marginalization and exclusion, lack of alternatives to wild species use, market-based resource management, and inequity of wealth distribution may all tamper efforts to move towards sustainability.

16 **Substantial knowledge gaps remain in the literature of scenarios of sustainable wild species use *(well established)* {5.4, 5.6}.** Examples of scenarios that assess the future of sustainable use are limited in number, but also in diversity. There are scenarios on fishing and logging, yet other practices remain greatly under-represented in the literature, for example around terrestrial animal harvesting, indigenous and local knowledge, non-extractive practices and gathering of plants, algae and fungi. There is also a deficit of scenarios that explore cultural aspects and equity issues. In addition, while there are many scenario studies around the future of biodiversity and ecosystems *per se*, studies focused on sustainable use that are embedded within these broader futures remain less prevalent *(well established)* {5.4, 5.6}. Thus, there is a need for a greater focus on scenarios of sustainable use within the context of more integrated solutions, and consideration of how sustainable use interacts with conservation and other elements of a sustainable society. Issues around inequalities and people in vulnerable situation who are dependent upon wild species are also not well represented in the scenarios' literature.

5.1 BACKGROUND AND INTRODUCTION

5.1.1 Focus and structure of the chapter

Chapter 5 assesses pathways toward sustainable futures and examines a range of future scenarios for the drivers of sustainable use and their effects on the conservation and management of wild species in their wider social-ecological context. Specifically, this chapter:

- Examines the literature on modelling and scenarios of drivers of sustainable use and policy responses across a wide range of practices to synthesize information on pathways towards the sustainable use of wild populations, potential tipping points, and areas in which further scientific understanding and knowledge generation is needed.
- Assesses the implications and trade-offs of these driver trajectories for the future levels of wild species use.
- Explores the implications of various levels of use for the future of wild species populations and the future contributions of wild species to people.
- Examines how scenarios might be used in decision-making under uncertainty and given the gaps identified herein.
- Explores visions for transformative change through synthesizing the scientific knowledge into archetypal scenarios, recommending leverage points and positive actions to enhance the sustainable use of wild species.
- Integrates visions for transformative change and leverage points for the sustainable use of wild species in plausible futures.
- Explore issues of equity, indigenous peoples and local communities and indigenous and local knowledge, and their representation in scenarios.

The objectives of this chapter are therefore to review the available range of knowledge on future scenarios and modelling of the drivers of sustainable use of wild species, including indigenous and local knowledge and the scientific consensus when such exists, and draw lessons for future transformative change. The different practices considered in the assessment will be treated in detail in order to critically examine the specific drivers of sustainable use that affect each one. This chapter also explores the IPBES scenarios and models frameworks, and in particular the nature futures framework (being developed by the IPBES task force on

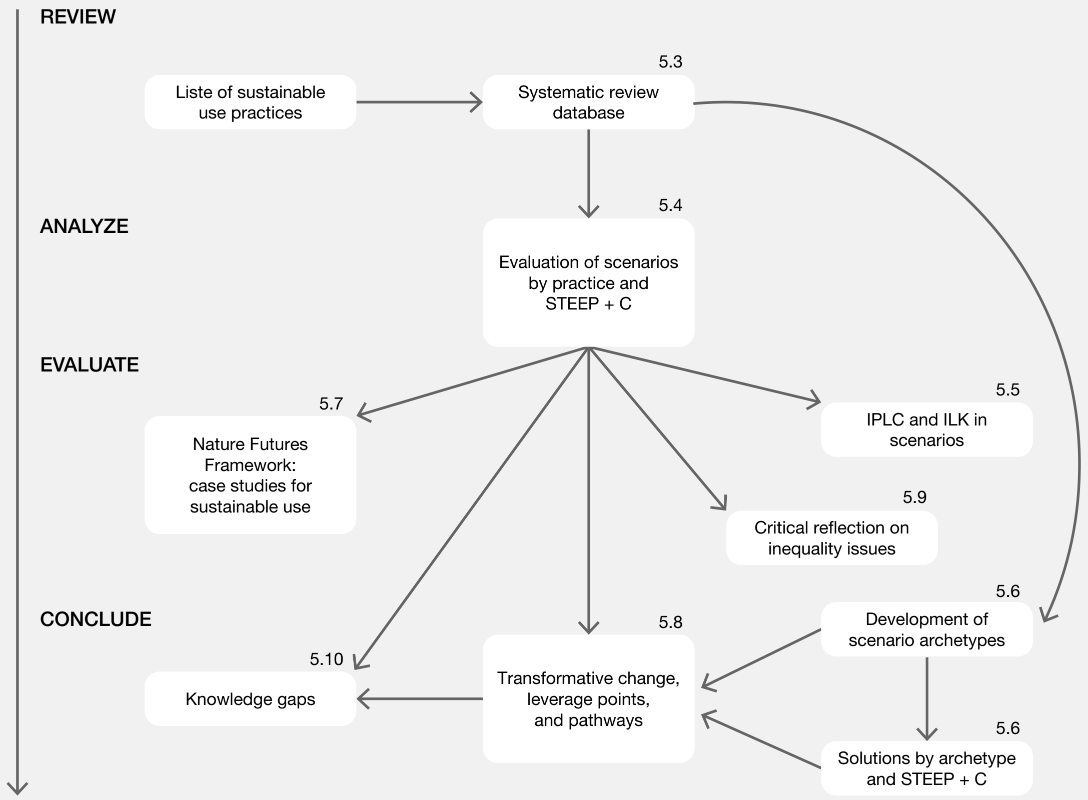


Figure 5 1 **Conceptual outline of Chapter 5.**

Numbers refer to chapter sections.

scenarios and models), through the lens of the sustainable use of wild species. The conceptual structure of the chapter is depicted in **Figure 5.1**.

5.1.2 Framing within IPBES assessments and the assessment of the sustainable use of wild species as a whole

The chapter builds on the chapters of the IPBES Global Assessment of Biodiversity and Ecosystem Services on scenarios and transformative change towards sustainability (IPBES, 2019), IPBES Regional Assessments (e.g., IPBES, 2018), and the Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services (IPBES, 2016). It draws on Chapter 4 of the IPBES Global Assessment of Biodiversity and Ecosystem Services (particularly the archetype scenarios) and attempts, where possible, to mirror the structure of that chapter. It also makes use of the examples, models and data from the IPBES Global Assessment, where applicable. The chapter differs from the IPBES Global Assessment in two respects:

i. The IPBES Global Assessment examined published global scenarios of biodiversity change and projected their future interactions with nature, nature's contribution to people and good quality of life. In particular, the IPBES Global Assessment focused on direct drivers of biodiversity change, such as climate change and changes in land use, and indirect drivers such as demography, economics, and governance. In contrast, this chapter considers scenarios of the underlying drivers of sustainable use of wild species rather than biodiversity change, which are in places equivalent to the indirect drivers in the global assessment, since they are frequently management or policy actions or socio-economic changes. In part, this is because the approaches needed to ensure sustainable use across multiple sectors result from addressing these underlying societal drivers in policies and strategies. In common with IPBES Global Assessment, however, the downstream impacts of changes in drivers of sustainable use are considered, as well as the interventions (levers) to generate sustainable use.

ii. While the IPBES Global Assessment predominantly assessed global scenarios of biodiversity, this chapter also includes scenarios of and impacts on the sustainable use of wild species at multiple scales, including local and national levels.

Within the IPBES assessment of the sustainable use of wild species, the chapter draws on Chapter 3 (status of and trends in the use of wild species, the environment and people) – particularly for the present status of and historical trends in the sustainable use of wild species. It also draws heavily on Chapter 4 (drivers of the sustainable use of wild species) to identify the influencing factors that affect extractive and non-extractive practices and how they influence nature, nature contributions to people and good quality of life. The archetype scenarios described herein are used to develop plausible futures for these drivers wherever possible. Chapter 5 also provides material around scenarios and the futures of sustainable use to help inform the governance strategies and policy options explored in Chapter 6.

5.2 WHAT IS MEANT BY SCENARIOS

With the increase of the use of scenarios and the number of publications reporting on them, the number of definitions of what a "scenario" is also increased. Some scholars treat scenarios as being tightly connected to models, and therefore use both terms inseparably. This chapter follows the definition of scenarios as provided in the IPBES Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services: "Scenarios are representations of possible futures for one or more components of a system, particularly, in this assessment, for drivers of change in nature and nature's benefits, including alternative policy or management options" (IPBES, 2016). It is important to highlight the last part of this definition,

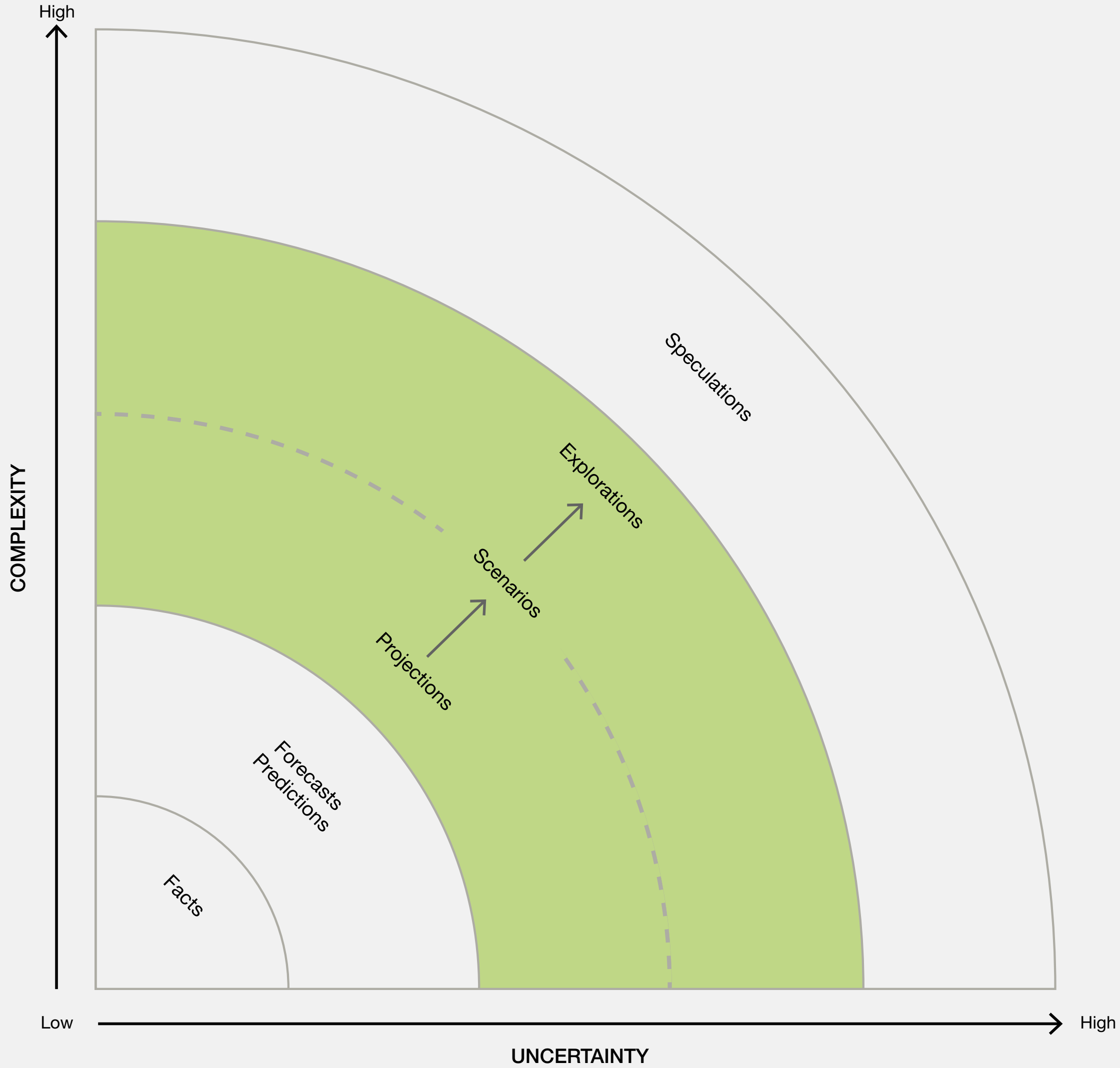


Figure 5 2 **Scenarios in the spectrum of complexity and uncertainty.**

Source: Zurek & Henrichs (2007) © 2006 Elsevier Inc., license number 5154260505736.

as it points at a crucial distinction that most scholars acknowledge (e.g., Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006; Kok *et al.* 2011), namely between exploratory scenarios and target-seeking scenarios. This fundamental division is also highlighted in several IPBES assessments, notably the Methodological Assessment Report on Scenarios and Models, where four types of scenarios are discerned, three of which are of importance here: (i) "exploratory scenarios", which represent different plausible futures, often based on storylines; (ii) "target-seeking scenarios", also known as "normative scenarios", which represent an agreed-upon future target and scenarios that provide alternative pathways for reaching this target; and (iii) "policy-screening scenarios", also known as "ex-ante scenarios", which represent various policy options under consideration (IPBES, 2016).

Scenarios are distinguished from other approaches to future assessment, such as forecasting and risk assessment, by being specifically intended for situations in which the factors shaping the future are highly uncertain and largely uncontrollable (Biggs *et al.*, 2008; see **Figure 5.2**). Scenarios thus serve to structure the uncertainty of future developments of complex systems, and to provide a palette of plausible futures and possible actions.

In this chapter, scenarios are used both to explore what could happen (exploratory scenarios) and to present strategies and actions for what should happen (target-seeking and policy-screening scenarios). Analyses of the scenarios' literature based on the different projections and plurality of visions were conducted to evaluate what drives sustainable use in general. Section 5.2.1 elaborates on the most important aspects of scenarios and how to understand them in this chapter.

5.2.1 Types of scenarios included

5.2.1.1 Terminology

The term "scenario" is used by many different communities across scientific domains, scales, as well as in policy and practice. The scenario literature is therefore, vast, rapidly increasing, and in partial disagreement on what a scenario is, what it can be used for, what methods are most appropriate, and what results it generates. In general, the term "scenario" is most often used by those that set out to develop exploratory scenarios and translate those into model projections. It is reasonable to assume that papers included in this assessment will largely belong to the category of model-based explorations. More importantly, target seeking scenarios are often not referred to as scenarios. Particularly at local scales, normative scenarios are mostly referred to as "pathways". When it concerns policy screening scenarios, a range of other terms is often used to describe them, including strategies, plans, policies, options, or actions. It is also reasonable to assume that the papers included in this assessment might not have picked up on all the target-seeking scenarios. A number of keywords were added to the search string to ensure that the database was not limited by terminological differences.

5.2.1.2 Exploratory scenarios

Exploratory scenarios (Van Notten *et al.*, 2003; Van der Heijden, 2005; Avin & Goodspeed, 2020) examine plausible futures, based on potential trajectories of drivers, either indirect (e.g., socio-political, economic and technological factors) or direct (e.g., habitat conversion and climate change). Exploratory scenarios can illuminate the discourse on specific problems, by illustrating various potential futures starting from the current point in time. Despite the relatively short history of developing exploratory scenarios – that started with the publication of the Global Scenario Group scenarios (Gallopin *et al.*, 1997; P. Raskin *et al.*, 2002) – an enormous number of scenarios have been developed across the full range of scales from local to global (e.g., Hunt *et al.* (2012); Amer *et al.*, (2013); Priess & Hauck (2014); Rothman (2008); Rounsevell & Metzger (2010). Influential global scenarios include those of the Global Environment Outlook 3 and 4 (United Nations Environment Programme & Earthscan, 2002; United Nations Environment Programme, 2007), the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (Nakicenovic *et al.*, 2000), the shared socio-economic pathways-representative concentration pathways (SSP-RCP; van Vuuren *et al.*, 2011; O'Neill *et al.*, 2013), and perhaps most relevant in this context, those developed within the Millennium Ecosystem Assessment (Cork *et al.* 2006). Likewise, there are a large variety of (global) models that provide quantifications of one or more of the sets of storylines. Examples of sectoral models that address environmental change include, water (WaterGAP; Alcamo *et al.*, 2003), agriculture (IMPACT; Rosegrant 2012; GLOBIOM, Havlik *et al.*, 2011), natural vegetation (LPJ; Smith, Prentice, & Sykes, 2001), and biodiversity (GLOBIO; (Alkemade *et al.*, 2009). In summary, there are a large and growing number of initiatives that have developed qualitative stories and/or quantitative models to explore what could happen to a range of environmental issues, including biodiversity and nature's contributions to people.

5.2.1.3 Exploratory scenario archetypes

"Scenario archetypes" describe different general patterns of future developments and can be useful in summarizing and harmonizing the overwhelming amount of information in individual sets of scenarios. The scenario archetype approach (IPBES, 2016) has been recognized by IPBES as a way to help to synthesize findings from scenarios for the IPBES Global Assessment of Biodiversity and Ecosystem Services (IPBES, 2019) and throughout the four IPBES

Regional Assessment Reports. A set of six global scenario archetypes was used, based on scenario families described by van Vuuren *et al.*, 2012. In the regional assessments, these six archetypes were also used, although in some cases with slight modifications. In the IPBES Regional Assessment on Biodiversity and Ecosystem Services for Europe and Central Asia, for example, "reformed markets" was omitted as a separate archetype, and another sixth archetype was added ("inequality").

In this chapter, a set of four main archetypes is used, most of which are further subdivided into 2 or 3 subtypes **(Box 5.1)**. This set does not completely match any earlier proposed set, but it does include all archetypes used in the global and regional assessments. The main reason for deviation from previous sets is the fact that they will not be used on their own, but in combination with target-seeking scenarios. This set was seen as the best option to facilitate combination with normative scenarios, while maintaining a similar selection.

Box 5 1 The 8 types of scenarios considered.

1. **Market forces.** Global developments steered by economic growth result in a strong dominance of international markets with a decreasing degree of regulation. Environmental problems are only dealt with when solutions are of economic interest. This archetype includes two recurrent variants:

   1a. A less extreme variant includes **business-as-usual** and reference type of scenarios, as well as those scenarios typified as strongly market-driven. All assume current trends to continue without strong, nonlinear changes. Typical examples: Shared socioeconomic pathway 2 (O'Neill *et al.*, 2017) and Markets first (from the Global Environment Outlook 3, United Nations Environment Programme & Earthscan, 2002).

   1b. A more extreme variant of **market-led environmental management** with highly equal and healthy societies. In terms of biodiversity and nature's contributions to people, this archetype can range from devastating (environmental destruction) to positive (economically viable nature-based solutions). Typical example: Shared socioeconomic pathway 5 (O'Neill *et al.*, 2017).

2. **New sustainability paradigm.** A world with an increasingly proactive attitude of policymakers and the public at large towards environmental issues and a high level of regulation. All variants of this archetype are beneficial for biodiversity, either through behavioral change, top-down "green" policies, or through green technology development. In all cases, this is reinforced by a proactive attitude to dealing with environmental problems. Three main variants can be discerned:

   2a. Technological solutions with strong technological development in all sectors, including for example engineered ecosystems to deliver ecosystem services. Typical example: TechnoGarden (Cork *et al.*, 2006).

   2b. Global sustainable development with strong, mostly top-down, governance structures that are effective in realizing a more sustainable world. Typical example: Policy first (from the Global Environment Outlook 3, United Nations Environment Programme & Earthscan, 2002).

   2c. Regional sustainability with fundamental change being initiated by a broadly supported, and bottom-up enforced paradigm shift, often accompanied by a dematerialization process and a "back to nature" attitude. Typical example: Rural revival (in OpenNESS scenarios, Priess *et al.*, 2018) or B2 (Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios, IPCC, 2000).

3. **Fortress world.** A regionalized world based on economic development. The market mechanism fails, leading to a growing gap between the rich and the poor. In turn, this results in increasing problems with crime, violence and terrorism, which eventuate in strong trade and other barriers. Two variants exist:

   3a. Regional economic growth. A less extreme variant where, despite strong barriers, the quality of life for most is secured and most problems are dealt with adequately. Typical example: Order from strength (Cork *et al.*, 2006; Millenium Ecosystem Assessment, 2005).

   3b. Breakdown. A more extreme variant, where organized crime and terrorism eventually lead to institutional disintegration and economic collapse. This variant is rarely elaborated in the literature. Typical example: Breakdown (Gallopin *et al.*, 1997).

   The effects on the environment and biodiversity are mixed. Overall, there is a tendency towards increased security, which can either be positive (protect biodiversity) or negative (intensify agricultural production). Particularly in low-income countries, deforestation and loss of natural areas is a risk.

4. **Inequality.** A world of growing inequalities, both within and between countries. The increasingly powerful elite takes environmental responsibility, while the large lower class is poor but kept satisfied. The effects on the environment differ greatly, depending on location and type of issue. Importantly, the global "green" elite actively combats globally important issues, such as climate change, which has a positive impact on biodiversity. Although increasing inequalities have negative consequences for economic and social development, biodiversity and ecosystems by and large benefit. Typical example: Shared socioeconomic Pathway 4 (O'Neill *et al.*, 2017).

Of particular relevance to the focus of this assessment, the exploratory archetypes encompass important obstacles and limitations for sustainable use, such as follows:

1. **Market forces: t**here is a lack of interest in the environment. Sustainable development is not a focus and many wild species that generate less direct economic revenue might not be protected sufficiently.

2a. **Technological solutions:** there is a very strong emphasis on technological "end-of-pipe" solutions. Not all wild species can be used sustainably this way, and technological solutions are likely to have a limited scope.

2b. **Global sustainability:** top-down enforcement of laws and regulations might be ineffective for many local-specific contexts.

2c. **Regional sustainability:** bottom-up solutions will hamper those aspects that need global coordination, such as climate change mitigation; pandemics; or ecological corridors.

3 & **4. Fortress world and inequality:** in these archetypes, social and human problems will worsen, including increased poverty and inequality. This is likely to strongly inhibit sustainable development, because of a lack of financial support, lack of public and political interests, and/or lack of general importance.

In this chapter, the archetypes will be used in an overarching way, but the analysis is not confined to these archetypes. As these scenario archetypes are constructed to categorize exploratory scenarios, the set as shown above cannot be directly adopted, but needs to be linked and combined with target-seeking scenarios. The procedure used to do this will be explained in section 5.2.1.6.

5.2.1.4 Intervention scenarios: target-seeking and policy scenarios

"Intervention scenarios" evaluate alternative policy or management options, by developing either "target-seeking" or "policy-screening" scenarios. In policy-screening scenarios, a policy, or set of policies, is applied and an assessment of how the policy modifies the future is carried out. Target-seeking scenarios (also known as "normative scenarios") are a valuable tool for examining the viability and effectiveness of alternative pathways to the desired outcome. They start with the definition of a clear objective or a set of objectives that can either be specified in terms of achievable targets or as an objective function to be optimized. Both have in common the search for effective policies or actions to reach a commonly agreed (normative) target. In contrast to exploratory scenarios, intervention scenarios are much less developed at the global level, and as a result, there is a much larger diversity. This is due to the disconnectedness of communities of practices, but also the more diverse set of locally or regionally contextualized issues that need to be addressed. As a result, it is much more difficult to provide a concise overview or attempt to categorize that overview into a limited number of archetypical descriptions. To illustrate this diversity, this chapter refers to the different IPBES Regional Assessment Reports, all of which include a section on pathways and other normative scenarios.

5.2.1.5 Pathway archetypes

To illustrate an attempt to categorize archetypes at the regional level, the IPBES Regional Assessment Report on Biodiversity and Ecosystem Services for Europe and Central Asia recognizes four "clusters of internally consistent pathways" based on Luederitz *et al.* (2017):

- The "green economy" pathway addresses transitions toward decreased environmental degradation and resource depletion through green growth supported by policy instruments that stimulate specific economic activities.

- The "low carbon transformation" pathway encompasses all pathways focusing primarily on mitigating climate change and adapting to climate change impacts, locally and globally.

- The "ecotopian solutions" pathway addresses transitions towards increased social-ecological integrity. It does this by challenging current belief systems, lifestyles and living spaces with bottom-up, politically alternative initiatives of self-organization at the community or neighborhood level to work towards local-scale, self-sufficiency.

- The "transition movements" pathway also focuses on fundamental individual and social changes, but in contrast to ecotopian solutions, transition movements aim to scale-up to a whole system transformation.

5.2.1.6 Integrated scenarios and pathways

Exploratory scenarios, target-seeking pathways and intervention scenarios provide a palette of plausible futures and possible policies, actions, and other management options. Often, they are used together in what is referred to as "scenario planning". Exploratory scenarios sketch future possibilities and are used as multiple baselines against which the effectiveness of policies and pathways can be tested. This approach yields "robust" or "no-regret" policies that would work in all plausible different future outlooks.

Table 5 1 **Combining exploratory and normative archetypes.**

The symbols indicate the degree of matching (xxx=strong; xx=medium; x=weak; -=no match).

Archetype	Green economy	Low carbon	Ecotopian	Transition
Market forces	xxx	xx	-	x
New sustainability				
Technology	xxx	xx	-	x
Global	xx	xxx	-	x
Regional	x	x	xxx	xx
Fortress world	-	-	x	x
Inequality	-	xx	xx	x

Here, this chapter takes a different approach by combining exploratory and normative scenarios in one set of integrated archetypes. The starting point is the exploratory scenario archetypes that are combined with the pathway archetypes by indicating whether or not a specific pathway of interventions is compatible with the archetype **(Table 5.1)**. There are strong matches between the market forces and green economy archetypes as well as between regional sustainability and ecotopian solutions. The low carbon society could be combined with many archetypes but is less relevant for the assessment of the sustainability of use of wild species, while the transition archetype combines top-down and bottom-up elements from almost all archetypes and would thus partly work in all archetypes.

This set of plausible changes and possible intervention archetypes will be the starting point for the elaboration of the scenarios in this chapter.

5.2.2 Methodological considerations for scenario development

This chapter assesses the scenarios and interventions that have been proposed in the literature, thus focusing on the resulting future outlooks and measures, and much less on the process and methods that were used to develop the scenarios. There are, however, a number of methodological aspects that are strongly tied to the outcome of this assessment. The methods employed can also facilitate processes of change that can be part of the solution. Scenarios can be co-created with stakeholders and this participatory process offers the possibility to aim for, among others, social learning, conflict management, or understanding of multiple perspectives. As such, scenarios can be a platform for public participation, and the process of deliberation and negotiation (Patel *et al.*, 2007; Reed *et al.*, 2013; Rounsevell & Metzger, 2010). This transdisciplinary process of stakeholder engagement resonates well with the regional sustainability/ecotopian pathway archetype and is often seen as essential for its implementation. **Box 5.2** elaborates on an example of multi-scale participatory scenario development.

Many scenario-development methods advocate the development of multi-scale scenarios. Kok *et al.* (2016) advise on an overall strategy for incorporating multiple scales in IPBES assessments. In a landmark paper, based on the experience within the Millennium Ecosystem Assessment, Zurek & Henrichs (2007) provide an overview of the degree to which scenarios can be linked across scales. The process of multi-scale scenario development can either be predominantly top-down (e.g., Millennium Ecosystem Assessment, see Biggs *et al.*, 2007; Kok, Biggs, & Zurek, 2007) or predominantly bottom-up (e.g., Seeds of a good Anthropocene, Bennett *et al.*, 2016). Top-down scenarios can easily be classified as they are linked to higher-level, often global, scenarios. Local scenarios developed through bottom-up processes can benefit from alignment with scenario archetypes to facilitate comparison and synthesis. The fact that many scenarios are either bottom-up or stand-alone studies, was an important justification for the consideration of scenario archetypes in this chapter.

One essential feature of scenarios is their ability to integrate. This can be across scale, sectors, actor groups, or topics. Particularly when combining narratives and models, scenarios are an excellent tool to deal with the complexity of the entire social-ecological system under study. The level of integration increases further when exploratory and target-seeking scenarios are combined. Not all scenario studies make use of the potential for integration – many modelling studies use a single, sectoral model and scenario to provide model input – but here scenario archetypes are combined with other approaches to sketch a more complete picture of potential futures.

Box 5 2 Co-creation and participatory processes in scenarios of sustainable use.

Scenarios and scenario planning have a long history, initiated by the Rand cooperation in the 1950s (Kahn & Wiener, 1967; Bradfield *et al.*, 2005), and extensively used by oil companies, such as Royal Dutch Shell (Wack, 1985). Up to 75% of all Fortune 100 companies were using scenario techniques in the 1980s (Rounsevell & Metzger, 2010); however, despite early environmental studies – notably the Limits to Growth report in 1972 (Meadows, 1972) and follow-up reports for the Rio Summits in 1992 and 2012 – scenarios only became popular as a tool to assess environmental change around the turn of the century. Global scenarios published by the Global Scenario Group (Gallopin *et al.*, 1997; P. Raskin *et al.*, 2002) and the Intergovernmental Panel on Climate Change (IPCC, 2000) were quickly followed by the Global Environment Outlook (United Nations Environment Programme & Earthscan, 2002; United Nations Environment Programme, 2007; United Nations Environment Programme, 2012), the Millenium Ecosystem Assessment (2005) and others. These early practitioners paved the way by showing the power of scenario assessments (Raskin, 2005), which also contributed to a rapid expansion of national and local scenario studies, for example through the sub-global assessments of the Millennium Ecosystem Assessment (Lebel *et al.*, 2006).

With this increase in use came an equally swift increase in the number of different methods employed to develop scenarios. An important dichotomy was the choice between qualitative and quantitative approaches. Recognizing their complementarity, Alcamo (2009) described an approach to develop scenarios by combining and integrating qualitative stories and quantitative models. This story-and-simulation approach shows how stakeholders can be involved in a participatory process of storyline development, and how stories can be translated into model inputs and outputs that can be discussed with the stakeholders in an iterative procedure. A wide range of participatory methods have since been developed and used to engage stakeholders in the process of scenario development. In a landmark paper, Reed *et al.* (2013) provide an overview of methods that have been employed and present a methodological framework including all steps from defining the context and aims of the process to the actual co-production methods. First described by Schwartz (1991), the "intuitive logic" or what has become known as the "2x2 matrix approach", is a way to develop a set of four scenarios with stakeholders that has now been mainstreamed (Ramirez & Wilkinson, 2014). Likewise, target-seeking scenarios have been closely linked to co-production techniques (IPBES, 2016). In the 1980s, the term "backcasting" was coined (Robinson, 1982), followed later by descriptions of participatory backcasting methods (Robinson, 2003), which is still being successfully applied (Vergragt & Quist, 2011; De Bruin, Kok, & Hoogstra-Klein, 2017). Other approaches that engage stakeholders in the process of developing target-seeking scenarios include transition management (Loorbach & Rotmans, 2010), visioning (van der Helm, 2009), or strategic niche management (Schot & Geels, 2008). Overall, a wide range of tools for scenario development exists, many of which can either be participatory or can be innovatively combined with a participatory component to answer different questions about the future. However, a gap persists in integrating these quantitative and qualitative methods at the global level (Pereira *et al.*, 2021).

Participatory scenarios have been applied to natural resource management and climate change mitigation as powerful, multi-scale processes. Some examples include integrated scenarios for: multi-scale stakeholder engagement (Gramberger *et al.*, 2015); qualitative stories (Pedde *et al.*, 2019); sectoral and integrated models (Integrated Assessment Platform, Harrison, Dunford, & Holman, 2019); and exploratory (Kok *et al.*, 2019) and target-seeking scenarios (Frantzeskaki *et al.*, 2019). **Figure 5.3** shows the sequence of events, the types of scenarios and type of stakeholder engagement that were undertaken in the European Union-funded projects CLIMSAVE and IMPRESSIONS. **Figure 5.4** exemplifies different products that were developed in a series of stakeholder workshops, preceded by interviews and interlaced with online questionnaires and email exchanges, where exploratory scenarios were developed and combined with pathways to identify sets of (robust) transformative solutions across scale. The effort convincingly demonstrates how using participatory methods in a co-creation process will not only yield qualitative products such as stories or cartoons but can also be used to determine model input and output. These products in turn are fundamental to discussions on target-seeking pathways and finding the most promising solutions, both for a single case study but also in a multi-scale design, providing insights in other places or at another scale.

Within the biodiversity and broader sustainability scenario area, participatory scenario processes have been widely used at the local level (Oteros-Rozas *et al.*, 2015). An attempt to collect these social-ecological scenarios into a database is now underway (https://www.biospherefutures.net/). One of the biggest benefits of participatory processes in co-creating futures with stakeholders is the ability to engage the imagination; something that has largely been lacking in global-level scenario processes, especially those used in assessments (Pereira *et al.*, 2020). Following the Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services (IPBES, 2016), the IPBES former expert group on scenarios and models undertook to stimulate the development of new global scenarios that put nature at the center of the story (Rosa *et al.*, 2017). The culmination of this process, following a participatory visioning process, has been the development of the nature futures framework (Pereira *et al.*, 2020, **Figure 5.6**) that has the participation of diverse stakeholders at its core.

Box 5 2

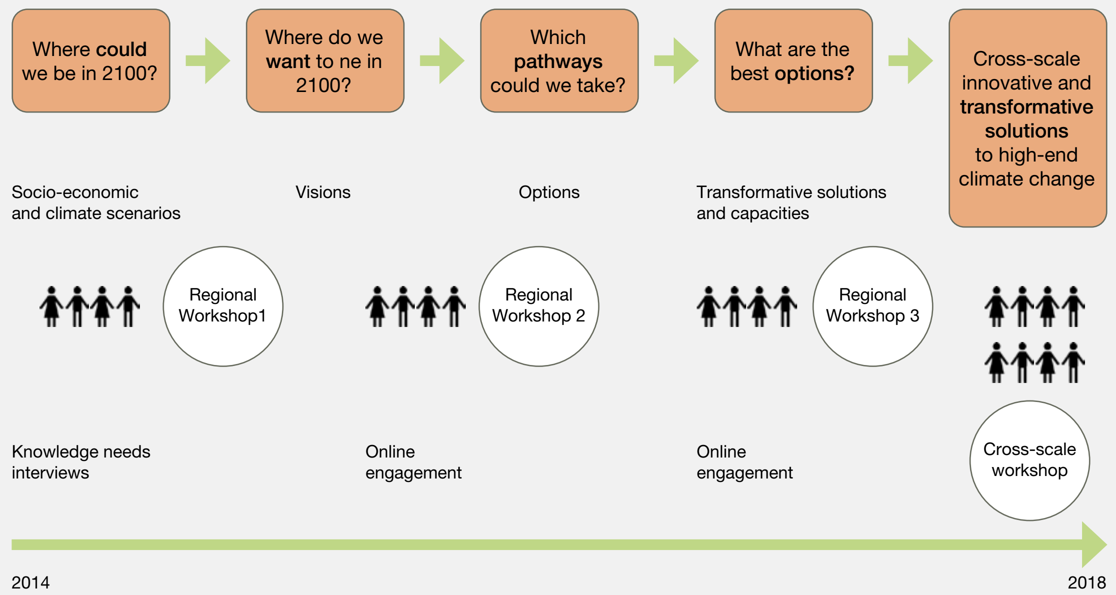


Figure 5 3 **Scenario development and type of stakeholder engagement undertaken in the European Union-funded projects CLIMSAVE and IMPRESSIONS.**

Source: Tabara *et al.*, (2018) under license CC BY-NC-ND 4.0.

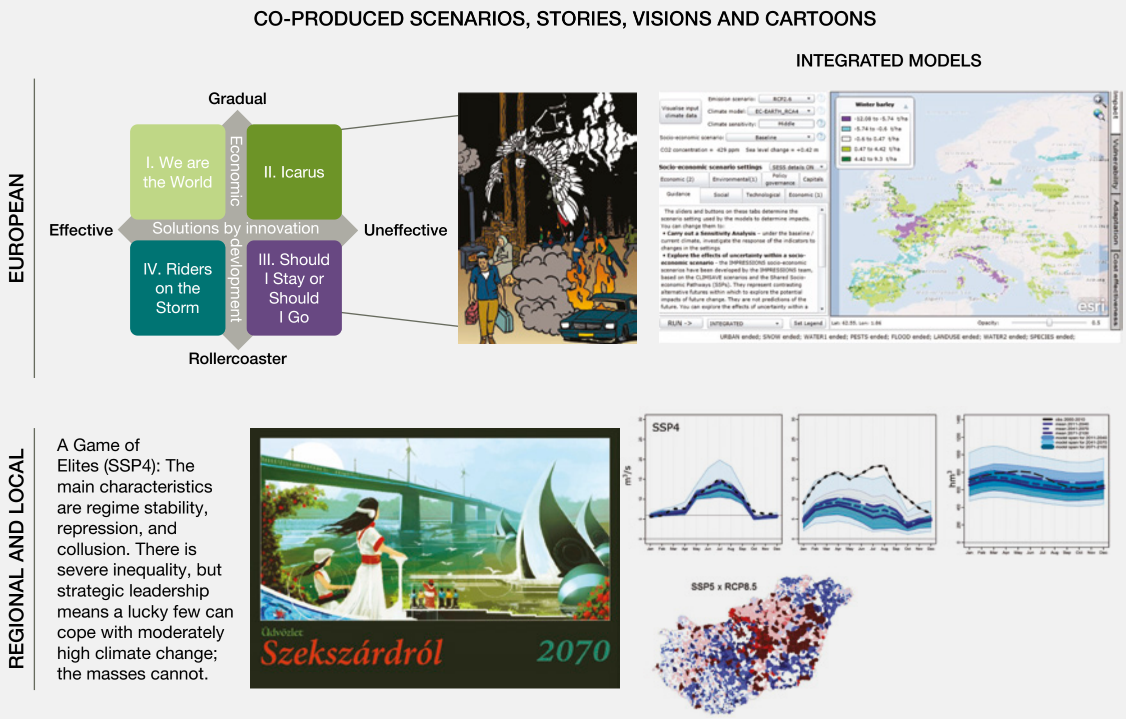


Figure 5 4 **Sequence of events, the types of scenarios and type of stakeholder engagement in the European Union-funded projects CLIMSAVE and IMPRESSIONS.**

Source: CLIMSAVE (http://www.climsave.eu), CLIMSAVE IAP (http://www.impressions-project.eu); illustration by © Talitha Dijkhuizen under license CC BY.

5.2.3 How scenarios might be used in decision-making under uncertain conditions

To summarize the previous sections, scenarios are an excellent tool to use when the system under study is complex and its future changes therefore uncertain. Scenarios come in many shapes and forms and can address fundamentally different questions that directly or indirectly speak to decision-makers. "What should happen?" is perhaps more often asked by decision-makers, and target-seeking or other intervention scenarios can help answering it. "What could happen?" seems to bear less direct relevance to decision-makers but is often an essential first step to map out the "uncertainty space", providing insights into changes beyond the control of the decision-maker, which will influence the solutions required. Scenarios can thus help to facilitate the process of identifying actions that need to be taken, given an uncertain future outlook that is continuously changing. A large diversity of concepts, methods and tools can assist this process. It is not a matter of wondering whether scenarios are good tools to use, but a matter of how scenarios might be best used in decision-making to help identify the actions that can be taken to move towards a better sustainability of the use of wild species.

5.3 ASSESSMENT METHODS USED IN THIS CHAPTER

5.3.1 Steps and processes for the assessment

The data used in this chapter were derived from both a systematic review of the literature and from expert knowledge. The literature review was used as a baseline that was then complemented by additional relevant papers that the review did not pick up. While the original search was conducted in November 2019, it was further updated in late 2020, in both cases using an expert-solicited search string on the Scopus and Web of Science databases.

Building on the IPBES global scenarios search string (IPBES, 2019), an expert solicitation method was used to further revise and fine-tune the search string specific to the assessment of the sustainable use of wild species, with the procedure as follows:

1. Search the literature using agreed search terms – aligned with the IPBES global scenarios search string;

2. Refine the search terms, based on the outcomes of Step 1;

3. Evaluate the search terms by checking whether known (existing and recommended) literature is found using them, and refine the search terms accordingly;

4. Identify key drivers that feature in the scenario literature found in 1) and 2) plus those provided by Chapter 4 of the IPBES assessment of the sustainable use of wild species;

5. Code scenarios according to keywords in a spreadsheet to create a uniform coding template;

6. Apply archetype scenarios to these key drivers;

7. Elaborate new archetypes based on the drivers of sustainable use;

8. Document plausible futures for key drivers of sustainable use.

The final search terms used in Steps 1-3 were:
plants, algae and fungi

Web of Science Search terms (Number of resulting bibliographies: 959 + 175):

(TS=(("Future impact*" OR "Future response*" OR "Future effect*" OR "scenario*" OR "vision*" OR "trajector*" OR "pathway*") AND ("use" OR "utilization" OR "utilisation" OR "contributions to people") NEAR/5 ("species" OR "nature" OR "biodiversity" OR "natural resource*" OR "ecosystem*" OR "ecological service*" OR "non-timber" OR "NTFP" OR "timber" OR "forestry" OR "wildlife" OR "fish*" OR "charcoal") NOT "land-use NOT "land use" NOT "nitrogen use" NOT "water use") AND SU=((Agriculture OR Environmental Sciences & Ecology OR Biodiversity & Conservation OR Fisheries OR Forestry OR Marine & Freshwater Biology OR Meteorology & Atmospheric Sciences OR Oceanography OR Acoustics OR Social Sciences Other Topics) NOT Biochemistry)) AND DOCUMENT TYPES: (Article OR Book OR Book Chapter OR Book Review OR Review). Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=2010-2019.

SCOPUS Search terms (Number of resulting bibliographies: 1378):

TITLE-ABS-KEY ((("future impact" * OR "future response" * OR "future effect" * OR "scenario" * OR "vision" *) AND ("species" OR "nature" OR "biodiversity" OR "natural resource" OR "ecosystem" OR "ecological service") W/5 ("use" OR "utilisation" OR "utilization" OR "contributions to people") AND NOT ("land use" OR "land-use" OR "nitrogen use" OR "water use"))) AND SUBJAREA (agri OR envi OR eart OR soci OR econ) AND PUBYEAR > 1999 AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "b")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "bk")) AND (EXCLUDE (SUBJAREA , "BIOC"))

The coding template in Step 5 was carried out to completion for the 2019 search, and for essential columns for the 2020 update. Classifying the material in this manner assisted with identifying relevant papers both for practices, and for the construction of archetypes (Step 7). The summary of the coding criteria is shown in **Table 5.2** and in **figures 5.5** and **5.6**.

After the search was completed and analyzed, additional papers were added for the purposes of the chapter and evaluation of each practice based on expert knowledge.

5.3.2 Incorporating the perspectives of indigenous peoples and local communities into the scenarios

In the systematic literature review, very few (six) publications were found that discussed scenarios and models from the perspective of indigenous peoples and local communities. The results were therefore supplemented with the dialogues conducted on the IPBES assessment of the sustainable use of wild species in May 2019 and October 2019 with indigenous peoples and local community representatives from Africa, Asia, Europe, Latin America, and North America, as well as submissions solicited by the IPBES technical support unit on indigenous and local knowledge. Input from consultations with organizations working with indigenous communities such as the ICCA consortium, the Non-timber forest products exchange programme, the Asian indigenous peoples pact etc. were included in the review.

Table 5 2 **Summary of the criteria used in coding the literature.**

Basic information	Methodological information	Analytical information
Year of publication	Key question/focus	Type of scenario
Type of paper (original; reviewer meta-analysis)	Importance or significance of paper	Driver of use
Inclusion of indigenous and local knowledge	Scale of analysis	Scenario archetype
Mention of the Aichi Biodiversity Targets from the Convention on Biological Diversity	Geographic area of study	Model name and type
Mention of Sustainable Development Goals	Main type of ecosystem	Nature's futures (impact on ecosystems)
	Main practice	Nature's futures (nature's contribution to people)
	Units of analysis	Nature's future (good quality of life)
	Purpose of use	
	Scale of use	
	Mode of use	

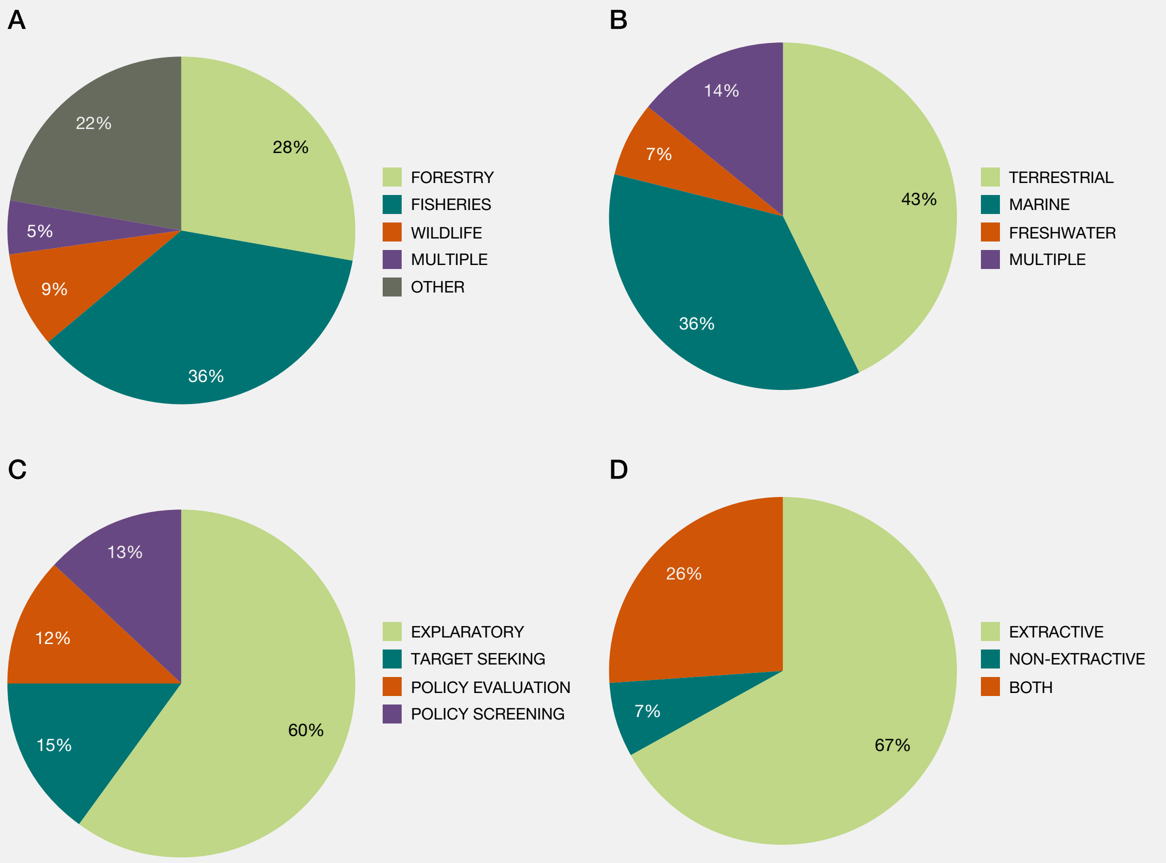


Figure 5 5 **Distribution of scenario studies from the literature search and coding, separated by practices and types.**

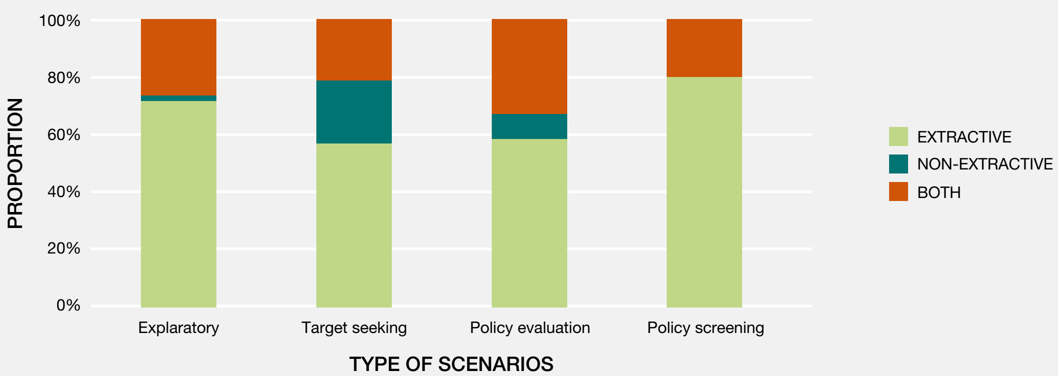


Figure 5 6 **Classification of scenario studies on the sustainable use of wild species from the systematic literature search and coding.**

Community plans were also consulted, as well as workshop reports from indigenous and local knowledge dialogues, which observed the principles of free, prior, and informed consent of indigenous and local community participants in the dialogues.

5.4 SCENARIOS BY PRACTICE

5.4.1 Introduction

In this section, scenario material from the literature search, supplemented with expert knowledge (see data management report at https://doi.org/10.5281/zenodo.6453277), is assessed by resource use practice, based on social, technological, economic, environmental, political (STEEP) categories (Reed *et al.*, 2016), including cultural, here through referred as STEEP+C. Crucially, it is important to recognize that for some practices (e.g., gathering), scenarios and projections are extremely limited and/or unavailable in the literature. In such circumstances, rather than leaving the sections empty, "scenario-based drivers" of sustainable use are explored instead; that is, studies of factors that could affect sustainable use when integrated into scenarios. These sections are then identified as knowledge gaps.

5.4.2 Fishing

5.4.2.1 Introduction

Fisheries contribute to food security with fish being a major source of animal protein for about 1 billion people worldwide (FAO, 2020b). Annual marine fisheries production has been relatively stagnant over the past 3 decades. In 2018, global catch totaled 84 million tons with about 73% of catches destined for human consumption and the remaining 27% for fishmeal and fish oil. Fisheries production is expected to stay at high levels, reaching about 96 million tonnes in 2030 (FAO, 2020b) and almost 100 by 2050 (United Nations Nutrition, 2021). The proportion of fish production destined for human consumption is projected to continue to grow, reaching 89 percent by 2030 (FAO, 2020b) and 92% in 2050 (United Nations Nutrition, 2021). Future patterns of demand for marine biological resources will be shaped by social, environmental and economic factors including stagnating capture fishery production, a growing population, increasing wealth (Garcia & Grainger, 2005; Garcia & Rosenberg, 2010; Guillen *et al.*, 2019), increasing aquaculture production and competition with wild capture fisheries for natural resources (Kristofersson & Anderson, 2006; Tacon & Metian, 2008, 2009, 2015), dietary preferences, and the impacts of climate change on existing and novel fisheries.

As well as providing a source of calories and protein, aquatic species provide many nutritional benefits to the human population. An assessment of the nutritional value of aquatic animal food-sources in comparison to terrestrial has shown that the top seven categories of aquatic food, including pelagic fishes, some shellfish, and salmonids are more nutritious than beef, lamb, goat, chicken or pork when averaging across the seven nutrients assessed (i.e., omega-3 long-chain polyunsaturated fatty acids, vitamins A and B12, calcium, iodine, iron and zinc) (Golden *et al.*, 2021). In addition to their contributions to global and local food security and nutrition, fisheries are economically and culturally important, providing social opportunities such as for recreation and contributing to cultural/traditional heritage.

Nevertheless, the development of modern fishing practices driven by advances in technology and growing demand, particularly with the advent of industrialized fishing practices, has led to the depletion of numerous individual fish stocks and a decline of the genetic diversity of harvested fish populations (Pinsky & Palumbi, 2014). According to the most recent Food and Agriculture Organization Report of the State of World Fisheries and Aquaculture (FAO, 2020b), in 2017 just under 66% of assessed fisheries remain within biologically sustainable levels, meaning that about 34% of fish stocks are overexploited. Annual marine fisheries production has been relatively stagnant over the past 3 decades. In 2018, global catch totaled 84 million tons with about 74% of catches destined for human consumption and the remaining 27% for fishmeal and fish-oil.

In the following sections, models and scenarios for the future of fisheries are explored, to examine what insight can be gained around the challenges and solutions that lie ahead. Projections of the future of fisheries at multiple scales are examined from social, technological, economic, environmental, political and cultural perspectives.

5.4.2.2 Social

Small-scale fisheries are prevalent in tropical and developing countries where dependence on fish for food and livelihoods is high. Fish consumption can address micronutrient (e.g., vitamin A, calcium and iron) deficiencies and improve human health by providing the dominant source of the omega-3 long-chain polyunsaturated fatty acids (Golden *et al.*, 2021). In some countries with inadequate nutrient intakes, fish catches exceed dietary requirements for populations within 100km of the coast, emphasizing the local and regional nutritional and income benefits from fishing (Hicks *et al.*, 2019). Climate change is broadly expected to reduce fish catch potential in many regions (e.g., Lotze *et al.*, 2019; Lam *et al.*, 2020; Tittensor *et al.*, 2021), disrupting food security and livelihoods. For instance, domestic demand for fish in the Solomon Islands is expected to exceed supply from domestic capture fisheries and aquaculture if no climate adaptation action is taken (FAO, 2020b). Expected decreases in global crop production after 2050 due to warmer temperatures will exacerbate food insecurity, and impose additional pressure on small-scale fisheries to fill the food gap with some countries facing a "double-jeopardy" of simultaneous impacts on both marine and terrestrial production (Rosenzweig *et al.*, 2014; Blanchard *et al.*, 2017). Demographic pressures such as high population growth both globally and in individual regions, conflicts in sea-use, and land-use practices that degrade marine habitats may aggravate climate impacts and amplify fisheries overexploitation, biodiversity loss and environmental degradation. Given the diversified nature of small-scale fisheries, fishers may be able to shift to exploit less climate-impacted fish species, but this is contingent on fishers' knowledge, gear and spatial use practices, and the status of alternate fish stocks (Bell *et al.*, 2018).

Projected demographic and social trends may also affect recreational fisheries. Arlinghaus *et al.*, 2015 argued that urbanization reduces individuals' exposure to traditional rural recreational activities like fishing, which may lead to reduced participation rates. However, human population growth also could maintain or even increase absolute levels of recreational fishing (Hunt *et al.*, 2017).

Future socio-economic conditions will also influence the fleet behavior of large-scale fisheries. The application of a scenario planning approach for the Indian Ocean tuna purse seine fishery identified some critical aspects of fleet dynamics to take into account for future management interventions, such as a switch in fishing practices, a reallocation of effort in space, or an exit from the fishery (Davies, 2015).

On the other hand, the emergence of social responsibility principles that adhere to a human rights-based approach to management in recent policy discourse could steer fisheries development along a fairer path. Such a path would enable vulnerable groups such as small-scale fishers and indigenous and local communities to continue accessing their resource base and the significant benefits that fisheries provide (Teh *et al.*, 2019).

Projections of both fish production and per capita consumption by 2050 under 3 different scenarios are indicated in **Table 5.3**. It is notable that production from aquaculture will substantially surpass capture fisheries in all scenarios. This might attract more interest in aquaculture than in fishing with implications in policy and management shifts (e.g., a diminishing importance of fisheries management with reduced investment which would severely affect sustainable use).

It is pertinent to note that projections indicate that increasing fish yield reduces land and water use by up to half, and optimizing gears reduces capture fishery emissions by more than half for some species groups, which highlights opportunities to improve environmental performance (Gephart *et al.*, 2021).With regard to demand and supply scenarios, projections showed that edible food from the sea could increase by 21-44 million tons by 2050, a 36–74% increase compared to current yields (Costello *et al.*, 2020).

The social benefits of small-scale fisheries (SSF) are broader than economic value alone. Small-scale fisheries are important for food and nutrition security, and globalization can force trade-offs between economic gains from distant markets and a reduction in nutritional benefits to local communities (Short *et al.*, 2021). Maintaining and expanding the diversity and flexibility of small-scale fisheries and addressing possible unintended consequences will be crucial. Characteristics such as gender but also class, education, and identity strongly affect the experiences of different small-scale fisheries participants (including women in post-harvest and trading), and future projections and scenarios could recognize that those characteristics have particular consequences for local communities (Short *et al.*, 2021).

Table 5 3 **Projection of production and per capita consumption of fish under 3 different scenarios.**

Source: United Nations Nutrition (2021). Abbreviations: mt: million tons.

	Business-as-usual	Low road	High road
Marine capture (mt)	85.4	65.8	95.5
Inlande capture (mt)	13.0	10.1	13.5
Total capture (mt)	**98.3**	**75.8**	**109.0**
Inland aquaculture (mt)	89.9	75.6	98.4
Marine aquaculture (mt)	50.1	45.3	62.0
Total aquaculture (mt)	**140.0**	**120.8**	**160.3**
Total production (mt)	238.3	196.7	269.3
Fish for direct food (mt)	217.4	180.5	248.2
Per capita apparent consumption (kg/year)	**22.3**	**18.5**	**25.5**

5.4.2.3 Technological

Technological advances have been identified as a key aspect affecting the economic viability of fisheries, and need to be incorporated into scenarios and storylines (Maury *et al.*, 2017). Broadly speaking, this includes technologies that lead to an increased ability to find fish and reduce bycatch or catch of undersized fish, improvements in gear design and processing capacity, and so forth. "Technological creep" has been identified as increasing catchability by around 2-4% per year (Palomares & Pauly, 2019), a trend which is likely to continue. However, future scenarios of the global tuna supply chain suggest a limitation of technical efficiency as a potential countermeasure to reduce the negative effects of increasing demand (Mullon *et al.*, 2017).

Technological advances to reduce environmental impacts may also play a role that could be captured in scenarios and projections. Regarding climate change, reducing fuel use represents the primary stressor improvement opportunity. In this sense, projections show that increasing stock biomass could reduce fuel use per tonne of fish landed, where a 13% catch increase with 56% of the effort corresponds to a 50% reduction in greenhouse gas emissions (Gephart *et al.*, 2021). Alternatively, prioritizing low-fuel gears within each fishery could reduce greenhouse gas emissions by 4–61%, depending on the species. In some cases, this could create co-benefits for biodiversity impacts. Another important strategy is to transition fishing fleets to low-emission technologies (Gephart *et al.*, 2021).

5.4.2.4 Economic

Fish is among the most traded food commodities, with about 38% of global fish production entering international trade in 2018 (an export value of 164 billion United States dollars), an annual growth rate of 8 percent in nominal terms from 1976 (FAO, 2020b). International trade expansion has been facilitated by globalization and rapid improvements in logistics (i.e., transportation, post-harvest handling, processing, preservation, packaging and storage). In addition, population and economic growth drive higher demand for seafood. The average global per capita consumption of marine fish (including shellfish) was approximately 8 kg per annum in 2016, and seafood demand is expected to rise in line with projected growth in national economies and spending power. However, the relationship between per capita fish consumption and gross domestic product per capita is significantly weaker for fish than for terrestrial meat (Naylor *et al.*, 2021).

The interlinkages between social and economic scenarios are considerable. According to Naylor *et al.* (2021), global fish demand is projected to almost double by mid-century, and will increase in all regions of the world. Asia will continue to lead in freshwater fish consumption and is projected to have the highest demand for fish overall in 2050, with China remaining the world's largest fish consumer and demand in India greatly increasing (FAO, 2020b). While the individual species consumed by different nations is likely to remain variable, increasing fish consumption is likely to benefit diets in terms of micronutrients (Golden *et al.*, 2021; Naylor *et al.*, 2021). Estimates show China, Europe, North America and South America consuming a diverse set of species in 2050, including crustaceans, demersal fish, and cephalopods, while Ghana and Peru will continue to dominate the consumption of small pelagic fish.

Projections of future food systems to 2030 suggest that high levels of growth in aquatic animal-source food production may decrease food prices by up to a quarter, resulting in increased consumption and potentially causing reductions in both consumptions of red and processed meats and micronutrient deficiencies (Golden *et al.*, 2021).

The operating cost of global fisheries was approximately 73 billion United States dollars in the mid-2000s (Lam, 2011). Fishing costs and cost structures vary widely by type of fishery and country. For example, global estimates of operating and total cost associated with catching a ton of fish using nets typical of small-scale coastal fisheries averaged 180 and 241 United States dollars respectively (2005 values), while costs of off-shore fishing for tuna using longlines were 2,604 and 2,903 United States dollars respectively (Lam, 2011). On the other hand, the financial subsidies given to industrial fleets – even to those causing overfishing – are key elements for future scenarios and are very much aligned with the need for a reduction of overcapacity. Indeed, the analysis of global marine fisheries subsidies revealed that almost 90% of capacity enhancing subsidies (22.2 billion United States dollars) are provided to large-scale industrialized fisheries, which impair the viability of small-scale fisheries (Schuhbauer *et al.*, 2017). In addition to impacts on the level of fishing, harmful subsidies result in increased greenhouse gas emissions (Machado *et al.*, 2021).

Another ongoing economic consideration is the blue economy initiatives that are making their mark on national and international agendas. In the context of fisheries, blue growth policies lean towards a rights-based approach to fisheries management, which aim to achieve economic efficiency in resource exploitation by defining exclusive ownership or access to fisheries resources. However, this conversion of public goods to private goods can potentially lead to inequalities in how stakeholders access and share ocean benefits. Furthermore, climate change may exacerbate disparities between fishing sectors. Simulations of Australian and New Zealand fisheries using the Intergovernmental Panel on Climate Change Special Report on Emissions A2 emissions scenario and moderate global economic growth revealed a relative increase in the value of large-scale commercial fisheries by 90%

but decreases in small-scale and recreational fisheries of between 30% and 50% (Fulton, 2011). Small-scale fishers often engage in alternative economic activities to supplement their income, but these too may become threatened by climate change, thereby limiting small-scale fishers' livelihood options and perpetuating pressure on fisheries.

Allocating a relatively small amount of time to fishing can make a notable contribution to livelihoods with modest investment and minimal exposure to risks. However fishing strategies such as damming channels, applying destructive fishing methods, or using fine mesh nets could threaten future fish stocks (Bailey & Sumaila, 2015; Short *et al.*, 2019; Sugden, & Punch, 2011; Sumaila *et al.*, 2021). Moreover, weak governance and erosion of cultural norms can produce social-ecological interactions that create more hardship for small-scale fisheries. Participatory modelling approaches with greater stakeholder involvement at the local level are useful for applications involving the sustainable governance of natural resources, including the management of fisheries (Daw *et al.*, 2015).

The economic impacts of climate change on marine fisheries are likely to be substantial, particularly given the ongoing shifting redistribution of fish stocks in response to climate change (Cheung *et al.*, 2010; Pinsky, Selden, & Kitchel, 2020). Projections of bio-economic impacts on wild-capture fisheries operating in European waters highlight the importance of future developments in fuel and fish price to the viability of these fisheries (Hamon *et al.*, 2021). In tropical fisheries, climate change impacts are expected to affect sustainable development of both local economies and communities in these regions and the maximum revenue potential is projected to decline by an average of 33% by the middle of 21st century under the Representative Concentration Pathway (RCP) 8.5 high-emissions scenario (Lam *et al.*, 2020). In the high seas, projections suggest that catches of 30 major straddling fish stocks could decline by 11% (Standard deviation ±7%) in the middle of the 21st century relative to 2000 under the Representative Concentration Pathway 8.5 (Cheung *et al.*, 2016). The projected annual losses under high relative to low emissions have been estimated at 278-901 million United States dollars by 2100 for sixteen major United States of America fisheries, based on predicted changes in thermal habitat (Moore *et al.*, 2021). However, complex networks of resource use may help to buffer the impacts of climate shocks (Fisher *et al.*, 2021).

Financial subsidies given to industrial fleets that promote overfishing could be eliminated (Sumaila *et al.*, 2021), while the global efforts to reduce illegal, unreported, and unregulated fishing in the high-seas will require investments in surveillance and international coordination. These economic factors will also shape future scenarios.

5.4.2.5 Environmental

Climate is a key factor in biophysical, chemical and ecological changes that regulate the distribution of fish species, their abundance, physical condition, and their use of habitat. In a future with high greenhouse gas emissions (Representative Concentration Pathway 8.5), marine species in the Atlantic and Pacific oceans are projected to generally shift poleward following the coastline, with many species shifting more than 1,000 km (Morley *et al.*, 2018). Fisheries management will have to be anticipatory rather than responsive to predicted climate impacts on marine ecosystems in order to ensure that use remains sustainable as ecosystems change. Indeed, climate change impacts might affect exploitation reference points and the associated level of catch (Travers-Trolet *et al.*, 2020). Yet uncertainties over adaptation and evolutionary processes in marine organisms and the temporal scale at which they occur, the influence of climate change on life history traits, impacts of extreme events (e.g., Babcock *et al.*, 2019) and morphological constraints that limit certain species' response to environmental change, may reduce the effectiveness of climate mitigating measures. For example, even in the absence of fishing, climate change has been projected to decrease marine animal biomass (which underlies wild capture fisheries) by around 5% for every one degree of warming (Lotze *et al.*, 2019), and historical modelling supports an impact of warming on stock biomass, though the impacts on individual species vary (Free *et al.*, 2019). However, effective management, including transboundary management, can help to offset these impacts (Gaines *et al.*, 2018), emphasizing the crucial importance of governance structures (Free *et al.*, 2019). Despite these projections many uncertainties abound. Surprises may also emerge as the future veers into environmental conditions that have not been previously experienced. For example, climatic changes may increase some species' susceptibility to disease and has the potential to cause unforeseen collapse in fisheries. Climate impacts on fisheries will be felt unevenly, with the tropics predicted to bear the brunt of losses in fish catch potential and fisheries revenues. On the other hand, climate change may open up the potential for new Arctic marine fisheries through increased access to fish stocks and increased catch potential (Burgass *et al.*, 2019).

To give a specific example of an important commercial taxon, most of the 14 distinct species of tuna from 4 main genera (*Auxis, Euthynnus, Katsuwonus* and *Thunnus*) are commercially harvested. Tuna have high economic value, representing about 9% of the internationally traded fish and fishery products in terms of value in 2018 (FAO, 2020b). Climate change will affect the phenology, physiology, biology and ecology of tuna and the ecosystems within which they exist, and the impacts will vary across species, life history stage and population/region. The outcomes of climate change on tuna will have knock-on effects on the distribution, composition and timing of tuna catches worldwide.

Rising water temperature impacts tuna survival by affecting habitat suitability for tuna species at different life stages. By 2100, climate change projections suggest that Western Central Pacific water temperatures will be too warm for *T. obesus* to spawn, while temperatures will be optimal in subtropical latitudes and the Eastern Tropical Pacific (Lehodey *et al.*, 2010). Rising temperatures will lead to an expansion of favorable habitat for adult skipjack tuna *(Katsuwonus pelamis)* throughout the tropics; however more recent estimates indicate a deterioration of tropical habitats and an improvement of habitat at higher latitudes. Nonetheless, there is agreement that rising temperatures will drive moderate increases in skipjack tuna catch and biomass until 2050. On the other hand, under current fishing pressure the population of albacore tuna *(Thunnus alalonga)* in the South Pacific is predicted to keep declining until 2035 when they may begin to stabilize. By 2080, new spawning grounds are predicted to emerge in the North Tasman Sea, helping reverse some of the decline (Lehodey, 2015).

Small pelagic fish are extremely abundant and support large capture fisheries for human consumption, aquaculture feed, and fish oil. Between 2005 and 2014, 16.2 million tons of small pelagic fishes were caught each year, representing 20% of the global catch of all fish species (FAO, 2018). Small pelagic fishes exhibit natural, multidecadal fluctuations in abundance (Soutar & Isaacs, 1969; Soutar *et al.*, 1974; Baumgartner., Soutar, and Ferreira-Bartrina, 1992; McClatchie *et al.*, 2017) that have led to rapid and dramatic fluctuations in industrial and small-scale fisheries (Chavez *et al.*, 2003). Due to the observed occurrence of these fluctuations prior to large-scale exploitation, these changes in small pelagic fish biomass are usually attributed to variations in oceanic climate rather than overexploitation. Small pelagic fishes typically respond to warming water temperatures by undergoing poleward distribution shifts (Beare *et al.*, 2004; Hsieh *et al.*, 2008; Nye *et al.*, 2009; Kanamori *et al.*, 2019). Projections of the spatial distribution of seven of the most harvested small pelagic fish species in Europe suggested that environmental suitability for most of these species may strongly decrease and local extinction are expected under the “business-as-usual” (Representative Concentration Pathway 8.5) climate change scenario (Schickele *et al.*, 2021). In addition to spatio-temporal distribution shifts, changes in the productivity of upwelling ecosystems and plankton species composition under global warming (Marinov *et al.*, 2010; Rykaczewski *et al.*, 2015; Rykaczewski & Dunne, 2010) are likely to impact fisheries for small pelagic species. Under a high emissions climate change scenario habitat suitability for sardines in the Gulf of California is projected to decline by as much as 95% (Petatán-Ramírez *et al.*, 2020). Further, ocean acidification has been associated with reduced survival of small pelagic fish eggs (Shen *et al.*, 2016), while habitat compression can potentially alter the fishes’ mortality rate by increasing spatial overlap between small pelagic species and their predators (Netburn & Anthony Koslow, 2015). In the Eastern Mediterranean Sea, future scenarios of marine resources showed that alien species invasions may have substantial impacts on fisheries and ecosystems in addition to sea warming (Corrales *et al.*, 2018).

Human use of small pelagic fishes is expected to increase in the future due to both greater demand for aquaculture feed and for fish-based protein due to population growth and projected declines in agricultural productivity under climate change (Checkley *et al.*, 2017). However, improved ecological forecasts that anticipate climate-related fluctuations in fish abundance may aid sustainable exploitation of small pelagic fishes in the future (Kaplan *et al.*, 2017; Tommasi *et al.*, 2017). Additionally, trends such as the shift away from fish protein to seaweed in aquaculture could improve sustainability (Emblemsvåg *et al.*, 2020).

Finally, coral reef fish are important for livelihoods and food security in many tropical countries. Climate change impacts on coral reef fishes are varied and difficult to predict, and are influenced by species’ sensitivity to increased temperatures and rising CO_2 levels as well as their capacity to adapt to environmental change (Pratchett *et al.*, 2017). Research on climate change effects on coral reef fishes has been limited to relatively few species. Recent studies on the sensitivity of commercially valuable coral grouper *(P. leopardus)* to climate change indicates that sustained increases in ocean temperature will negatively affect the performance and fitness of coral groupers (Pratchett *et al.*, 2017). This will potentially decrease catchability and availability of the fish, and ultimately lead to a drop in coral grouper catches in the tropics, where much of the world’s *Plectropomus* fisheries occur. Ecosystem models of Caribbean coral reefs show that deoxygenation from warming temperature and rising CO_2 levels will lead to a drop in fish biomass and produce negative economic consequences, with the sharpest biomass declines likely to be in some commercially important species such as sharks, snappers, lobsters, shrimps and bivalves (Alva-Basurto & Arias-González, 2014).

5.4.2.6 Political

Effective fisheries management, combined with broader marine spatial planning efforts and a wider recognition of sustainable small-scale fisheries to food security, will together play a key role in the sustainability of wild capture fisheries into the future. Managing all fisheries to maximize long-term food production would result in 2050 in an increase of 16% of total harvest (Costello *et al.*, 2020), requiring governance at local, national and inter-regional levels to ensure equity and sustainability.

Fisheries face constant change in their social, economic and governance spheres, and drivers in these systems may interact with, amplify, or overshadow climate impacts on fish stocks. Data scarcity undermines fisheries management, particularly for tropical fisheries, increasing their vulnerabilities.

Climate-driven impacts on ocean biomass are also likely to widen the socioeconomic equity gaps between nations (Boyce *et al.*, 2020), and interact with impacts on agricultural food sources (Blanchard *et al.*, 2017). These interactions compound the uncertainty associated with predicting how climate impacts will actually play out, particularly at the household and community level.

Enhanced fisheries management may be able to reduce the negative effects of climate change, or at least reduce the pace at which multiple climate drivers act upon the ocean and buy time for marine social-ecological systems to adapt (Gaines *et al.*, 2018). A better understanding of the relationship between people, their communities and the environment will be required to enhance adaptation planning for communities that are most dependent on climate-impacted fisheries. Transboundary management will also become crucial; geopolitical issues may arise from the redistribution of resources in and out of countries' jurisdictional areas. Sustainable management of fisheries that straddle the high seas may be able to mitigate climate impacts on fisheries within countries' exclusive economic zones, but the extent to which this generates benefits to society and biodiversity varies depending on the type of ocean governance that prevails. At the extreme, a full closure of the high seas to fishing would increase the resilience of many commercially important fish stocks to both climate change and fishing (Cheung *et al.*, 2016).

Scenarios of global governance, management, and economy (the "oceanic system pathways"), including geopolitics and corporate influence, have been developed for oceanic fisheries (Maury *et al.*, 2017), broadly mapping on to the shared socio-economic pathways. However, they have not yet been fully applied in making explicit projections around the sustainability of stocks into the future. A nationalistic outlook where fisheries are propped up by subsidies would cause fishing profits to fall in all countries, as would scenarios characterized by a fossil fueled lifestyle, while ecological productivity would be negatively affected in both scenarios. More stark inequalities may emerge under worsening climate change. High seas fisheries could become increasingly economically viable for high-income countries under high carbon emissions (Representative Concentration Pathway 8.5) and a rapid economic development model, but the increased fishing intensity could potentially deprive middle and low-income countries of fishing opportunities.

With multiple interactions taking place across spatial and temporal scales, outcomes will vary depending on whether they are viewed from ecological, economic, or social perspectives. Furthermore, an exploratory scenario approach based on socio-economic and political trends suggests that overfishing and climate change could increase the likelihood of fishery conflicts in the mid-century (Spijkers *et al.*, 2021).

Marine protected areas for biodiversity conservation can also provide benefits for food provisioning (e.g., Gill *et al.* (2019), but social equity and the systematic assessment of the marine protected areas local impacts are critical to success, as is the case for fisheries more generally (Cochrane, 2020). Expanding the global marine protected areas network to cover 28% of the ocean could increase food provisioning by 5.9 million tonnes, as well as provide carbon sequestration benefits in addition to their biodiversity conservation benefits (Sala *et al.*, 2021). As with fisheries, it is also important to build climate resilience into marine protected areas and to recognize the challenges that climate change poses to their effectiveness (Tittensor *et al.*, 2019). In addition to marine protected areas, "human-used areas" (Hilborn & Sinclair, 2021) and other spatial management such as Other Effective Area-based Conservation Measures which can define fishery closures or areas with fishery restrictions, can also contribute to sustainable use (e.g., Petza *et al.*, 2019). The focus for the future must be on learning how to merge enhanced human food security with the long-term persistence of biota needed for the stability of ecosystems.

Overall, improving fisheries management and effective harvest control rules imply a reduction of overfishing in addition to the rebuilding of depleted stocks. Management actions show cumulative benefits and a broad suite of management measures at local, national and international levels appears to be key to sustaining fish populations and food production (Melnychuk *et al.*, 2021). Among the most effective actions are rebuilding plans that rapidly lower fishing pressure towards target levels, enabling overfished populations to recover (Melnychuk *et al.*, 2021). Additionally, the ratification of international fishing agreements, and harvest control rules specifying how catch limits should vary with population biomass help to reduce overfishing and rebuild biomass. Notably, the cumulative benefits of management actions lead to stock status improvements and predicted long-term catch increases (Melnychuk *et al.*, 2021).

Regarding policies for securing sustainable small-scale fisheries, investments in alternative livelihoods have been insufficient and deeper structural changes, such as changes to property rights that explicitly recognize securing sustainable small-scale fisheries and their unique needs are required. Policies that recognize, rather than undermine, traditional and indigenous rights and access rights, but that may also support more inclusive relationships with state and/or corporate actors may be an important element (Short *et al.*, 2021).

5.4.2.7 Cultural

Localized subsistence and indigenous fisheries tend to fall outside the scale at which global climate assessments are conducted, yet subsistence fishing in many developing countries takes place in intertidal areas including shallow reef flats and mangroves that are threatened by climate change. A large proportion of subsistence catch is made up of bivalves, gastropods and other invertebrates; calcifying species that are expected to be negatively impacted by ocean acidification. The predicted loss for subsistence fishing is likely to reduce overall household well-being, including health and socio-cultural aspects. However, at a local scale, invertebrates in the Pacific islands are expected to experience only moderate decline from climate change, thus subsistence gleaning may become even more important in the face of reduced coral reef fish catch. On a global scale, many of the world's poorest countries are also the most heavily reliant on fish for protein, thus future climate-driven impacts are likely to result in additional socio-economic hardship in countries that are more reliant on fisheries but have limited capacity to adapt (Nash *et al.*, 2020).

In North America, climate impacts on indigenous fisheries are expected to be variable. In western Canada, warmer-water species such as Pacific sardines are projected to increase and provide an opportunity to develop or expand new commercial harvests. However, declines are expected in commercial herring and salmon stocks that contribute significantly to First Nations' fisheries revenues, as well as in species important for food and ceremonial purposes (Weatherdon, 2016). From a nutritional perspective, health may be negatively impacted as nutrient intake derived from traditional seafood consumption declines, and this nutrient deficit is not easily substituted by other food sources. In order to meet future challenges related to food security, livelihoods, cultural integrity and equity provided by small-scale fisheries, it becomes important to support the diversity of small-scale actors through appropriate policies (Short *et al.*, 2021). and the inclusion of cultural asset preservation and benefits in future scenarios.

5.4.2.8 Summary of plausible futures for fisheries

Fisheries provide significant socio-economic benefits by contributing to local and global food security and employment. Characterizing the plausible futures of fisheries is key to assessing fish provision, demand and consumption in the next decades under differing projections of population, income growth and climate change.

Global catches are projected to stay at high levels with fluctuations due to the El Nino phenomenon in South America (FAO, 2020b). A continued trend of industrial exploitation rates (business-as-usual) may likely increase the number of overfished stocks. This could be reversed by improving harvest control rules, technological advances on surveillance, and recovery plans in fisheries management. Projections indicate that an increase of fish yields could also reduce land and water use by a half.

Climate change is recognized as a major threat, which will affect multiple aspects of marine ecosystems (e.g., species distribution, biological invasions, species life history traits, etc.) and impact aquatic food systems from production to consumption worldwide. The effects of climate change on fisheries production systems are already visible in some regions of the world and are projected to have higher impacts on the food security of fisheries-dependent communities, which could put more pressure on small-scale and subsistence fisheries. Additional pressures due to demographic growth and conflicts in sea use may aggravate climate impacts and lead these communities to adapt their fishing behavior and affect socio-cultural aspects of their practices. Climate-driven impacts on species ranges and changes in fisheries productivity are expected to profoundly affect the benefits that wild capture fisheries provide to the human population, including aspects such as food provision, nutrients, social benefits, and livelihoods.

Climate change projections from high-emission scenarios from the Intergovernmental Panel on Climate Change show a decrease in 2050 global ocean biomass; the global catch is projected to be potentially reduced, and more substantially in tropical systems.

Therefore, evaluating governance, fishing practices and economic factors to mitigate changes on current production systems could help transition operations and build climate resilience. This is even more important as global fish demand is projected to almost double by mid-century. In order to meet challenges related to food security, livelihoods, cultural integrity and equity, it is important to support the diversity of small-scale fisheries. Projections of bio-economic impacts on wild-capture fisheries show they are likely to be substantial for many regions of the world (in particular the Global South) both for small- and large-scale fisheries. Furthermore, future socio-economic and political trends show that overfishing and climate change could increase the likelihood of fishery conflicts by the mid-century.

Overall, the consequences of climate impacts on fisheries will reverberate into different sectors of society worldwide with those dependent on fishing for food, livelihoods and cultural purposes most severely affected. Climate change will interact in complex ways with other drivers of change in fishing practices and intensity, at multiple scales and across jurisdictions. Hence the need for effective coastal and high seas fisheries management into the future to ensure the sustainability of wild capture fisheries and the resilience of fish stock.

Preventing overfishing and developing management strategies that are robust to environmentally driven changes in productivity are essential to maintain and rebuild the capacity for global wild-capture fisheries to supply food. Harvest control rules and marine protected areas are among the management approaches that may provide benefits, help to prevent overfishing, and rebuild depleted populations. Yet the poor current status of many stocks combined with potentially maladaptive responses to range shifts could reduce future global fisheries yields and profits. However, reforming fisheries in ways that jointly fix current inefficiencies, adapt to fisheries productivity changes, and proactively create effective transboundary institutions to provide continuity in management practices are key elements for sustaining wild capture species and food production.

5.4.3 Gathering

5.4.3.1 Introduction

Globally, thousands of species of algae, fungi and plants are gathered for food, medicine, construction and other uses. Gathering occurs in ecosystems from boreal forests (Uprety, 2012) to semi-arid savannahs (Schumann, 2010), and from high altitude environments (Pradhan & Badola, 2015; Rana *et al.*, 2020) to near shore environments (McDermid *et al.*, 2019). Humans have been gathering for millennia (Delgado-Lemus *et al.*, 2014; Uprety *et al.*, 2012) but a lack of baseline data, as well as the highly dispersed, low entry cost of this practice make it challenging to determine trends in the number of people who gather and the volumes of all algae, fungi and plants gathered at a global scale. However, although incomplete, data are available for some gathered materials that are commercially traded and a number of studies detail the social, including cultural and economic significance of gathering and uses of gathered materials in all regions of the world.

Overexploitation has been identified as an important driver of global plant extinctions (Kor *et al.*, 2021). However, a systematic review of 101 ecological studies addressing population-level consequences of gathering (Stanley *et al.*, 2012) found that in almost two-thirds (63.3%) of the cases examined, rates of extraction were or likely were sustainable while less than one-fifth (17.8%) were unsustainable. Few scenarios explicitly address the sustainability of gathering (but see Bondé *et al.*, 2020), although scenarios that project possible futures for forests and other ecosystems in which wild algae, fungi and plants occur are relevant, as are broader climate change scenarios. In contrast, several modelling methods are commonly applied to predict the future social and ecological sustainability of gathering. Many models designed to assess ecological sustainability focus on changes in habitat extent and distribution under climate change alone or in combination with other drivers (Ardestani & Ghahfarrokhi, 2021; Asase & Peterson, 2019; Chitale, Silwal, & Matin, 2018; Groner *et al.*, 2021; Jansen *et al.*, 2018; Munt *et al.*, 2016; Yadav *et al.*, 2021; del Castillo *et al.*, 2013). Harvest response models are another common approach (Lázaro-Zermeño *et al.*, 2011; Gaoue, Sack, & Ticktin, 2011; Tilahun *et al.*, 2011; Chamberlain *et al.*, 2013; Pérez-Negrón, Dávila, & Casas, 2014; Hernández-Barrios, Anten, & Martínez-Ramos, 2015; Kindscher, Martin, & Long, 2019), some examining the interactions of harvest techniques with other social and environmental factors (Groner *et al.*, 2021; Hart-Fredeluces, Ticktin, & Lake, 2021; Isaza *et al.*, 2016). Projections of economic sustainability generally emphasize the financial returns to gatherers and/or the state (Saha & Sundriyal, 2012; Stanley *et al.*, 2012; Van Andel *et al.*, 2015), with the contributions of subsistence uses to local livelihoods rarely incorporated into models.

5.4.3.2 Social

Millions of people worldwide participate in gathering algae, fungi and plants (Gaoue *et al.*, 2011). One systematic literature review estimates that 80% of people living in developing countries rely on wild algae, fungi and plants as the main source to meet their nutrition and health needs (de Mello *et al.*, 2020). Gathering of algae, fungi and plants make important contributions to food security (Campbell *et al.*, 2021; Pérez-Moreno *et al.*, 2021), but knowledge regarding their nutritional contributions is limited (Vinceti *et al.*, 2013). In some places, however, participation in gathering and reliance on gathered materials may be declining in response to urbanization and increased access to infrastructure and services (Gray *et al.*, 2015). Nevertheless, few scenarios and modelling studies explicitly include non-economic social factors in their parameters and this remains a knowledge gap regarding sustainable gathering.

5.4.3.3 Technological

Typically, the tools used in gathering are manual. Thus, the methods or techniques used to gather wild algae, fungi and plants and the knowledge underlying those methods constitute the most significant technological aspects of gathering. Key dimensions of gathering techniques include the places and times in which harvesting does or does not occur, the individual specimen and part or parts thereof to be harvested and volumes of material to be taken. Harvest impact studies and models make it clear that the sustainability of harvesting techniques are species- and context-specific. While there are cases in which empirical data and models indicate that the techniques in use have or could reduce populations of the gathered species (García *et al.*, 2016; Hernández-Barrios *et al.*, 2015; Isaza *et al.*, 2016) and may present a risk of localized extinctions (De Angeli *et al.*, 2021) there are also cases in which the outcomes of gathering can be neutral at the population level or may even enhance the vital rates (i.e., growth, reproductive success and survival) of individual plants and/or populations (Hart-Fredeluces *et al.*, 2021; Kurttila, Pukkala, & Miina, 2018; Varghese *et al.*, 2015).

Modelling corroborates empirical findings that gathering techniques tailored to the biology, ecology and life stage of the target species are more likely to be sustainable. For many species, size and age class play an important role in whether gathering is sustainable (Groner *et al.*, 2021; Isaza *et al.*, 2017; Jansen *et al.*, 2018). For example, models of methods used in the harvest of natal lily (*Clivia miniata* (Lindl.) Verschaff) in South Africa found that gathering individuals from all life stages would have a more negative effect on the overall population than would the harvest of only juvenile plants (Groner *et al.*, 2021). Likewise, the sustainability of gathering frequently is contingent upon the habitat in which it takes place (Klimas *et al.*, 2012; Isaza *et al.*, 2016). For example, modelled effects of the compatibility of gathering seeds from the medicinal tree *Carapas guianensis* Aubl. and logging it for timber in western Amazonia indicate that there is no sustainable harvest level for seeds and full-tree harvest in upland forests, while in occasionally flooded forest lands populations could sustain gathering of 10% of seeds and logging of all trees over 50 centimeters in diameter. Landscape ecology also exerts a strong influence over the sustainability of gathering practices. One example is the interaction of gathering leaves from the western North American species beargrass (*Xerophyllum tenax* (Pursh) Nutt.). Scenarios examining this interaction forecast that in a business-as-usual future, in which there is a greater than 50% chance of high-intensity fire, and a future in which all fires are excluded, beargrass populations would be significantly lower than in a future characterized by cultural burning of the landscape by indigenous peoples (Hart-Fredeluces *et al.*, 2021).

5.4.3.4 Economic

Gathering provides essential livelihood resources to millions of people worldwide on an ongoing basis (Gaoue *et al.*, 2011; Jansen *et al.*, 2018) through subsistence consumption of gathered materials (De Angeli *et al.*, 2021; Pérez-Moreno *et al.*, 2021; Saha & Sundriyal, 2012; Stanley *et al.*, 2012) and income derived from trade (Mumcu Kucuker & Baskent, 2015; Van Andel *et al.*, 2015; Walsh & Douglas, 2011). In addition, gathering and gathered materials are important safety nets in times of environmental and economic shocks (de Mello *et al.*, 2020). Both subsistence uses of wild algae, fungi and plants and trade in them have particular importance for low-income and marginalized peoples (Pérez-Moreno *et al.*, 2021), although gathered materials are used by households across the economic spectrum. Subsistence use of and trade in gathered materials is fundamental to the lives and livelihoods of indigenous peoples (Isaza *et al.*, 2016, 2017) and local communities (Papageorgiou *et al.*, 2020) and a source of empowerment for women (Pérez-Moreno *et al.*, 2021).

A subset of the thousands of species gathered worldwide are commercially traded, with fewer still entering large-scale commodity markets. Most modelling and scenario development focuses on commercially traded species. In the case of wild algae, fungi and plants that enter large-scale commercial markets, gatherers can face the dilemma of maximizing harvest for short-term income, eventually reducing populations of the target species below commercially viable levels, or gathering lower volumes of material to sustain species populations and ensure income through time (Hernández-Barrios *et al.*, 2015). This dilemma may be particularly acute where the price per unit of raw gathered material is low and gatherers must increase harvest volumes to meet their economic needs or goals (de Mello *et al.*, 2020). Further, a review of 87 cases of hunting and gathering in developing countries found that, together with high species resilience, low gross domestic product per capita and high poverty ratios were strong predictors of unsustainable outcomes (Leao *et al.*, 2017). Over the long term unsustainable gathering adversely affects the livelihoods and well-being of local peoples (Vallejo *et al.*, 2014).

Modelling studies suggest a number of strategies to enhance the sustainability of gathering, with a focus on commercially traded species. Agroforestry may increase production to meet demand and decrease pressure on wild populations, while fair trade schemes may help to ensure equitable sharing of benefits with gatherers (Bondé *et al.*, 2020; Pérez-Negrón *et al.*, 2014). Some models indicate that multiple-use forest management can increase economic returns for forest owners and identify the optimal mix of logging and gathering under current and future conditions (Kurttila *et al.*, 2018; Miina *et al.*, 2020; Mumcu Kucuker & Baskent, 2015). Managing forests for both logging and gathering may enhance populations of gathered species. Where income from commercially traded wild fungi or plants becomes a priority for forest owners and forest managers, there is likely to be an increased emphasis on controlling access to such species.

5.4.3.5 Environmental

Scenarios and models, as well as empirical data, indicate that the future sustainability of gathering will be a function of interacting gathering techniques, environmental conditions and anthropogenic and biophysical drivers, including climate change (del Castillo *et al.*, 2013; Hart-Fredeluces *et al.*, 2021; Mandle *et al.*, 2015). These factors may interact in additive, synergistic or antagonistic ways (Groner *et al.*, 2021), producing species-, habitat- and site-specific outcomes for the sustainability of gathering. As a result, gathering regimes that are sustainable for one species may not be for another. Similarly, gathering techniques that are sustainable for a species in one location may not be so in a place where environmental conditions and drivers are significantly different.

As previously noted, species biology (e.g., growth rate, reproductive strategy and, sometimes, population density), plays an important role in their response to gathering (De Angeli *et al.*, 2021; Isaza *et al.*, 2016; Papageorgiou *et al.*, 2020; Walsh & Douglas, 2011; Yadav *et al.*, 2021), as does heterogeneity in individual specimens' responses to gathering given characteristics such as size and age (Jansen *et al.*, 2018). Landscape ecology also plays a determinative role, with habitat conditions such as topography and hydrology strongly influencing the outcomes of gathering (Benítez-Badillo *et al.*, 2018; Isaza *et al.*, 2016, 2017; Mumcu Kucuker & Baskent, 2015; Pradhan & Badola, 2015; Varghese *et al.*, 2015). Land-use and land-cover change is expected to accelerate, along with its adverse effects on the sustainability of gathering. Among the causes of land-uses and land-cover changes identified in scenarios and models as having significant impact on the sustainability of gathering worldwide are agriculture (Hertel & de Lima, 2020) and chemical runoff from it (Papageorgiou *et al.*, 2020), grazing (Benítez-Badillo *et al.*, 2018; Lima *et al.*, 2020; Mandle *et al.*, 2015; Walsh & Douglas, 2011) and changes in forest structure due to logging (Benítez-Badillo *et al.*, 2018; del Castillo *et al.*, 2013). Some land-cover changes and landscape management systems have been identified as enhancing the sustainability of gathering of particular species. For example, fungal biodiversity in Mediterranean scrublands is increased by carefully timed treatments including controlled burning and clearance of vegetation (Hernández-Rodríguez *et al.*, 2015), while forest fragmentation has increased populations of the epiphytic bromeliad *Catopsis compacta* Mez. in Mexico by opening up the canopy and increasing the area of forest perimeter (del Castillo *et al.*, 2013).

Similar patterns hold true for macrofungi gathered for food, medicine and other purposes. Mycorrhizal fungi associated with boreal pine forests are less adapted to high-intensity wildfires than are those in Mediterranean pine forests (Franco-Manchón *et al.*, 2019). In some cases, silvicultural prescriptions can increase fruiting by edible wild fungi, although the degree of this effect depends on the extent of thinning of the forest canopy and site hydrology and temperature (Miina *et al.*, 2020; Herrero *et al.*, 2019; Kurttila *et al.*, 2018; de-Miguel *et al.*, 2014).

Climate change will affect most of the variables that will determine the sustainability of gathering in the future. Many studies have modelled the probable occurrence of suitable habitats for individual species or taxa of gathered species under climate change scenarios (Heubes *et al.*, 2012; Miina *et al.*, 2020; Rana *et al.*, 2020; Sinasson *et al.*, 2021), as well as the effects of potential changes in precipitation and/or temperature (Ardestani & Ghahfarrokhi, 2021; Kumar *et al.*, 2021; Yadav *et al.*, 2021). Results suggest that some species will benefit from expanded distribution (Chitale *et al.*, 2018; Yadav *et al.*, 2021), the distribution of other species can be expected to decrease (Ardestani & Ghahfarrokhi, 2021; Chitale *et al.*, 2018; Uprety *et al.*, 2012; Yadav *et al.*, 2021), while some will remain largely stable (Asase & Peterson, 2019). A shift in range to higher latitudes and altitudes is expected for some species (Ardestani & Ghahfarrokhi, 2021).

Climate change may also affect the use of fire as a landscape management tool, as well as the frequency and severity of wildfires, which are expected to increase, with attendant effects on populations of gathered species (Franco-Manchón *et al.*, 2019; Hart-Fredeluces *et al.*, 2021; Sinasson *et al.*, 2021; Varghese *et al.*, 2015; Walsh & Douglas, 2011). However, different modelling approaches may produce divergent results about the impacts of fire on specific species (Klimas *et al.*, 2017). Models further suggest that outcomes of fire are a function of interactions with other factors (Mandle *et al.*, 2015).

5.4.3.6 Political

Although no model or scenario that explicitly addresses the outcomes of policies and governance for the sustainability of gathering was identified, many have clear policy implications. Models and scenarios help identify needs and opportunities for policy to support the social and ecological sustainability of gathering. The likelihood of shifting ranges for gathered species (Ardestani & Ghahfarrokhi, 2021; Sinasson *et al.*, 2021) makes it clear that existing governance regimes such as protected areas may no longer encompass important populations. Similarly, some species may migrate outside the territories of indigenous peoples and local communities, depriving them of important livelihood and cultural resources. Policies that support the contributions of gathering to food security and community well-being will benefit both people and conservation (Campbell *et al.*, 2021; Kor *et al.*, 2021). The results of several models also highlight current and likely future mismatches between regulations and other measures necessary to ensure sustainable gathering (de Mello *et al.*, 2020; Hernández-Barrios *et al.*, 2015), while assisting in the identification of locations where harvest regulations and monitoring can be especially effective (Franco-Maass *et al.*, 2016), as well as species that would benefit from strengthened legal and institutional frameworks (Garcia-Barreda *et al.*, 2018) and flexible management policies and plans tailored to species and context (Delgado-Lemus *et al.*, 2014; Franco-Maass *et al.*, 2016; Garcia-Barreda *et al.*, 2018; Kor *et al.*, 2021).

5.4.3.7 Cultural

Gathering has particular importance in the culture, myths, identity and spiritual practices of communities throughout the world including, but not exclusively, indigenous peoples. Notwithstanding this importance, less than half of studies examined in a systematic review of the literature on the social-ecological sustainability of non-timber forest products mention cultural dimensions of gathering (de Mello *et al.*, 2020) although it is a common focus of research in the fields of ethnobotany (Balick & Cox, 2020) and biocultural diversity (Baumflek *et al.*, 2021; Kassam, 2010). While not explicitly included in the parameters of scenarios and models relevant to gathering, modelling studies frequently make mention of cultural uses of gathered materials. Examples include use of the leaves from the cycad *Dioon merolae* (De Luca & Sabato; Nance 2009) for ceremonial purposes by indigenous and mestizo communities in Chiapas, Mexico (Lázaro-Zermeño *et al.*, 2011) and ceremonial uses of ectomycorrhizal fungi (Pérez-Moreno *et al.*, 2021), as well as tensions between commercial and cultural values (Walsh & Douglas, 2011). The effects of commercialization on the cultural values and ceremonial uses of gathered species has received little attention and remains an important knowledge gap.

As the case of beargrass above illustrates (Hart-Fredeluces *et al.*, 2021), the knowledge base on which gatherers draw can also exert a fundamental influence on the sustainability of their practices. Indigenous and local knowledge can, and often does, provide a foundation for sustainable gathering (Hart-Fredeluces *et al.*, 2021; Kor *et al.*, 2021; Papageorgiou *et al.*, 2020; Saha & Sundriyal, 2012; Walsh & Douglas, 2011). In western Australia, research shows that the ecological and economic future of small-scale trade in bush food will depend on intergenerational transfer of Aboriginal knowledge and skills (Walsh & Douglas, 2011). However, in many places indigenous and local knowledge has been subject to erosion (Uprety *et al.*, 2012). A study on the Greek island of Lemnos notes that new gatherers with limited knowledge and experience may diminish the future sustainability of gathering wild medicinal plants there (Papageorgiou *et al.*, 2020). Partnerships between indigenous peoples and local communities and scientists can also produce knowledge that will help sustain gathering in novel and changing landscapes (de Mello *et al.*, 2020).

5.4.3.8 Summary of possible futures for gathering

The gathering scenarios and modelling literature suggests that four interacting factors will determine the sustainability of gathering: (i) species biology and ecology (Gaoue *et al.*, 2011; Herrero-Jáuregui *et al.*, 2011; Jansen *et al.*, 2018; C. M. Klimas *et al.*, 2012), (ii) land-use/land-cover and land-use/land-cover change (Ardestani & Ghahfarrokhi, 2021; Groner *et al.*, 2021; Heubes *et al.*, 2012), (iii) climate change (Ardestani & Ghahfarrokhi, 2021; Groner *et al.*, 2021; Herrero *et al.*, 2019; Heubes *et al.*, 2012; Kumar *et al.*, 2021; Yadav *et al.*, 2021; Munt *et al.*, 2016; Herrero *et al.*, 2019; Karavani *et al.*, 2018) and (iv) gathering technique (del Castillo *et al.*, 2013; García *et al.*, 2016; Hart-Fredeluces *et al.*, 2021; Isaza *et al.*, 2016, 2017; Jansen *et al.*, 2018; Mandle *et al.*, 2015; Vallejo *et al.*, 2014). These factors can interact additively, antagonistically or synergistically (del Castillo *et al.*, 2013; Groner *et al.*, 2021; Hart-Fredeluces *et al.*, 2021; Mandle *et al.*, 2015), producing outcomes that are highly specific by species and social and geographic location.

While general trends at global and regional scales can be identified, policy and practice pathways will lead most surely toward sustainable gathering in the future when they are context-specific and build in the capacity for adaptation to changing conditions (Hart-Fredeluces *et al.*, 2021; Sinasson *et al.*, 2021). Localized monitoring and assessment can supply appropriately scaled information (Papageorgiou *et al.*, 2020; Sinasson *et al.*, 2021) to support adaptation. Similarly, local-scale scenarios and models can inform policy and practice about possible futures for gathering (Bondé *et al.*, 2020) and will be particularly valuable when they are transparent about the uncertainties built into the modelling process itself (Klimas *et al.*, 2017), validated with field studies, and when they take into account the interacting effects of species biology and ecology, land-use/land-cover change, the effects of climate change and gathering techniques (Groner *et al.*, 2021).

In the case of gathering that feeds commercial markets, agroforestry and cultivation may relieve pressure on wild populations of target species (Bondé *et al.*, 2020; Rana *et al.*, 2020; Pérez-Negrón *et al.*, 2014; Gaoue *et al.*, 2011) but can also shift the distribution of benefits from gathering. Fair trade schemes may help to ensure that local communities benefit from commerce in local resources and are invested in its long-term sustainability (Bondé *et al.*, 2020; Pérez-Negrón *et al.*, 2014).

Protecting habitat for gathered species will be especially important for the long-term sustainability of gathering (Rist *et al.*, 2010; Klauberg *et al.*, 2014; García *et al.*, 2016; Isaza *et al.*, 2016; Munt *et al.*, 2016; Isaza *et al.*, 2017; Bondé *et al.*, 2020; Sinasson *et al.*, 2021) with land-use and land-cover change likely to represent a particular threat (Groner *et al.*, 2021). In some cases, population- and landscape-scale management will help to create and/or maintain such habitat (de-Miguel *et al.*, 2014; Hart-Fredeluces *et al.*, 2021; Herrero *et al.*, 2019). Measures to support, promote and enforce sustainable gathering techniques will also be essential (Groner *et al.*, 2021; Hart-Fredeluces *et al.*, 2021; Isaza *et al.*, 2016, 2017; Jansen *et al.*, 2018; Klimas *et al.*, 2012) but, again, must be tailored to the context within which the gathering occurs. Indigenous and local knowledge can serve as a source for design and implementation of sustainable landscape management and gathering techniques (Hart-Fredeluces *et al.*, 2021; Papageorgiou *et al.*, 2020; Walsh & Douglas, 2011) and offers valuable input to modelling processes where principles of free, prior and informed consent are observed. However, in many places indigenous and local knowledge is being eroded and sustainable gathering will require efforts on the part of communities and policymakers to ensure that youth and future generations have the opportunity to acquire and use such knowledge (Walsh & Douglas, 2011). Participatory research (Varghese *et al.*, 2015) and bringing science and indigenous and local knowledge into conversation with each other will also advance design and implementation of policies to address the challenges of sustainable gathering in the novel ecologies emerging from climate change and other local and global changes (Hart-Fredeluces *et al.*, 2021).

5.4.4 Terrestrial animal harvesting

5.4.4.1 Introduction

In this present assessment, terrestrial animal harvesting is defined as the removal from their habitat of animals (vertebrates and invertebrates) that spend some or all of their life cycle in terrestrial environments. Terrestrial animal harvesting often results in the death of the animal, but it also includes temporary or permanent capture of live animals from their habitat without intended mortality, such as for pet trade, falconry or green hunting. This chapter focuses on hunting, i.e., the lethal category of terrestrial animal harvesting which leads to the killing of the animal.

It is important to add a few notes in terms of approach at the start of this section. There were, in fact, very few studies addressing scenarios for hunting in the literature search database; these were complemented with literature derived from expert sources. Of those, almost none could really be considered as “scenario” papers in the strict sense. The studies evaluated did, amongst other foci, consider some drivers of changes in hunting practice, but usually did not engage in future projections, with a few exceptions. Often studies would have a generic discussion at the end considering, in broad terms, what the future might be for hunting in that specific case/area. This is, of course, very different to a rigorous consideration of plausible futures, and means that the evaluation of scenarios generally is limited. In addition, the majority of studies consider legislation, or the legal framework as a key driver of changes in hunting practice (even where this is not the key focus of the paper). Although many papers (including those focused on here) discuss hunting with respect to local sustainability, there is also a need to explore the drivers and sustainability of the international trade in wild species (Harfoot *et al.*, 2018; ‘t Sas-Rolfes *et al.*, 2019; Tittensor *et al.*, 2020), and in particular scenarios of the future of the legal and illegal trade in wild species. Finally, Booth *et al.*, (2021) highlight the risk of food insecurity from wild meat prohibitions, with 15 countries already identified as being food insecure that would be affected. Thus, while COVID-19 has given rise to calls for increased regulation of and/or bans of wild meat trade and consumption to protect both public health and biodiversity (see, for example, the discussion in **Box 5.6**), a complete removal of wild meat from diets and markets would severely impact both food security and biodiversity (Booth, Clark, *et al.*, 2021).

5.4.4.2 Social

Illegal hunting can be driven by a social context (for example, poverty driving illegal poaching in parts of southern Africa), with the recognition that this applies at certain scales and in combination with other drivers **(Box 5.3)**. For example, the actual act of poaching may be socially driven, but the market for products are an economic driver. In the case of large carnivore species such as tigers, Carter *et al.* (2019) consider overhunting and illegal hunting as one driver of changes in tiger space use and population persistence, referring in turn to drivers of such change in hunting practice as legal control. However, this study is far more about hunting as one of a range of drivers of species change itself rather than about which drivers affect hunting practice. Travers *et al.* (2019) used an unmatched count technique to identify the drivers of illegal hunting in communities adjacent to Ugandan national parks. They discovered that poverty, victims of human-wild species conflict, and exclusion from revenue of nature-based tourism often triggered poaching within the parks. They also explained that intervention programs that mitigated the identified drivers would reduce illegal hunting. However, there is limited evidence of threats of imprisonment or fines changing hunter behavior (Dobson *et al.*, 2019).

5.4.4.3 Technological

Only two of the studies under consideration indirectly considered technological changes as a driver of changes in hunting practice. In their approach to the use of hunting dogs (highly detailed, but not, as in the case of many other papers, a “scenario” paper), Koster & Noss (2013) show how the intensification of hunting by dogs (a technological change) is largely driven by increases in population (in certain areas) and changing cultural and market demands (in others). Such intensification has implications for the conservation of hunted species, and, if a future trend, conservation of hunted species in those areas would be increasingly challenged.

Easily available and cheap light emitting diode (LED) flashlight technology enables hunters to pursue game more intensively at night than before, affecting killing rate and the number of kills made. In Brazil, these findings were supported by harvest data. This poses a major threat to wild species (Bowler *et al.*, 2020). Likewise, the availability of motorized snowmobiles makes it easier for Alaskan Native American hunters to access hunting areas (Huntington *et al.*, 2017), reducing the need for overnight stays and camping, thus changing the temporal and spatial nature of the hunting practice. Such technological changes in how driving affects hunting practice interact with, for example, significant ongoing changes in the physical environment, including major changes in the sea ice. Other technologies have increased the effectiveness of hunting and trapping, including (but not limited to) the use of airboats, surface-drive boats and further use of outboard motor boats. Detection of hunted animals is further supported by the increased affordability of technology such as game cameras and unmanned aerial vehicles.

In terms of hunting methods, snaring is almost universal in the tropics, whereas firearms require more of a financial and time investment (Dobson *et al.*, 2019). Thus technology use depends on capital and time availability and physical capability, as well as social and cultural constraints (Dobson *et al.*, 2019). Technologies and their evolution in temperate regions were mentioned above.

Wild species farming has been considered a conservation strategy that can help reduce harvesting pressure on some wild populations (Tensen, 2016). Broadly speaking, domestication and farming of wild animals of commercial value and high demand can also help to reduce the pressure on wild stocks (Nogueira & Nogueira-Filho, 2011; Tensen, 2016), although it may affect land-use pressures, and in some parts of the world the options are limited (Secretariat of the Convention on Biological Diversity, 2011). Expanding wild species production cannot occur at the expense of other species, biodiversity or ecosystem services (Gortázar *et al.*,2006; Mustin *et al.*, 2018). Other concerns regarding farming of wild species have been raised elsewhere (e.g., Tensen, 2016 considers the particular conditions under which wild species farming may actually benefit species conservation). Insect farming is a potentially viable option to reduce dependence on wild meat and unsustainable hunting of wild animals for protein. Van Huis & Oonincx (2017), discuss the potential of small-scale and locally managed edible insect farming as well as industrial production.

5.4.4.4 Economic

As discussed above, studies (again, not "scenario" studies *per se*) show how changing market demand may drive, in certain areas, intensification of hunting using dogs (Koster & Noss, 2013; Huntington *et al.*, 2017). Poverty, unemployment, economic hardship and poor law enforcement are important motivators for poaching, especially when risks are low due to e.g., corruption and wages. Increased per capita incomes in East Asia are an important factor influencing consumer demand for wild species parts and products. Huntington *et al.* (2017) observed that reduced demand for wild species products

Box 5 3 **Demand for wild meat: feedbacks between global and local drivers.**

Many rural communities rely on wild meat hunting for their income and subsistence needs. However, as population levels and urbanization rise, hunting can become unsustainable, due to a higher urban market demand driving the commercial trade of wild meat. This, in turn, is likely to impact the long-term food security of communities, as well as wild species conservation projects. In the greater Serengeti ecosystem area, the influence of available meat substitutes (chicken, lamb, beef, fish and goat), socio-economic aspects and location all played a major role in the price as well as demand for wild meat (Walelign *et al.*, 2019). An increase in the price of wild meat led to a decrease in the demand. The authors argue that it would thus be better to target poachers to increase their costs, rather than decrease the costs of substitutes. To reduce demand, policy interventions could be implemented that not only address a long-lasting conservation culture, but that also provide alternative means for income generation for hunters/poachers. The demand for wild meat in the future is, however, likely to change due to changes in cultural norms as well as preferences, whereby the younger "westernized" generation has a lower consumption of wild meat (Luiselli *et al.*, 2019).

Wild animals and the trade of their meat have a large impact on many countries' economies, as well as ecological impacts. Since the recent COVID-19 outbreak, the trade in wild meat has been under increased scrutiny due to the risks associated with an increasing urban population and decreasing natural habitats, which in turn can allow for rapid transmission of zoonotic diseases to humans. The wild meat trade has significant influence not only in terms of wild species impacts, but also on the livelihoods of those who rely on the trade. Many factors thus play a role in the supply and demand for wild meat (McNamara *et al.*, 2020). For example, a country's commitment to reduce the illegal trade in wild species and a ban of terrestrial wild animal consumption will have significant impacts on those relying on that trade for income, as well as on the risk of emergence of zoonotic disease. Legalized markets could, in theory, allow for more regulations and strict protocols to be implemented, thus allowing better law enforcement and more control in order to reduce the spread of zoonotic diseases.

(such as animal skins) has changed hunting practice (amongst other drivers of change) in their study sites in northern and western Alaska.

5.4.4.5 Environmental

Few of the studies considered specifically environmental factors as a driver of changes in hunting practice. This is a clear gap. A study in northern and western Alaska, interviews with 110 individuals in 14 Alaska native communities point to a rapidly changing marine environment not only affecting the survival rate of mammals but also rendering sea-ice unsafe to travel on, thus making hunting more dangerous (Huntington *et al.*, 2017). Further, sea-ice changes modify the seasonal nature of hunting (there are, thus, both spatial and temporal changes). Changes in the physical environment are both expected to be ongoing and to interact with changing drivers in the social and technological dimensions. It is important to note that this study is not, strictly, a scenario-based analysis. Rather, climate projections are referred to as indications that currently observed trends (climatic trends influencing hunting practice and, thus sustainable use) are likely to continue.

5.4.4.6 Political

Legislation appears to be a key driver for changes in hunting practice. For example, Antunes *et al.* (2019) found that subsistence hunting in Amazonia has an unclear and controversial legal status, thus creating challenges in establishing consistent sustainable hunting management practices (changes have occurred since the 1967 legislation making hunting of all wild animals illegal). A range of studies examine legislative changes as drivers of changes in hunting practice, including changes from a total ban on hunting (for example, in Brazil) to fragmented or confusing legislative frameworks (for example, in the case of Brazil, although this certainly applies elsewhere). In Brazil, Nascimento *et al.* (2016) found that the hunting of other species posed an indirect threat to the species on which they focused. In this case, changes in the practice of hunting of other species were largely driven by changes in public policies.

Travers *et al.* (2017) used the unmatched count technique to identify the drivers of illegal hunting in communities adjacent to Murchison Falls and Queen Elizabeth National Parks in Uganda. Based on the identified drivers, they compiled a list of intervention options to reduce unsustainable and illegal hunting. The authors thereafter conducted surveys with stakeholders, including the local communities, to determine their preference for the intervention options and predict how they would respond to their implementation. The findings showed that livelihood was the main driver of wild species-related crime in both national parks, while the respondents preferred management practices that mitigated human-wild species conflict, and wild species-friendly enterprises in which local communities sign agreements to stop wild species crime in turn for average earnings of 500,000 shillings per year per household. The authors also noted that wild species laws and implementation such as arrests, imprisonment, and fines are not effective in deterring wild species-related crimes. The study observes, however, that protectionist policies are having some influence in these areas (at both Murchison Falls and Queen Elizabeth National Parks). Aerial surveys some years ago show for both parks increasing or stable populations of nearly all surveyed species (Wanyama *et al.*, 2014).

Bollig & Schwieger (2014) consider local institutional change as a key driver of changes in natural resource management in Namibia, including hunting practices (here, commercial hunting is allowed as a permitted land-use under conservancies established by communities). As local institutions such as conservancies evolve, together with challenges in their establishment, control over hunting practices (amongst other land-uses) affects such practices. This includes, for example, issues of monitoring and sanctions. This trend is likely to continue in the future, as hunting regulation in Namibia evolves.

Alternative income generating strategies have been advocated by conservation managers, including wild species farming. However, Brown (2003) showed that wild species farming has not been successful in tropical regions, while the economic viability of wild species farming has been challenged by Mockrin *et al.* (2005). An “enhanced livelihood approach” (Blum, 2009) was used in Mount Cameroon tropical forests. It included hunting regulations through the issue of hunting licenses, allocation of hunting quotas and punishment of poachers (Blum, 2009). While this pilot project had been implemented since 1994 (Akumsi, 2003), it faced challenges, such as inadequate knowledge of natural history and population dynamics of wild species in the region, as well as a lack of long-term monitoring data to evaluate success of the project and facilitate adaptive management (Blum, 2009). Other hunting regulations focused on seasonal hunting, hunting methods which discouraged the use of traps and allocation of hunting tags to members of organized hunting groups with subsequent monitoring along the wild meat value chain (Olsen *et al.*, 2001). Observations from Gashaka Gumti National Park in Nigeria showed that community-based management through allowing seasonal hunting and involving hunters in enforcing laws in “no-take zones” was very effective (Dunn, 1994).

Wilkie *et al.* (2016) examined overhunting in Africa and the four challenges to effective conservation, including lack of commitment by local communities, unsustainable harvesting methods, inability to expand wild species production like livestock, and habitat loss due to land-use change. They further identified the drivers and actors in wild meat consumption, and provided a synthesis of solutions to this intractable issue. They discussed the fact that wild species are harvested by local people, and mainly consumed by both rural and urban families, with economic incentives for the local hunters. They concluded that wild species can be best protected by effective protected area management and enforcement of wild species conservation laws (Wilkie *et al.* 2016). In a broad review of hunting, Dobson *et al.* (2019) further suggest that the effectiveness of interventions would need to be evaluated against alternatives.

Box 5 4 Trade-offs between wild species, livestock and livelihoods.

Trade-offs exist between wild species, livestock, and people's livelihoods in many areas, which may allow for conflicts to arise between both human and wild species needs. In east African savannas, this challenge is addressed in part by habitat being provided for both wild species and livestock production. Improved integration between livestock and wild species may alleviate the conflicts that arise and allow for certain ecological benefits, such as a reduction in tick loads, thus preventing tick-borne diseases, as well as improved vegetation and forage cover. In addition, this allows for socio-economic as well as financial benefits from tourism and wild species-livestock production systems. The integration of livestock with wild species land-use therefore can provide benefits to wild species and human well-being. The political and governance implications of future conflicts over land and resources may, however, influence trade-offs; and equitable land ownership serves as a key driver of wild species-livestock coexistence (Keesing *et al.*, 2018). Similar trends and issues are evident in North America and Europe (in the case, for example, of wild boar and agricultural land-use conflict). Globally, a shift in the way livestock and wild species interact is needed, via management frameworks that empower communities and allow for direct benefits from both wild species and livestock farming (du Toit *et al.*, 2017). This is particularly the case now that pandemic disease risk has come into focus as an issue relating to the interface between wild species hunting and agriculture (Rohr *et al.*, 2019).

Box 5 5 Trade-offs between trophy hunting, wild species protection, nature-based tourism and local livelihoods.

Well-regulated trophy hunting is recognized as a conservation tool. However, there is a debate as to its sustainability. Muposhi *et al.* (2016) conducted a review on the various trade-offs, as well as implications of trophy hunting when used as a conservation tool.They found that in some countries the populations as well as quality of the species hunted are declining due to hunting pressure influencing the overall flight and foraging activity, which in turn affects species fitness levels. In addition, selective harvesting of trophy species ultimately leads to a decrease in the desirable phenotypic traits of the species, as well as increases their physiological stress levels. Effectively, trophy hunting can provide financial support and resources but requires sustainable practices.

There is frequent debate between, for example, conservation non-governmental organizations and governments on the effectiveness as well as acceptability of using trophy hunting as a tool for conservation, possibly in part driven by a lack of reliable information on its economic and ecological impacts. Trophy hunting can provide economic incentives for conservation of large areas that might otherwise be unsuitable for other wild species-based land-use (Lindsey *et al.*, 2006). There are, however, aspects of the industry in certain areas that may hinder the conservation benefits. Factors limiting the role of trophy hunting as a conservation tool include issues relating to private and public land-use, over- and under-offtake, corruption, competition, the Convention on International Trade in Endangered Species of Wild Fauna and Flora limitations and inadequate regulation of the industry.

In a specific example, Parker *et al.* (2020) addressed the impacts that hunting bans have on private land conservation in South Africa, particularly on biodiversity hotspots. Landowners observed a significant drop in biodiversity following a hunting ban, as well as a transition to other forms of income generating activities such as livestock farming. On the other hand, there are case studies where trophy hunting bans have had positive effects on, in this case, lion demographics (Decker *et al.*, 2016; Mweetwa *et al.*, 2018). Essentially, the incorrect management and inappropriate regulation of trophy hunting can lead to negative consequences. However, there are also conservation and economic benefits that occur. More evidence needs to be provided on the economic and ecological impacts of trophy hunting to ensure appropriate trade-offs with multiple benefits.

Detailed studies on countries need to be undertaken to assess the role of hunting in conservation, diagnose problems, and propose sustainable site-specific solutions. Improved monitoring and enforcement of existing legislation, as well as the creation of new legislation and incentives for conservation performance are all aspects that need to be addressed to ensure that sustainable wild species management is practiced, both now and in the future, as such tradeoffs may become more difficult to achieve.

5.4.4.7 Cultural

Values and/or cultural practices can serve as key drivers of changes in hunting practice. For example, Glas *et al.* (2019), using an Indiana case study in the United States of America, show how wild species value orientations (fundamental beliefs or mental constructs that people use to view wild species) can help (in certain circumstances) show how certain wild species-related actions may be viewed and accepted (or not) by the public. In this case study, wild species value orientations are interestingly most predictive for lethal management actions (such as hunting), and the acceptance of such management actions increased as wild species-human conflict increased (with, presumably, knock-on effects on the engagement of such actions). As a result, wild species value orientations can be useful in informing wild species management using lethal actions, for example, in the management of large predators.

In their approach to wild species governance in the 21st century, Decker *et al.* (2016) observe a decline in interest in hunting in the United States of America, and show how sustainable use principles may affect wild species governance principles which could, in turn, affect the social acceptability of particularly wild species uses (such as hunting). Such views will have significant impacts on whether a particular wild species use or management is viewed as legitimate, with, as above, presumably knock-on effects on hunting practice **(Box 5.5)**.

In Alaska, changes in cultural practices among Native American Inuits, such as reduced use of animal skins for clothing, have influenced demand for hunted marine mammals (Huntington *et al.*, 2017). Further, the extent to which hunters in these study sites in northern and western Alaska use indigenous knowledge in adaptation to a changing environment, and also integrate new knowledge, is key to how their hunting practices adapt to multidimensional changing conditions.

Changes in human values, for example the rise of the animal rights movement (e.g., Hampton *et al.*, 2021) and animal empathy could be important factors affecting the cultural acceptability of consuming wild animals, on the one hand, while driving a demand for certain wild plant products on the other. This could have negative impacts on livelihoods depending on wild species trade or hunting, and positive impacts on livelihoods derived from marketing wild plant products. There is also a move in Europe and North America for rising consumption demand for game meat, as well as in South Africa, in part due to perceived health benefits and the meat being considered (on occasion) "organic" (Archer *et al.*, 2015). Saif *et al.* (2020) use the wild species tolerance model to understand what drives tolerance of Asian elephants in rural Bangladesh, finding that monetary costs do not have a significant influence, while intangible costs and benefits do **(Box 5.4)**, with important implications for future conservation decision-making. Finally, Lopes & Atallah (2020) consider the importance of the spiritual value accorded to certain species in some indigenous communities, looking at population dynamics of tigers in a reserve in India under several management scenarios. A key finding shows that if the Soligas tribe, who consider tigers as sacred, are evicted from the reserve (losing security of tenure), localized tiger extinction is likely.

5.4.4.8 Summary of plausible futures for terrestrial animal harvesting

As indicated earlier (5.4.4.1), few studies explicitly address scenarios for hunting. Few papers could really be considered as "scenario" papers, and they largely considered drivers of hunting practice. However, some key

Box 5 6 **Case of wild species use for cultural purposes and potential links to the spread of the COVID-19 coronavirus.**

In the context of the COVID-19 pandemic, a range of studies has tried to determine the source of the virus, with a wild source (probably a bat) considered (WHO, 2021). Wild species have been used for centuries for cultural purposes (including food and medicinal use), and the conditions in which animals are kept while in transit from source to final destination are often extremely poor (noting that wet markets do not always include live animals). A clear priority for action to reduce the risk of future pandemics is to conserve wild species and their habitats. Turcios-Casco & Cazzolla Gatti (2020) for example suggest four actions. Firstly, closing wet markets could reduce zoonotic disease spread (as well as illegal wild species trading). Secondly, the authors recommend conservation of natural areas and reduction of human-animal interaction. Thirdly, pangolins, bats and other species could be conserved rather than exploited (with some recommended measures). Finally, the authors recommend further regulation of medicinal use of such species. The authors argue that with increased control and stricter regulations, fewer animals would be illegally exploited and the risk of zoonotic disease spread will decrease. However, the issue is complex and the best approach is still contested (e.g., Roe & Lee, 2021), both because of the reliance of many poor communities on trade in wild species for their livelihoods (Booth *et al.*, 2021a) and because of the potential for unintended consequences for both conservation and food security (Booth *et al.*, 2021b). A pandemics treaty (proposed at the May 2021 World Health Assembly) could be key in terms of legally binding instruments to address these public health risks.

trends can be identified and considered as likely to continue in the future. Firstly, key social drivers include legislation and regulation, illegal hunting and poaching, values around hunting and institutional change, linked in some areas to changes in legislation. Certainly, attitudes to terrestrial animal harvesting, or hunting, are evolving and, in certain areas, appear to be shifting in a way that affect their recognition. In addition, in certain countries, legislation regarding, for example, illegal hunting and poaching is both evolving and being more stringently implemented, with impacts on hunting practice on the ground.

Secondly, technological drivers of changes in hunting practices are likely, in some areas, to continue to evolve, including intensification of hunting due to improved technology, such as high beam hunting spotlights and faster vehicles. Conversely, in some areas, technologies to detect poaching and illegal trade are improving, providing improved support to anti-poaching measures (for example, the integrated surveillance system developed for South Africa's Kruger National Park, with a command center near the main camp, Skukuza). Another trend here that is likely to only intensify in the future is the increased availability of motorized vehicles for hunting.

Thirdly, the environment in which hunting occurs is changing and, particularly in regard to climate change, this can be considered an ongoing and intensifying trend. Examples here would include higher temperatures and changing sea-ice conditions, with clear implications for hunting practice in these areas.

Economic changes affecting hunting practice include changing market demand, including the demand for wild meat, which, in some areas, is projected to increase in the future. In other areas, however, reduced market demand for wild species products is a clear future trend, in addition to being currently observed.

Political drivers include aforementioned ongoing legislative changes (including the rise in hunting bans in some countries), as well as non-governmental organization participation in the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which is likely to increase in the future.

Finally, cultural drivers of change in hunting practice are, in certain areas, likely to continue to change in the future, including changes of social acceptability of hunting in some areas, as well as loss of traditional knowledge regarding sustainable hunting practice (a clear ongoing trend in certain sites).

It is clear that the limited presence of scenario studies in hunting is a key knowledge gap. One key finding of this assessment is that such studies would have significant value, if using scenarios approaches explicitly and in a way that would allow for comparison across regions where possible.

5.4.5 Logging

5.4.5.1 Introduction

This assessment has a focus on sustainable use of wild species; therefore, the definition of sustainable logging focuses on activities in natural forests and secondary regrowth, and does not include plantations, which are often established using exotic species. Logging from planted forests often acts as a substitute for wood supply from natural forests, yet depends on the regional context of timber extraction and the end-uses of wood, mediated by global trade (see section 3.3.4 in Chapter 3).

Logging is defined as the removal of whole trees or woody parts of trees from their habitat. It generally results in the death of the tree, but also includes cases in which it may not, such as coppicing. Some activities that constitute part of forest management and use such as extraction of plants, algae, and fungi products (e.g., resins or fruits) are in some cases undertaken along with logging as part of integrated forest management practices.

Most scenarios analyzed here are associated with forest futures in the context of climate mitigation — linked to carbon emissions and removals — and energy supply, and their trade-offs. Often, such scenarios tend to focus on planted forests, or do not make a distinction between planted and natural forests, nor capture the substitution effects between these two different types of forest. Much less attention has been paid to scenarios of the sustainable use of natural forests in the context of climate change, development, biodiversity protection and poverty reduction, which tend to differ depending on biomes (tropics, subtropics, temperate and boreal).

Multiple drivers influence the future of wild or natural forests vis-à-vis planted forests, and furthermore sustainability differs depending on whether harvesting is for diverse wood-based products (e.g., furniture, plywood, paper and paper-like products) or energy, and is influenced by consumption, trade and material substitution dynamics. In addition, increasing human disturbance, along with climate change (e.g., fires, drought) and biotic factors (e.g., pest infestations) create additional stress on forests, particularly natural forests, with direct implications for forest condition that also affect their actual and future capacity to respond and adapt to climate-related risks. The future of natural forests is also intimately associated with plantation development, which may reduce the pressure on natural forests to meet demand for harvested wood products. It is also linked to the different forest management systems used for logging, which can affect forest population structure and genetic diversity (Ratnam *et al.*, 2014). The dynamics of forest regeneration also play a role, with impacts not only on wood supply but also on the provision of (forest-related) nature's contributions to people (Shimamoto *et al.*, 2018). Finally, the future of natural forests, and thus logging, is directly and indirectly linked to wider land-use dynamics.

The total global forest cover area has decreased over time, including a persistent trend of natural forest decline, despite gains from natural forest regeneration (FAO, 2020a). In addition, a significant portion of the remaining cover of natural forests is degraded due to effects of conventional logging, edge effects due to fragmentation, and incidence of fire (Finegan, 2016). If current trends continue, natural forests will be much smaller, simpler, steeper and emptier in the future. This is because natural tropical forests are expected to keep diminishing in size and become more fragmented, with larger areas in edges and patches, and with reduced structural and species complexity. The better-preserved forests will be restricted to steeper and less accessible areas (Edwards *et al.*, 2019). In addition, forests in the future may be more exposed to fires and diseases, which can also affect the survival of species less resilient to stress (Anderegg *et al.*, 2020).

The demand for wood-based panels, paper and paperboard has been estimated to double between 2005 and 2030, and the demand for sawn wood to increase by 50% over the same period (FAO, 2010), though with a growing share of recycled materials and wood residues lowering the demand for primary timber. Logging in natural forests is expected to continue, yet this supply will also be substituted over time by timber from plantations to keep up with global demand for industrial roundwood (WWF, 2012; FAO, 2015). Planted forests and trees outside forests will also become an important source of wood production but probably for domestic markets (FAO, 2019). Demand will also depend on the prospects for the use of wood for construction and buildings, and innovations to increase the durability of wood as a construction material in the building sector.

5.4.5.2 Social

Market demand is influenced by population growth, and urbanization is a key driver affecting the area of natural forests threatened by conversion to agriculture and the volume of wood (or fuelwood) supply originating from natural forests. Population increases in rural areas may lead to further occupation of land for commercial agriculture (Haller, 2014). This is likely one of the most important drivers of deforestation in the tropics and sub-tropics (Pacheco *et al.*, 2021). A major proportion of projected global population growth is predicted to take place in Africa. Of the additional 2.4 billion people projected between 2015 and 2050, 1.3 billion will be added in Africa, 0.9 billion in Asia and only 0.2 billion in the rest of the world (UN DESA, 2016). Population growth may lead to an increase in the unsustainable consumption of forest products. Yet changes in consumption behavior may reduce the demand for forest-risk commodities, and protect forests from further conversion, as explored in future positive scenarios for Para State, Brazilian Amazon (Siqueira-Gay *et al.*, 2020). A global analysis suggests that food systems transformation is one of the pathways towards terrestrial biodiversity conservation, and thus protection of natural forests (Leclère *et al.*, 2020), yet it could constrain wood supply.

Wood demand is linked to product substitution with metals and plastics, the digital era (McEwan *et al.*, 2020), and the potential demand from bioenergy markets for wood-based biomass (Nepal *et al.*, 2019). Urban population growth expands demand for energy, which in countries in Central and East Africa predominantly originates from traditional sources such as fuelwood and charcoal (Ahrends *et al.*, 2010). Global demand for charcoal will continue to increase due to urban population growth in developing countries, mainly in sub-Saharan Africa where demand for charcoal and fuelwood relates to its affordability, easy access and transport, and tradition. Currently one third of residential energy use is based on traditional bioenergy, including charcoal (Santos *et al.*, 2017). Projections of charcoal production and use in urban households in Central & South America, Africa and Indonesia to 2100 using scenarios based on the shared socio-economic pathways and an energy model (Santos *et al.*, 2017) estimated an increase in demand for forest biomass for bioenergy ranging from 31.5 million tons in the most sustainable scenario to 450 million tons in the least sustainable scenario by 2100 (Santos *et al.*, 2017). However, this study showed that all of the regions examined have the forest biomass capacity to meet this demand, especially in Africa and South America, although of course there can be substantial ramifications of changes in biomass use for bioenergy.

5.4.5.3 Technological

Technological innovations could support sustainable use of natural forests through multiple routes. Improving the uptake of technologies for sustainably advancing agricultural intensification, particularly in working lands of producer countries, could enable land to be spared for forest conservation, conditional on the type of governance in place (Ceddia *et al.*, 2014). Technologies in wood manufacturing will also contribute to the expansion of their use in buildings (Ramage *et al.*, 2017), along with the wider adoption of technologies for improving the efficiency of wood-biomass use for energy production (Proskurina *et al.*, 2019). Yet, much of this wood supply may originate from plantations, which may substitute for wood from natural forests, thus reducing the pressures on natural forests as a source of wood supply. Expansion of forest cover can be facilitated by forest restoration — mainly linked to assisted natural regeneration or reforestation — which will benefit from the increasing use of technologies and data to determine the technical potential of large-scale restoration, machine learning to determine tree species composition (Lang *et al.*, 2018), and the potential use of aerial seeding by drones or other aircraft, among others. The success of regeneration can depend on silvicultural practices that ensure the survival and establishment of tree saplings and also affect economic viability (e.g., Graefe *et al.*, 2020). Routa *et al.* (2019) investigated this in *Picea abies* and *Pinus sylvestris* in Finland, finding that during a 50 to70-year rotation, the use of improved varieties of tree species, with or without nitrogen fertilization, increased timber production by up to 28% and economic profitability (net present value) by up to 60%, regardless of the tree species and the impacts of climate change. This highlights that the use of improved practices can increase the output of forest plantations and promote sustainable forestry management.

In addition, a greater uptake of sustainable forest management practices in natural forests (e.g., reduced impact logging) has the benefit of ensuring higher rates of forest regeneration compared to traditional harvesting methods, thus making it possible to sustain future logging but with comparatively lower volumes over time (Putz *et al.*, 2012). Furthermore, innovations in forest management systems are expected in industrial timber production (e.g., technology used in harvesting machines, and the choice of harvesting machines, systems and methods) linked to variations in tree size, plantation areas and forest composition, including harvesting in more difficult terrain (McEwan *et al.*, 2020). Still, a source of debate is whether the use of improved technologies in small-scale artisanal logging will significantly enhance the sustainable supply of timber from natural forests, particularly in tropical areas where smallholders constitute the main forest users (Asamoah *et al.*, 2011). Finally, the application of timber tracking and origin verification may offer quick and reliable information to support the implementation of sustainable practices and monitoring for compliance (Lowe & Cross, 2011), and in natural forests such practices can be expected to supply consumer markets with more stringent import regulations. In developing economies, forests may increase their contribution to economic development and well-being if the industry is restructured in ways that increase the value of the harvested wood, which can then compete with traditional sources of income from extractive industries (e.g., oil and gas), and reduce forest depletion (Izursa & Tilley, 2015).

5.4.5.4 Environmental

Moderate increases in average temperatures can likely be absorbed by forest ecosystems, since most species are capable of acclimating to small increases in temperature (Yamori *et al.*, 2014; Way & Yamori, 2014; Reich *et al.*, 2016; Slot & Winter, 2017). However, more extreme climate-change driven weather fluctuations, particularly the combination of high temperature and drought, can induce tree mortality, or may weaken forests and make them prone to insect attacks, which then finish them off (Anderegg *et al.*, 2015). Extreme temperatures can also lead to leaf damage and death, which reduces the overall health of the trees and predisposes them to other potentially lethal agents. There is also a greater likelihood of fire outbreaks in drier seasons, and droughts, which also expand fire incidence and have important direct consequences for tree mortality (Brando *et al.*, 2014). Furthermore, at higher temperatures insect herbivores need to consume larger quantities of food to meet their metabolic demands, which could increase the amount of herbivore damage to plants (Jamieson *et al.*, 2015). In addition, fast-growing species may tend to perform better in adapting to high temperatures than more conservative, slow-growing species. This might reflect the fact that the early-successional fast growers tend to germinate and grow in hotter, sun-exposed sites, whereas the slow-growing species tend to germinate and grow in the cooler understory. Therefore, climate change may tend to induce changes in forest composition through a range of direct and indirect processes which vary across biomes (Halofsky *et al.*, 2020). Such changes in forest composition can have lasting impacts on sustainable forestry management practices and other drivers of the use of wild species.

Longer rotation periods are important for silvicultural management and have economic and environmental impacts. Using expert-based evaluation in a multi-criteria decision analysis framework, Eggers *et al.* (2019) investigated the effect of 10 forest management scenarios in two municipalities in Sweden. Modelling a hundred-year period, current forest management practices (business-as-usual) with a focus on wood production were economically beneficial but fell short of environmental and social goals (Eggers *et al.*, 2019). Alternative scenarios of integrated forest management policy that supports longer rotation periods, have reduced thinning, and set aside forests for strict protection better balance economic, environmental and social impacts (Eggers *et al.*, 2019). A literature review supports the environmental benefits of longer rotation periods, including supporting and provisioning ecosystem services and climate mitigation (Roberge *et al.*, 2016).

Lundholm *et al.* (2020) modelled species-specific climate change adaptation and the dynamics of timber prices for 11 tree species in the Irish peatland forests. The objective was to assess the net present value of Irish peatland forests based on several regulating, provisioning, and cultural ecosystem services indicators. Scenarios to 2100 assessed a baseline model, a reference model of increased global temperature with forest set-asides, and two alternative models describing the European Union's and global efforts to mitigate climate change through increased bioeconomy (Lundholm *et al.* 2020). Ecosystem services indicators were mainly affected by intensified logging caused by global timber prices; the greatest differences were noted in estimated carbon storage and windthrow risk. The outcomes of the different scenarios also highlight complex interactions among the ecosystem services indicators, which may result in conflicting management objectives. For example, increased use of bioenergy reduced dependence on fossil fuel in Ireland, but resulted in shorter rotation periods and reduced forest biodiversity, while longer rotation periods and forest set-asides were effective for short-term carbon sequestration. Furthermore, intensified logging led to short-term freshwater nutrient enrichment and reductions in forest carbon storage (Lundholm *et al.* 2020). Overall, the models suggest higher levels of carbon storage, regulatory, provisioning, and cultural ecosystem services from longer rotation periods which allow individual trees to mature. However, these benefits may be offset by greater windthrow risks (Lundholm *et al.* 2020).

It is important to note that intraspecific variations due to micro-ecological conditions may warrant varying management practices for populations of a tree species occupying different habitat conditions within the species geographical range. Greater population genetic differentiation due to divergent microhabitat conditions, and isolation by geographic distance and by environment patterns, have been widely reported for many plant species (Borokini *et al.*, 2021; Sexton *et al.*, 2014), including trees (Buzatti *et al.*, 2019; Garot *et al.*, 2019; DeSilva & Dodd, 2020). Likewise, different biotic and abiotic selection pressures such as climatic heterogeneity, wind speed, frequencies of parasitism (pest density and pathogenic load), pollination and herbivory across a species range can drive local adaptations resulting in intraspecific genetic and morphological variations within a tree species (Savolainen *et al.*, 2007; Sobral *et al.*, 2015; Zhang *et al.*, 2021). Differences in microhabitat conditions can affect post-harvest regeneration rates in natural forest as well as recovery rates for plants, algae and fungi (Foahom *et al.*, 2008; Cunningham *et al.*, 2017). Therefore, effective forest management policies need to move beyond species-specific to landscape approach based on the prevailing site environmental conditions. **Box 5.7** illustrates how varying vulnerability to climate change necessitates different management practices across Finnish boreal forests.

5.4.5.5 Economic

Economic drivers have an important influence in shaping the future of logging and natural forests, including land competition driven by the opportunity costs of land-use (Smith *et al.*, 2010). Given the greater profits obtained from agricultural land-uses, and since the ecosystem services of forests are often not internalized, transaction costs associated with keeping standing forests tend to be higher; thus, there is a trend for logged-over forests to be converted to agriculture. In the tropics, the economic value of land with no forest tends to be higher than similar lands with standing forests (Pokorny & Pacheco, 2014). While sustainable forest management may be costlier than predatory logging, benefits tend to be higher in the long term. However, it still cannot compete with agricultural land-uses. As indicated in the gathering section (see 5.4.3), forest multi-use and integrated management that allow for plants, algae and fungi cultivation and collections between timber rotation periods may increase the economic value of natural forests (Klimas *et al.*, 2012; Sist *et al.*, 2014). Global trends analysis signals that competition for land to meet food supply will persist, yet there will be scope for reducing food waste and opportunities for shrinking the land demand for animal feed (Griscom *et al.*, 2020). There is also the potential for contributions to human diets from aquaculture, fisheries and other sources to change. However, future projections

Box 5 7 **Lessons learned from the environmental effects on forest management in Finland.**

To give a specific example, a study on management scenarios in Finland under a strong climate change scenario showed that timber production, net present values, and carbon stocks of forests would be reduced in southern Finland and increased in northern Finland (Zubizarreta-Gerendiain *et al.*, 2016). In central Finland, climate change would have little effect. The use of optimized management plans resulted in higher timber yield, net present values, and carbon stock of forests compared with the use of a single management scenario, regardless of forest region and climate scenario applied. This suggests the need to modify the current business-as-usual management to adapt to the changing climate (Zubizarreta-Gerendiain *et al.*, 2016). Another potential impact comes through increasing wind damage due to climate change. A study on Finnish boreal forests used a forest ecosystem and a mechanistic wind damage risk model to predict wind speeds from global climate model predictions using two representative concentration pathway scenarios (representative concentration pathways 4.5 and 8.5) over the period 2010–2099 (Ikonen *et al.*, 2020). Predicted wind damage was projected to be more severe in southern Finland's forests dominated by *Picea abies* and *Betula pendula*, which are more vulnerable to such impacts. Therefore, climate change-induced wind damage needs to be considered to ensure sustainable forestry management and productivity in regenerated forests (Ikonen *et al.*, 2020).

suggest that meat production will keep growing to meet a projected expansion of urban demand, particularly in Africa (Byerlee *et al.*, 2017). In addition, analysis of the pathways for achieving climate targets stress the importance of forest restoration and reforestation for carbon removals from the atmosphere, which may also place additional pressure on non-forest land and ultimately food production (IPCC, 2019). Recent analysis of the cost-effectiveness of options for climate mitigation suggests that avoided deforestation would rank higher in the list than reforestation and planting trees in agricultural lands (Griscom *et al.*, 2020). When looking at the costs of stabilizing the climate, an analysis using the global timber model projects the mitigation potential and costs for four abatement activities across 16 regions for carbon price scenarios of 5 to 100 United States dollars/tons of CO_2 (Austin *et al.*, 2020). This analysis predicts global mitigation by 2055 to cost 2 to 393 billion United States dollars in year^{-1}, with avoided tropical deforestation comprising 30 to 54% of total mitigation. Higher prices incentivize greater mitigation via rotation and forest management activities in temperate and boreal biomes. Forest area increases by 415 to 875 million hectares relative to the baseline by 2055 at prices of 35 to 100 United States dollars/tons of CO_2, with intensive plantations comprising <7% of this increase. Yet for forests to contribute about 10% of the mitigation needed to limit global warming to 1.5 °C, carbon prices will need to reach 281 United States dollars/tons of CO_2 in 2055 (Austin *et al.*, 2020). Payments for avoidance of carbon emission through limiting deforestation may affect land-use decisions (Fuss *et al.*, 2020), though it is important to recognize that for these climate mitigation approaches, considerations of equity and implementation remain crucial (Demaze *et al.*, 2020; Dieterle & Karsenty, 2020). Explorations of sustainable utilization of forests for bioenergy have been conducted (e.g., Hernández, Jaeger, & Samperio, 2020). Changes in technologies and forest management practices are expected to unfold in the future, associated with the increased competition between wood for energy (Nepal *et al.*, 2012) and carbon removal since reforestation has been identified as the most cost-effective option for natural climate mitigation (Griscom *et al.*, 2017). More uncertain is whether enhancing innovations in plantation management will lead to reduced logging of natural forests due to market competition.

The trends in forest loss could be reversed if forest regeneration increases, but this is uncertain (Holl & Brancalion, 2020), and may result in favoring planted forests over natural forest regeneration. The total technical potential of areas suitable for forest restoration has been estimated at nearly 1 billion hectares (Bastin *et al.*, 2019), but the actual potential could be much lower, as has been suggested for the Southeast Asia region (Zeng *et al.*, 2020). The total area of plantations has tended to slow down, linked to a weak demand for wood due to product substitution with metals and plastics, and the digital era (McEwan *et al.*, 2020). Future expansion of planted forests will likely be more strongly linked to efforts for carbon dioxide removals (Bernal *et al.*, 2018) and the potential demand for wood-based biomass for bioenergy (Nepal *et al.*, 2019). This forest expansion will likely be due to higher economic benefit-cost ratios, and potential for carbon capture (Bernal *et al.*, 2018), but with adverse impacts on food security (Smith *et al.*, 2020). These trends will partially be reversed if greater investments are directed to supporting natural forest regeneration and agroforestry, as part of efforts to enhance local livelihoods and restore forest environmental functions within wider initiatives to enhance forest landscape resilience (Löf *et al.*, 2019).

The situation varies significantly by region. Africa's share of the global wood products trade is quite low, and the production of low-value-added products is absorbed by the domestic markets, with other timber exported. A significant portion of the timber cut in Africa supplies domestic fuelwood consumption (FAO, 2010). In Asia and the Pacific, plantations are projected to expand — mainly in the most developed countries — incentivized by a growing demand for industrial roundwood, following the growth in population and income, and logging of natural forests will continue in less developed forest-rich countries (FAO, 2010). In Latin America, demand for wood from natural forests is expected to gradually be substituted by the expansion of planted forests, yet the timber industry will face increased competition from wood products from Asia. Given persistent pressure for forest conversion some timber will continue to originate from natural forests converted to agriculture after logging. In Europe, the demand for wood (materials and energy) was projected to increase by about 20 to 50% over the period 2010–2030, with the largest share increase due to bioenergy (FAO, 2015). In North America, wood production was projected to double in this same period of time (FAO, 2010), and projected to increase by 60 to 110% in Russia (Petrov & Lobovikov, 2012).

The European Union is the major consumer of biomass for energy and also the main importer of most biomass products, particularly wood pellets (Proskurina *et al.*, 2019). Price oscillations in oil markets will influence timber prices as well (Härtl & Knoke, 2014). It is likely that more wood biomass and forest residues will be used for energy (e.g., thermal, electricity) than for material purposes, at least in some developed economies adopting targets for fossil fuel substitution more actively. Although much of that supply will originate from large-scale plantations, it may also impact timber extraction from natural forests, as has happened in the past. For example, it was argued that European Union bioenergy targets have led to a significant and growing share of biomass for energy being imported to the European Union from countries in the Global South, as well as from regions rich in natural forests, such as Canada, the United States of America and Russia (Andersen, 2016).

5.4.5.6 Political

Many political drivers have an influence on the protection of natural forests and the future of logging. For example, Oduro *et al.* (2014) showed that illegal logging, weak forest governance, high demand for timber due to population growth, and increasing land-use change to cocoa production facilitated forest degradation in Ghana. With a 2% population growth projection in Ghana, they developed and described four management scenarios for the timber industry in Ghana. These scenarios included a legal forestry scenario with well-enforced government regulation and fiscal policies, a degradation scenario with continued illegal logging and weak regulation, a transition scenario with tenure reforms that would give more rights to communities and farmers, and a timber substitution scenario with weak governance and incentives, and declining forest resources. A juxtaposition of the four scenarios showed that legal forestry best ensures timber use efficiency and promotes sustainable logging, followed by the forest transition scenario, underscoring the importance of effective governance. Similarly, analysis of positive scenarios in Para State, Brazilian Amazon suggests that effective land management is needed to avoid further forest conversion (Siqueira-Gay *et al.*, 2020). However, an exploratory analysis on the implications of tenure and forest regulations in the Caribbean forest shows that general harvest regulations do not guarantee sustainable forest management, thus applying rigid rules which do not take into account the current conditions of the stands entail a long-term risk of forest degradation (Gräfe *et al.*, 2020). At the international scale, regulations for reducing illegal timber trade (e.g., Forest law enforcement, governance and trade voluntary partnership agreements signed between the European Union and participant countries) have proven that voluntary partnership agreements have had positive outcomes in terms of improved forest governance, but have not solved illegality in domestic markets (Cerutti *et al.*, 2020).

Natural harvested timber may not regenerate to previous levels after harvesting, even if a forest is managed sustainably. An important trade-off in managing forests consists of reconciling aims for production and conservation, which may tend to diverge over time. For example, an assessment of the restoration potential for southern-boreal forests in the Border Lakes Region of northern Minnesota and Ontario, Canada, found that it may not be possible to achieve all objectives under a single management scenario (Shinneman *et al.*, 2012). Modelled outcomes of six different management scenarios suggested that fire management may be incongruent with forest restoration management, but reduces fire risks in protected forests, while logging and fire regimes that emulated natural disturbance patterns can transition forest landscapes closer to a natural condition (Shinneman *et al.*, 2012).

Estimations of forest carbon stocks and greenhouse gas emissions are not limited to logging events, but also consider downstream sectors, processing and use of the harvested wood and recycling of wood wastes. Chen *et al.* (2018) compared a baseline scenario (business-as-usual) of logging and use of wood-based products, based on historical rates (1990–2009) of logging below maximum allowable levels, with six alternative scenarios in Ontario, Canada, to simulate forest carbon stocks and emissions throughout the forest value chain system. These six alternative scenarios describe increased logging at different intensities coupled with harvested wood products end-use and substitution, as well as greenhouse gas emissions from the decomposition of harvested wood products wastes. Using forest carbon stocks and emissions as criteria, the authors observed that increasing logging beyond the current baseline but producing primarily solid harvested wood products for construction would minimize wastes which cause emissions from landfills (Chen *et al.*, 2018). However, these alternative scenarios would require between 20 and 60 years to achieve net greenhouse gas emission reduction; therefore, the authors recommended an integrated approach to forest harvesting to reduce emissions in the short-term (Chen *et al.*, 2018).

Similar results were obtained in Japan from projections using a harvested wood products carbon balance model. An estimated maximum 8.4 million tons carbon mitigation per year to 2050 was projected from the use of harvested wood products in place of fossil fuel-based energy (Kayo *et al.*, 2015). Of this, approximately half was projected to be generated from energy substitution sourced mainly from logging residues. Kayo *et al.* (2015) also highlighted the significant contribution of substituting non-wooden building materials with harvested wood products. In all modelling, they cautioned that business-as-usual is unsustainable and results in more greenhouse gas emissions (Kayo *et al.*, 2015). Similarly, Matsumoto *et al.* (2016) projected climate mitigation via a reduction in greenhouse gas emissions using a forest-carbon integrated model with three scenarios (baseline, moderate and rapid increases) of harvesting and use of timber products to 2050. They found that a baseline scenario, describing current and constant levels of logging (at 41,000 hectares), 64% replanting of harvested areas using existing tree varieties, the use of 35% of harvested wood for construction, coupled with recycling of 21% and 83% of residues from processing and waste wood respectively for bioenergy use, was the most effective in reducing greenhouse gas emissions at both short and long term (Matsumoto *et al.*, 2016). However, increased use of wood products and reforestation using high-yielding tree varieties, which characterised the rapid increase (70% harvesting increase from baseline) scenario also facilitated greenhouse gas emissions in the longer term. They concluded that in the long term, construction material and bioenergy substitutions with wood-based products were more effective in reducing greenhouse gas emissions (Matsumoto *et al.* 2016).

However, the case is different in the United States of America, where projections of intensified wood energy consumption and the growth of the global economy were associated with a substantial reduction in timber stocks and a significant increase in greenhouse gas emissions by 2060 (Nepal *et al.*, 2019). Similar trends in growth of the global economy but less wood energy consumption would result in a projected increase in forest carbon stocks. The authors used four global economic scenarios, three of which projected a reduction in global fossil fuel production post-2030, indicating a likely increase in reliance on bioenergy, and the fourth a business-as-usual scenario based on historical fuelwood use (Nepal *et al.*, 2019). Thus, differences in the projections of forest carbon stocks and greenhouse gas emissions across different countries may be associated with differing forest management policies.

The projected retention of forest carbon stocks depends on reforestation. Across the world, harvested timber is replaced mainly with plantations of exotic tree species, mainly for the pulp and paper industries and bioenergy. Rodríguez-Loinaz *et al.* (2013) investigated forest carbon stocks in exotic tree plantations *versus* native broadleaf tree species in Biscay, northern Spain. The authors compared future scenarios of carbon sequestration in exotic tree plantations to reforestation with native tree species, using a business-as-usual model for the next 150 years as a reference (Rodríguez-Loinaz *et al.*, 2013). The main finding was that the long-term reforestation with native tree species would have higher carbon stocks than plantations of exotic eucalyptus and pine trees.

Analysis of global pathways to reverse biodiversity degradation highlights the importance of increased protection of natural forests, but these analyses need to be combined with other pathways supporting system change such as food systems transformation, otherwise the full picture of the dynamics of the system as a whole will be missed (FABLE *et al.*, 2020).

5.4.5.7 Cultural

Enhancing the efficiency of logging may impact local people's cultural values and livelihoods. For example, logging in the tropics has often transitioned from large-scale conventional logging to more sustainable forest management incorporating reduced impact logging (Finegan, 2016). Yet, the costs of sustainable management operations have tended to impair the uptake of recommended practices by smallholders and communities, who often tend to opt for non-planned informal logging. This works against the potential for local forest users to capture a higher portion of the benefits from logging (Pacheco, 2012). Nothing suggests that these trends will be reversed in the future if institutional and policy drivers continue unaltered. With regard to the recognition of customary tenure rights in forest management, there is still a major gap between indigenous peoples' land-use rights and the actual recognition of those rights (Khare *et al.*, 2020).

5.4.5.8 Summary of plausible futures for logging

There is a continued reduction in global forest cover despite the increase in global forest restoration, which suggests a trend of net forest loss. This trend is further exacerbated by forest fragmentation due to logging. Changes in food production and agricultural practices in the future, as well as population increases in rural areas, will affect deforestation and land conversion rates. Additionally, climate change may increase tree mortality due to drought, changes in pest attacks and insect herbivory, wind damage, and wildfires, while post-disturbance passive restoration may favor early successional tree species and alter forest composition. The global demand for wood products depends partly on product substitution, especially in developed countries. Demand for wood-based bioenergy continues to increase both in developing countries where growth in population and urbanization drive charcoal and fuelwood production and markets, and in developed countries adopting fossil fuel substitution policies that can stimulate the use of wood-based biomass for energy purposes. Forest plantations may meet some of the growing demand for wood and reduce the overexploitation of natural forests.

Scenarios and future projections suggest that integrated management that includes sustainable forest management practices, multi-use forests (logging and plants, algae and fungi gathering), forest restoration using fast-growing tree varieties, and food systems transformation can support sustainable use. Technological innovations including sustainably intensifying agricultural production, reducing wasteful logging and processing, increasing efficiency of wood biomass use and increasing the success of large-scale reforestation projects can also help support the sustainability of natural forests. Economic and political initiatives that may incentivize the forest sector towards sustainability can include higher forest carbon pricing, payments for emission avoidance through avoiding deforestation, and sustainable land management. Such policies are more efficient when they consider customary, tenure and land-use rights for local communities. There may be trade-offs between the use of natural forests for logging, conservation, and/or carbon sequestration. Reforestation with native species and longer rotation periods may also facilitate higher forest carbon stocks.

5.4.6 Non-extractive practices

5.4.6.1 Introduction

For the purposes of this assessment, non-extractive practices are defined as "practices based on the observation of wild species in a way that does not involve the harvest or removal of any part of the organism. The observation can imply some interaction with the wild species, such as the activities of wildlife and whale watching or no interaction with the wild species, such as remote photography". This includes activities such as wildlife watching, photographic safaris, whale watching, botanizing, and hiking. Although non-extractive practices are primarily observational, there can be some interaction with the wild species, such as activities that involve handling, touching or feeding wild species. According to this definition, regulatory ecosystem services such as carbon sequestration are not included in this assessment. Thus, non-extractive practices are considered to be part of a range of uses where there are no direct offtakes of resources from nature, such as non-material benefits and cultural ecosystem services (Costanza *et al.*, 1997; Watson, 2005).

The trends in demand for non-extractive use of wild species for ceremonial and cultural uses (e.g., worship in sacred groves) are not well documented, but changing social contracts with nature and an erosion of traditional ways of life are a threat to both local use and local protection of wild species (see Chapter 3, Findlay & Twine, 2018; Fournier, 2011; Juhé-Beaulaton & Salpeteur, 2017; von Heland & Folke, 2014). There is some evidence that the non-extractive use of wild species for mental and physical health through preventive and restorative practices may be increasing, such as the use of trees in "forest bathing" (Shin *et al.*, 2017) or bird-watching to support life satisfaction (Methorst *et al.*, 2021). Indeed, the use of national parks and green spaces for tranquility and general recreation increased dramatically during the COVID-19 pandemic (Spenceley *et al.*, 2021; Venter *et al.*, 2020). For example, visitation to nature areas around Oslo, Norway has increased up to 290% (Venter *et al.*, 2020), while some national parks in Sweden witnessed a 75% increase in visitors even before the peak season (Hansson, 2020).

The demand for non-extractive recreational use of wild species (e.g., bird-watching tours, scuba diving), especially commercial tourism, is projected to grow exponentially in the future, potentially with a short-term decline at the global level due to COVID-19 (Gössling *et al.*, 2021). For instance, in both Africa and Asia-Pacific, it is predicted that demand for wildlife watching tourism will increase, particularly within protected areas (Frost *et al.*, 2014). Drivers of this growth include the following "megatrends": social (population growth, urbanization, changes in household composition, aging populations, health and well-being, changing work patterns, gender equality, values, and lifestyle); technological (transportation, high-tech equipment, information and communication technologies); economic (economic growth, sharing economy, fuel costs); environmental (climate change, land-use and landscape change); and political (political turbulence, changes in border regulations, health risks, geopolitics) (Elmahdy *et al.*, 2017).

Growth in wildlife watching tourism may manifest itself in overdevelopment and overuse of natural areas. These global trends and commercialization of wild species have raised concerns of unsustainable use and an increasing disconnectedness of people from nature (see Chapter 3). Nature-based tourism is increasingly becoming characterized by the importance of experiences, well-planned activities, and a sense of adventure and achievement, rather than appreciating wild species through simple leisure and observation (Buckley, 2000; Buckley *et al.*, 2015; Curtin, 2005; Dwyer, 2003; Elmahdy *et al.*, 2017). There is a trend towards recreational activities in nature becoming specialized, motorized, sportified and adventurized (Öhman *et al.*, 2016; Sandell *et al.*, 2011), an opportunity for photographic "selfies" with wild species (World Animal Protection, 2017), with nature transformed into a scenic backdrop for tourist experiences. These experiences affect tourists' expectations regarding the availability of "pristine" nature that simultaneously has high levels of comfort, accessibility, and high-quality experiences (Elmahdy *et al.*, 2017; Fredman *et al.*, 2012). Increasingly, tourism brochures feature herds of teeming game, absent of local communities that live alongside these wild species (Montgomery *et al.*, 2020).

But the projected increasing interest in wildlife watching tourism also provides opportunities for a significant tourism economy, supporting conservation and the livelihoods of local communities, as well as contributing to the enjoyment and education of wildlife watching tourists (Dou & Day, 2020; Tapper, 2006; WTTC, 2019b). Drastic decreases in tourism revenues due to COVID-19 pandemic have also demonstrated the important role of this practice for wild species conservation, especially in developing countries (Newsome, 2020). It has been suggested that the ultimate outcome related to the impacts of COVID-19 pandemic on wildlife watching tourism depends on political support, funding of protected areas, role of non-governmental organizations and the renewed confidence of local communities (Newsome, 2020).

While there are studies that examine scenarios of sustainable tourism broadly (i.e., in terms of many axes of sustainability (Stratigea & Katsoni, 2015), including scenarios of emissions footprints (Whittlesea & Owen, 2012), a focus on non-extractive use of wild species is substantially rarer (i.e., specific incorporation or discussion within scenarios of sustainability for wildlife watching and nature-based tourism or other non-extractive practices). Similarly, while there are numerous studies of sustainable nature-based tourism in terms of drivers, historical changes over time, conceptual frameworks, or strategies for enhancing sustainability (Reynolds & Braithwaite, 2001; D'Lima *et al.*, 2018; Finkler & Higham, 2020), studies on non-extractive practices that include scenarios or scenario development are much rarer, and suggest that this aspect may be less explored. Non-extractive practice scenarios that do exist have been conducted mostly for multiple species and at system level, rather than single species scenarios. Models have been used to explore different futures, including tourism, and explore trade-offs with other uses and values (Fulton *et al.*, 2015). While non-extractive practices are a growing phenomenon, these uses are unlikely to halt extractive uses, which can also contribute to livelihoods and/or foster cultural practices. Careful consideration of the relative trade-offs between practices and uses are needed to guide interventions that favor one over the other.

5.4.6.2 Social

The global population is projected to increase to 9.7 billion people by 2050, 68% of which are forecast to live in urban areas (UNDESA, 2019), and the number of people seeking experiences with wild species as an escape from urbanized environments will also rise. With fewer people living in rural areas, natural areas are increasingly perceived as spaces for leisure experiences. Animal roles in leisure have become especially evident during the COVID-19 pandemic, as social isolation created demand for interaction with animals in general and wildlife-related leisure practices in particular (DeMello, 2021). Urbanized populations are known to have views of nature different from those of rural inhabitants, which include, for example, romanticisation and anthropomorphisation of wild species, often coupled with unrealistic expectations of safety and control in nature (Gstaettner *et al.*, 2020). There is an increase in novelty-seeking behavior, driving up the demand for unique nature experiences, which is likely to drive strong tourism demand both regionally and globally (Frost *et al.*, 2014). Lin & Lee (2020) found that recreational experiences positively influenced both environmental attitudes and place attachment in Taiwan, province of China, and can indirectly engender pro-environmental behaviors. It is also expected that knowledge about biodiversity degradation and endangered species may raise interest towards the "last remaining" wild area and species (Jackson, 2016; Tapper, 2006; World Animal Protection, 2017; WTTC, 2019a).

5.4.6.3 Technological

Information and communication technologies have the potential to enable sustainable non-extractive forms of wild species use, such as virtual wild species viewing. For example, experiences may be obtained through tailor-made, interactive, real-time nature tours, through 5G streaming using 360-degree view cameras, webcams, or drones, given the appropriate hardware, software and infrastructure (Fennell, 2020). These technological innovations are forecast to change how people consume tourism experiences, to create new markets and disrupt value networks. While new technologies may create opportunities for wildlife watching tourists to stay at home whilst gaining some of the benefits of travel virtually, technological innovations can also enrich the experiences of tourists during *in situ* wild species viewing by, for example, providing additional educational content. In this regard, technology can become a powerful driver for sustainable wildlife watching tourism. If virtual experiences replace *in situ* experiences, they have the potential to alleviate travel-associated carbon emissions, but will have knock-on repercussions for tourism-based economies. However, current evidence suggests the growth of media documenting wild species (e.g., BBC Planet Earth documentaries) has stimulated demand for real-life experiences with wild species in their natural habitat (Jackson, 2016; The World Bank, 2018; World Animal Protection, 2017; WTTC, 2019b). The interlinkages between tourism, representations of wild species on media (social media, documentaries, virtual tours etc.), conservation and sustainability have acquired great importance and warrant further research and policy attention.

5.4.6.4 Economic

The wildlife watching tourism industry expects long-term growth, and one can reason that this growth is desirable (from an economic, though not necessarily sustainable) perspective for the sector. Such growth is mainly a result of rising global integration in trade and business, and generally rising wealth and incomes. Travelling has become easier, faster and cheaper. Addressing the detrimental impacts of increasing travel and travel-related impacts on natural systems remains a challenge. As well as indirect travel-related impacts such as carbon emissions (Peeters *et al.*, 2018.), there are direct impacts from an increased physical presence on wild species and ecosystems, some of which may be harder to quantify (see Chapter 3 for details). Yet wildlife watching tourism has the potential to benefit local communities, accrue considerable funds for conservation and raise public awareness of the need for conservation (Tapper, 2006). In addition to wildlife watching tourism, there are other emerging novel financial instruments that have potential to affect future non-extractive uses of wild species economies. For example, existing or proposed instruments include Rhino Impact Bonds (rhinoimpact.com), Lion Carbon (www.lionlandscapes.org/lioncarbon), The Lion's Share Fund (www.thelionssharefund.com).

5.4.6.5 Environmental

Wild species habitats that are major tourism destinations are projected to undergo large climate-driven changes that may threaten biodiversity (Weber *et al.*, 2017). Indeed, the tourism sector contributes to the problem of climate change. Climate change impacts on tourism, wild species and local communities requires intensive and urgent attention, particularly for regions in the Global South where adaptation and mitigation options are underexplored (Hoogendoorn & Fitchett, 2018). Wild species tourism is dependent on wild species, whose existence may be threatened by climate change, and largely occurs outdoors, which requires amenable weather conditions (Hoogendoorn & Fitchett, 2018). Climate change adaptation and mitigation options in the context of wildlife watching tourism are likely to be highly contextual and will need to be assessed on a case-by-case basis (Hoogendoorn & Fitchett, 2018). Climate change effects can also impact wild species use through indirect pathways, such as differing cultural and traditional knowledge from climate migrants (Fournier, 2011).

The environmental consequences of species or ecosystem restoration initiatives can also impact non-extractive practices. For example, as tourists prefer areas they deem "pristine" (i.e., more ecologically and aesthetically "sound"), there are opportunities to boost tourism-based economies through ecosystem restoration. Research on wetlands in India listed under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention) suggests that annual recreational visits could increase by 13% if the water quality could be improved to maintain wild species and fisheries diversity and abundance (Sinclair *et al.*, 2019). Although the nature of interrelationships between tourism and landscape-scale ecological restoration are largely unknown (Clark & Nyaupane, 2020), it appears that many nature-based solutions and rewilding projects have embedded in them a component of wildlife watching tourism, which could result in a significant growth of the industry or redirection away from more harmful activities, potentially helping in part to combat some of the impacts of increased tourism.

5.4.6.6 Political

Political drivers influence non-extractive practices of wild species in a variety of ways. The recognition of local-scale non-extractive users and uses by governance systems plays a substantive role in which non-extractive contributions from wild species are incorporated into regional, national and global ecosystem and species management plans (Brondizio *et al.*, 2009; Chaudhary *et al.*, 2019). Political recognition also has the potential to mitigate the unsustainable use of wild species. This is particularly important in cases where local protection has eroded, as the vacuum can be filled by more formal protection, such as in Estonia where government, in conjunction with local communities (Maausk) conferred legal protection to 550 sacred groves (Kaasik, 2012). Similarly, the Korean government has recognized the importance of forest therapy in mitigating modern day health crises and has passed legislation specifically for "health forests", gazetting the use and restoration of forests for health reasons (Shin *et al.*, 2017). Government and other stakeholder laws and guidelines (even if only voluntary) have been very effective in mitigating the negative impacts of tourism on wild species and wildlife watching tourism sustainability (see Chapter 3 for details). This is particularly effective when management has inclusive stakeholder engagement. For example, Projeto Tamar worked with local communities and fishermen to promote turtle conservation on the Brazilian coastline resulting in improved hatching success and alternative employment and income opportunities based on tourism and turtle protection (Tapper, 2006). A public-private initiative in Majete Wildlife Reserve, Malawi, was so effective at reducing poaching and providing alternative revenue that wild species are again abundant in the reserve (Twining-Ward *et al.*, 2018).

5.4.6.7 Cultural

A growing middle-class seeking rest, spiritual experiences, a deeper connection to historical roots and a frame for cultural identity in natural settings that are seen as authentic and transformative supports the non-extractive use of wild species. However, it can also threaten the supply of these experiences, through commodification and failure to protect fragile environments from overuse (Frost *et al.*, 2014).

The contributions of wild species to human well-being (e.g., spiritual, recreational) are perceived and valued differently by different stakeholders, which influences the type and extent of use (Pascual *et al.*, 2017; Satz *et al.*, 2013). In addition, the different uses and values of wild species have the potential to create conflict between stakeholders (Pascual *et al.*, 2017). For example, residents near ski resorts placed high emphasis on recreational access whereas urban residents preferred the mountain area "pristine" with no visible tourism infrastructure (Saremba & Gill, 1991). Recreational users may also disagree with local communities' consumptive natural resource use. Conflicts have been documented between tourists and indigenous Inuit hunters in Arctic wilderness areas where seals and narwhales are hunted for both subsistence and income (Buckley, 2005). Conflict may also arise out of exclusion from traditional practices or impediments to livelihoods through conservation or tourism restrictions on local communities (Stone, 2015; West *et al.*, 2006). Cases of prohibition of traditional activities that involve unsustainable use of natural resources in favor of conservation have been reported in many countries (see Chapter 3). A high dependence on natural resources for subsistence (Belsky, 2009; Moswete *et al.*, 2009; Prachvuthy, 2006; Rozemeijer, 2000; Wunder, 1999) may leave communities with little choice but to engage in activities that have been criminalized. This highlights the need to manage both physical and cultural conflicts between recreational users and indigenous peoples and local communities, through temporal or spatial zoning, as well as by addressing the disparate cultural and social values of the respective stakeholders sensitively and realistically (Zeppel, 2010).

Another potential driver of cultural change is environmental education. Environmental education is recognized as the key aspect of social sustainability of wildlife watching (see Chapter 2). However, there was no consensus in the environmental education research that interventions resulted in long-term improved attitudes towards wild species and a desire to look after the environment (see Chapter 3).

5.4.6.8 Summary of plausible futures for non-extractive practices

A systematic literature review indicates that there is a paucity of research on scenarios of non-extractive practices in general and wildlife watching in particular. The majority of studies discuss trends and drivers, which have the potential to affect future development directions of this practice (addressed in Chapter 3 and 4 in greater detail), while existing scenarios are exploratory at best. Wildlife watching is the best researched practice when it comes to trends/scenarios of non-extractive use of wild species. There seems to be an overarching global consensus that non-extractive use of wild species will continue to grow and will bounce back successfully after the COVID-19 pandemic, perhaps even with a renewed interest in and demand for nature-related experiences, primarily through tourism and recreation, but also through recognition of mental health benefits. Predicted growth is based on a number of supporting global trends, including economic growth, media impacts on demand, greater environmental awareness and feasibility of travel.

Global socio-cultural trends (e.g., increasing urbanization) will continue to contribute to a growing human disconnectedness from nature in everyday life, resulting in a change in views on and modes of engagement with nature and wild species, such as a growing demand in visitation to natural areas as part of leisure, as well as increased facilitation of wildlife-based experiences. More and more wild species are integrated into commercial processes of non-extractive practices, as sources of experiences, both directly (through immediate interaction with visitors) or indirectly (through image circulation via media channels or "virtual" wild species viewing). This has resulted in an unprecedented increase in environmental awareness among the global population and created a positive feedback loop in growing demand for wildlife watching and other "shareable" nature-based experiences. This, in turn, has potential to facilitate more pro-environmental and sustainable behavior in the long term, but the "value-action gap" remains. There also remains the potential for conflict and differing perceptions of wild species use between stakeholders from different backgrounds or cultural settings.

The distribution of costs and benefits, i.e., positive and negative impacts of this growth, however, remain uneven and unequal. On the one hand, tourism generates a much-needed alternative source of income for communities and regions where few such opportunities exist, as well as generates funds for conservation. This is particularly crucial for wild species conservation in developing countries. The collapse of tourism due to the COVID-19 pandemic has demonstrated the vital role of tourism-generated income for multiple protected areas and wild species conservation projects in many parts of the world. On the other hand, tourism itself is a contributing force to a number of negative environmental trends, such as climate change and carbon emissions or biodiversity decline. Under the projected international tourism growth scenario, therefore, significant additional efforts will be necessary to mitigate negative impacts. Furthermore, climate-driven impacts on wild species and ecosystems may affect tourism potential in many regions.

Overall, the research on non-extractive use of wild species is dominated by discrete case studies, often micro-level, and the lack of higher-level or longitudinal studies and syntheses makes this sector notoriously challenging for generalizations (see also Chapter 2). Similarly, a lack of consistent global and regional-level governance, weak legal base and scarcity of reliable scientific information makes this practice particularly high in uncertainty when it comes to global scenario development.

5.4.7 Examples of factors affecting sustainable use in scenarios

The scenario literature on the five practices of wild species use (fishing, gathering, terrestrial animal harvesting, logging and non-extractive practices) described in the previous sections indicated several factors that can drive more sustainable or unsustainable futures.

Some examples are summarized in **Table 5.4**. covering the multidimensional aspects (social, technological, economic, environmental, political, and cultural) that could be considered in scenario-building processes.

Table 5 4 **Examples of factors that will impact scenarios of sustainable use of wild species, organized into social, technological, economic, environmental, political and cultural categories.**

For details and references, see sections dedicated to each practice.

	Terrestrial animal harvesting	Fishing	Logging	Gathering	Non-extractive
Social	• Legislation/regulation • Illegal hunting • Attitudes and values regarding hunting • Recognition of traditional and indigenous knowledge systems • Institutional change • Social trends influencing food consumption patterns (e.g., organic products consumption, demand for game meat) • Increased social pressures (e.g., using social media to refrain from lethal extractive activities)	• Demographic trends • Domestic demand and supply • Increase in urbanization • Conflicts in sea use • Switch in fishing practices • Traditional fishers' rights • Gender and other aspects of identity for small-scale fisheries	• Urbanization and demand for fuelwood and charcoal • Rural population increases and conversion of land for agriculture • Product substitution with non-wood derived alternatives	• Urbanization • Distance from natural systems • Access of local communities to local markets • Educational level • Household size • Community structure	• Population growth and increasing urbanization • Greater environmental awareness • Pandemic impacts on tourism (including wildlife watching)
Technological	• Availability of more efficient gears enabling intensification of hunting (e.g., firearms, modes of transportation, lights) • Technologies to detect poaching and illegal trade • Domestication and farming of animals of commercial value and/or for a protein alternative	• Technology creep affecting catchability • Transition of fishing fleets to low-emission technologies • Technological advances to reduce bycatch species and improve selectivity	• Technologies to intensify food production to reduce land conversion from forest to agriculture • Technologies to enhance the efficiency of wood-biomass use for energy production • Planning, monitoring and tracking technologies for forest restoration and regeneration (e.g., aerial seeding using drones) • Timber tracking and origin verification	• Cultivation of commercially viable species • Tools used (e.g., for tree debarking) • Research and development of improved varieties to support plants, algae, and fungi cultivation • Rotation period for tree bark harvesting	• Technologies enabling virtual wild species viewing (e.g., webcams, drones) • Technologies enhancing tourist experiences • Media and social media impacts on demand
Economic	• Changing market demand for wild and domesticated species • Incomes and preferences of consumers affecting demand • Alternative income streams • Alternative livelihoods • Increased co-operation between countries and regions to detect and reduce illegal wild species products trafficking • Increased engagement of indigenous peoples and local communities in wild species management and wild species-related law enforcement	• Livelihood options for small-scale fishers • Industrialisation of fishing fleets • Improvements in logistics • Financial subsidies	• Land competition from agriculture to meet food supply needs • Payments/price for avoided deforestation and restoration for climate mitigation • Forest plantations, using improved tree varieties to support increased demand for bioenergy and reduce logging of natural forests • Changes in timber prices • Demand for bioenergy	• Market demand • Income diversification and multiple uses • Incentives for sustainably harvested or cultivated plants, algae, and fungi	• Global economic growth leading to rising incomes and increased demand for wildlife watching tourism • Ease and price of travel

Table 5 4

	Terrestrial animal harvesting	Fishing	Logging	Gathering	Non-extractive
Environmental	• Changing climate conditions • Temporal changes to hunting practices • Zoonotic disease spread • Land-use change	• Climate change impacts on fish distribution • Ocean acification • Marine biomass, species compositions and ecosystem dynamics	• Extreme weather fluctuations (high temperatures and drought) • Changes in wind damage due to climate change	• Biological traits of gathered species • Ecosystem type (e.g., level of water stress) • Habitat quality • Understanding of individual species functional traits (e.g., growth rates) to determine harvest rotations	• Climate change impacts on wild species tourism • Species and ecosystem restoration impacts on tourism potential
Political	• Legislative changes (including hunting bans) • Effective protected area management • Enforcement of wild species conservation laws • Equitable land ownership • Increased governance/controls for invasive species • Increased penalties for poaching and illegal wild species trafficking • Increased emphasis on identification and prosecution of criminal organizations responsible for large-scale poaching	• Transboundary management • Marine protected area networks • Strong fisheries management to limit impacts of climate change • Geopolitical issues	• Regulations for reducing illegal timber trade • Effective governance • Trade-offs between forest management policies for production, conservation, and/or carbon sequestration • Reforestation policies for native *versus* exotic species	• The International Union for Conservation of Nature Red List/Convention on International Trade in Endangered Species of Wild Fauna and Flora listing of heavily exploited species • Traceable supply chains for cultivated species • Awareness and enforcement of local laws • Education for tourists and local people to reduce illegal wild species trade • Incentives for sustainably harvested or cultivated species	• Recognition of non-extractive users and uses in management plans and formal protection • Legal frameworks and guidelines to mitigate negative impacts of tourism on wild species • Projects to provide alternative revenue streams for local communities from non-extractive practices
Cultural	• Changes in social acceptability of certain wild species uses (including hunting) and cultural norms • Wild species value orientations • Loss of traditional knowledge about sustainable use	• Climate change impacts on subsistence fishing • Changes in social acceptability of some fishing activities	• Impacts of enhanced efficiency of logging on local cultural values • Recognition of customary tenure rights in forest management	• Integration of cultural uses and traditional ecological knowledge in management approaches • Strong traditional institutions and knowledge • Respect for traditional laws, institutions, and cultural norms	• A growing middle-class seeking spiritual experiences and cultural identity in natural settings • Differing perceptions of wild species use and conflict between stakeholders (e.g., urban/rural) • Conflicts arising from exclusion from traditional practices through conservation or tourism restrictions

5.5 INVOLVEMENT OF INDIGENOUS PEOPLES AND LOCAL COMMUNITIES AND THEIR KNOWLEDGE IN SCENARIOS

Almost 500 million people that self-identified indigenous in more than 90 countries around the world have a special role to play in the sustainable use and management of natural resources. Their in-depth, varied and locally rooted knowledge can help the world adapt to, and mitigate the consequences of climate change, being also stewards of cultural and natural diversity (Padulosi *et al.*, 2019).

In this section, examples of incorporating indigenous peoples and local communities and their knowledge into scenarios are presented for three practices (fishing, gathering and logging). These are not necessarily scenarios that are used for future projections *per se*, but nonetheless demonstrate how indigenous peoples and local communities and their knowledge can be included into scenario development, recognizing that this is an important but under-represented aspect in the scenario literature for sustainable use (e.g., see section 5.4 above). Some examples from indigenous peoples and local communities have been formulated focusing on narratives rather than on models.

5.5.1 Fishing

Merrie *et al.* (2018) represent narrative scenarios in a two-dimensional space, with each scenario showing a key defining element for one of four "radical ocean futures" **(Figure 5.7)**. The archetypal characters of the scenarios in **Figure 5.7** can be both desirable and undesirable, because desirability is relative. For example, a fishing conglomerate that is aiming for a large-scale harvest of skipjack tuna *Katsuwonus pelamis* in the Western Pacific is likely to have very different ideas about what is "desirable" (or even what is "sustainable") compared to a group of small-scale fishers in Palau (Merrie *et al.*, 2018). This points to the importance of including indigenous and local perspectives into visions and scenarios, to ensure that multiple views of desirable outcomes and aspects of future projections are accounted for.

Many scenarios are based on modelling of the relative outcomes of cooperative and uncooperative behavior. For example, Gutierrez *et al.* (2017) compared a cooperative

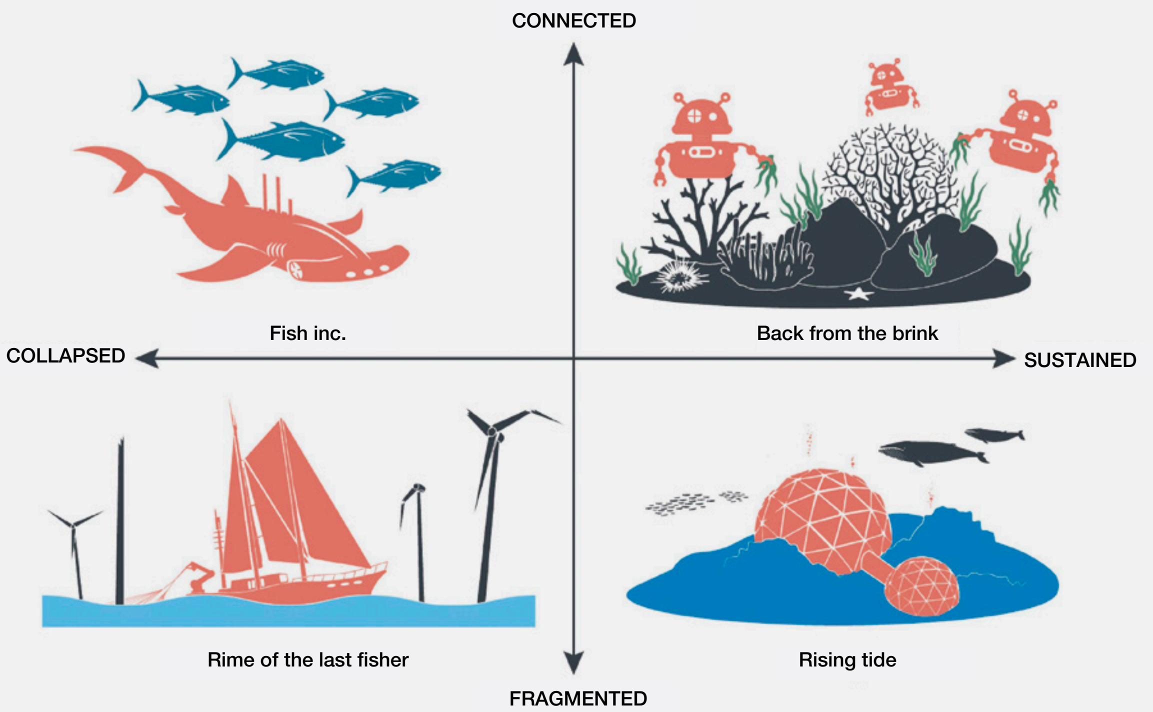


Figure 5.7 **The scenario space.**

The "collapsed to sustained" horizontal axis refers to the ecological dimension and the "fragmented to connected" vertical axis refers to the societal dimension. Source: Merrie *et al.* (2018) under license CC BY-NC-ND 4.0.

harvesting scenario where divers consistently targeted areas with higher yields, avoiding low-quality sea urchins, against a non-cooperative situation where divers harvested at random or based only on densities of sea urchins. The sea urchin population at the end of the simulation period was 20% higher for the most cooperative scenario compared to the non-cooperative fishery. Further, for the most cooperative scenario where information sharing among divers was greatest and harvest coordinated, sea urchin catches were at least 10% higher and gonad yield 35% higher than in the non-cooperative scenario. In this model, information sharing and organized harvesting typical of well-functioning cooperatives allowed fishers to optimize the use of the resource in terms of higher gonad yields per unit of effort while maintaining the productivity of the stock.

Similarly, in Spain, a management scenario explored limiting the fishing season of one of the main types of fishing gear (fish traps, locally known as "paranzas"). Results showed that a reduction in fishing mortality of two overexploited species (*Sparus aurata* and *Lithognathus mormyrus*) would help recover the biomass of these stocks by more than 40% as well as increase the economic value of the fishery, with profits increasing by 17% over a 4-year period (Maynou *et al.*, 2014).

5.5.2 Gathering and logging

Examples from discussions with indigenous peoples and local communities provide examples of scenario-based thinking. For example, in Asia, indigenous honey hunters prefer healthy forests because an abundant honey world – where bees are able to go about their usual business of building hives on tree branches, crevices, and logs – can only exist in such a setting (NTFP-EP, 2021a). However, with external shocks from strong climate change, the indigenous honey hunters foresee that this may no longer be possible.

COVID-19 was another shock to society in general, but areas conserved by indigenous peoples and local communities in places such as the Philippines proved to be wild food-resilient as the food supply within the community was sufficient to supply their needs and they did not have to go to the city or outside their communities to buy food (NTFP-EP, 2021b). Thus, one vision of indigenous communities in the "new normal" after COVID-19 is to ensure increased self-sufficiency under a scenario of reduced global market forces.

In Vietnam, indigenous women in the village of Binh Son actively participate in conservation and forest management and clearly understand the dynamics of forest conservation, believing that sustainable development of forests is anchored through the sound application of traditional knowledge (Tebtebba Foundation, 2011). Conversely, indigenous women believe that "if the forests continue to be unprotected in another ten years, the natural forest area will become smaller and the quality of the forest resources will decrease, while forests newly planted with pure species will increase". The indigenous women "wish to recover natural forests because these provide them with diverse and precious resources" (Tebtebba Foundation, 2011). This type of information and preference, including beliefs around the forest's future without protection, can be readily integrated into scenarios.

A case study in Norway conducted a scenario building exercise with a local community, Vega, which developed scenarios that fall into the exploratory category, i.e., probing of several alternative and plausible futures, including around use of natural resources. They were not predictive or normative in the sense that they did not try to ascertain what Vega will or should look like in 2025, although there are inevitably some normative and predictive elements that enter into the process when a group of local people think creatively about their future. In this particular case the scenario group developed four alternative scenarios constructed around the following themes: community/ society, commerce, transportation, energy supply, landscape and tourism. In each scenario the group applied a particular selection of development paths and drivers. These were assumptions about population development, land-use management, state subsidies, tourism management and regulation, climate change, research monitoring and documentation of changes. A cross-cutting issue in all of the scenarios is the balance between the conservation and use of natural and cultural heritage resources (Kaltenborn *et al.*, 2012).

5.5.3 General considerations on involving indigenous peoples and local communities in future-making

Sustainable use by indigenous peoples and local communities based on customary laws (e.g., in the case of mushroom collection, leaving some mushrooms for animals or for other people) will be impacted by several drivers of change **(Table 5.5)**. These might include policies that prohibit traditional practices like rotational agriculture, traditional fishing canoe construction, hunting or ceremonies. Tourism is also expected to further impact indigenous peoples and local communities' customary management of resources, e.g., in marine areas by the sound of motors due to tourist boats. Education systems will also have crucial and potentially adverse impacts if they devalue small-scale food production, farming or practices considered of low prestige, even though such production systems generate 70% of the global food stock. This may drive youth to either exploit resources unsustainably to gain income, or to leave their communities to live in cities.

Global markets (e.g., palm oil), business exploitation (e.g., pharmaceutical companies) and large-scale infrastructure development (e.g., dams and roads) will interact with indigenous peoples and local communities' customary management of wild species (IPBES, 2019).

Scenarios of the effects of climate change on wild species use could also consider the impacted ability of elders and communities to predict the weather and phenology (i.e., life stages of wild species) using indigenous and local knowledge, making it harder for communities to plan their activities such as harvesting, and leaving them more exposed to climate related risks such as droughts. Climate change may also lead to a greater reliance on wild species, rather than cultivated species which may need more water and be less resilient, and if crops fail or domesticated animals die, people may turn increasingly to wild species to supplement diets. This can have both positive and negative consequences for sustainable use and indigenous peoples and local communities' culture (e.g., declines in wild species, or a resurgence in traditional gathering and hunting) (IPBES, 2019).

Table 5 5 **Identified drivers of sustainable use, or approaches to assessing sustainability, based on specific indigenous and local knowledge studies which use scenarios-based approaches, by category.**

Category	Outcomes
Social	Information gathering and sharing is usually enhanced in fishing communities with strong and well-organized local institutions such as cooperatives or committees (Gutierrez *et al.*, 2017).
	Management regimes can be fairly restrictive, but well established since objectives and regulations are well understood and accepted locally and in line with community values (Kaltenborn *et al.*, 2012).
	The scenario analysis showed that increased monitoring and punishment (including societal pressure) could enhance compliance, especially among younger fishermen, who claimed not to depend solely on fisheries (Karper & Lopes, 2014).
Technological	Agent-based models can evaluate the benefits of cooperative and coordinated harvesting, which requires a model that includes the biological dynamics of the resource, the dynamics of the harvesters and their choice of fishing times and locations, and the feedback between these two elements (Gutierrez *et al.*, 2017).
Economic	Agriculture and coastal fisheries are central economic pillars and modern aquaculture/fish farming is well controlled in terms of diseases and fish escaping from the nets (Kaltenborn *et al.*, 2012).
	Constant or increased income and cheap fuel costs (Maynou *et al.*, 2014).
	To promote sustainable management, the current marketing chain can be targeted. Since the middlemen occupy a bottleneck in the marketing chain, they are a more suitable target for regulatory measures than the local community of fishermen (S. Sen & Homechaudhuri, 2017).
Environmental	Stable climate (Kaltenborn *et al.*, 2012).
	Population dynamics of fish stocks in the adjacent sea (in this case, Mediterranean) (Maynou *et al.*, 2014).
	The traditional knowledge of the fishermen can be a source of information about the life cycle, migration and preferable habitat for crabs and evolving fishing pressure over the years (S. Sen & Homechaudhuri, 2017).
	Harvesting of crabs should not be done during breeding season (S. Sen & Homechaudhuri, 2017).
Political (Governance)	High level of cooperation between local and state management agencies and strict regulations imposed on fish farming (Kaltenborn *et al.*, 2012).
	Closed fishing seasons (Maynou *et al.*, 2014).
Cultural	The use of logbooks, information-sharing groups, folk knowledge, and other informal methods to track and monitor differences in spatial abundance and productivity of target fish species (Gutierrez *et al.*, 2017).
	Conservation of local heritage and environment has also added new opportunities in the employment structure (Kaltenborn *et al.*, 2012).
	The artisanal fishermen of Indian Sundarban inherit the knowledge of crab fishing through generations. Their involvement may help in laying grounds for the management of the fishery as a sound way of improving community livelihoods and management of resources (S. Sen & Homechaudhuri, 2017).
	Intraspecific variation, which includes the genomic and phenotypic diversity found within and among species populations, is often implicitly recognized by indigenous peoples due to consistent long-term observation (Des Roches *et al.*, 2021).

5.6 EXPLORING ARCHETYPE SCENARIOS AND NARRATIVES FOR SUSTAINABLE USE

After synthesizing material on scenario explorations in individual practices (section 5.4; data management report https://doi.org/10.5281/zenodo.6453277), drafting narratives of the sustainable use of wild species required examining the links between the exploratory and the normative archetypes described earlier in this chapter. A start was made in **Table 5.3** which provided examples of factors affecting sustainable use by practice, but **Table 5.6** below provides a many-to-many link. This suggests that most, but not all, target-seeking scenarios of sustainable use of wild species could be developed under most plausible exploratory future outlooks.

However, the remainder of this section is based on the choice to reduce the number of possibilities to one target-seeking overall strategy per exploratory archetype. In some cases, a clearly described mix is proposed. The purpose of the set of integrated archetypes is not to reduce uncertainty or to increase predictability, but only to ensure that the diversity in the number of futures that are included is maximized. This chapter refrained from using more formalized methods to decide on the combinations that would maximize diversity, because existing methods would have needed to be adapted and tested, as they are not developed to combine archetypical information.

The final archetype combinations that were explored were selected to be logically consistent, while equally emphasizing all normative types, and maximizing diversity in combinations of future outlooks and possible solutions. While by no means the only or even the best set of archetypes, this set does sketch a number of very different future directions for the sustainable use of wild species.

Once these archetypes were identified, first the main challenges and opportunities presented by the exploratory archetypes were summarized. This was followed by an elaboration of how changes related to the target-seeking pathways would play out against that backdrop. This led to an overall assessment of how sustainable use of wild species would be achieved in each archetype. This process is captured in **tables 5.7** and **5.8,** which are followed by a short summary for each archetype combination.

1. Market forces-green economy:

Context: In a globalized world, behavioral change and innovations lead to a new business model where sustainability sells. A large-scale circular economy sets the stage for a marketable sustainable use of wild species within the planetary boundaries. There is a strong focus on reducing greenhouse gas emissions.

Sustainable use of wild species: Strong focus on nature for society and the use of nature's contributions to people, and thus also a large market for the sustainable use of wild species, which becomes a market instrument in a (globally connected) circular economy.

2a. Technology-transition/green economy:

Context: Technological innovations in many areas, but importantly including green technologies, lead to high-tech solutions towards sustainability. There is a strong focus on tech-fixes, which limits transformative changes in society.

Sustainable use of wild species: Green technologies will reduce the environmental impact of the use of wild species,

Table 5 6 **Combining exploratory and normative archetypes.**
See data management report https://doi.org/10.5281/zenodo.6453277

Archetype	Green economy	Low carbon	Ecotopian	Transition
1. Market forces	yes	yes		
2. New sustainability				
2a. Technology	yes			yes
2b. Global	yes	yes		
2c. Regional			yes	yes
3. Fortress world			yes	yes
4. Inequality		yes	yes	

Table 5 7 **Challenges and opportunities related to the exploratory archetypes.**

See data management report https://doi.org/10.5281/zenodo.6453277

Exploratory archetype	Social	Technological	Economical	Environmental	Political	Cultural	
	Population growth	**Technology development**	**Economic growth**	**Environmental quality**	**Political effectiveness**	**Societal values**	**Overall challenge level**
1. Market forces	More people, more consumption	More technology, but not always for sustainable use	More growth, more purchasing power, more demand, but also more financial resources	Not a main focus	Effective and global, but not with sustainability goals	Materialistic: most people do not care for sustainability	++
2. New sustainability paradigm *2a. Technological solutions*	More people, but effect limited through technological innovations	Widespread green technologies	Less growth, less demand increase	Engineered nature	Effective, but not of central importance	Nobody needs to care as technology saved the day	- -
2. New sustainability paradigm *2b. Top-down governance structures*	More people, but effect limited through lifestyle changes	More (green) technology, but not a main focus	Low but consistent growth	High level of environmental protection	Very effective, focus on sustainability	Decision-makers care	- -
2. New sustainability paradigm *2c. Bottom-up enforced shift*	Growth slows and strong behavioral change	Limited spread and higher challenges	Low growth or even de-growth	Increases, but with regional (high) pressure	Ineffective as the world fragments	Everybody cares	- – -
3. Fortress world	More people, more needs	Limited development and transfer	No growth, no increased purchasing power, less pressure but also less opportunities	Under pressure, but partly protected	Strong and effective at national level. No sustainable priority	Survival: most people do not have the luxury to care	++
4. Inequality	Strong increase in inequality	More technology, but only for the elite	Growth, but very unequal	Lower, except where in the interest of the elite	Internationally effective, regionally weak	Most people are not well informed	+

Table 5 8 **Target-seeking pathways and sustainable use of wild species.**

	Social	Technological	Economical	Environmental	Political	Cultural	
Target-seeking pathways	**Population growth**	**Technology development**	**Economic growth**	**Environmental quality**	**Political effectiveness**	**Societal values**	**Key direction of sustainable use of wild species**
1. Market forces and green economy	The growing population is a growing market for sustainable products	Once a market for wild species is created, green technologies are developed	Financial resources provide opportunities for investments	Nature for society: nature's contributions to people are maximized	Environmental policies ensure sustainable use	As wild species and the environment provide crucial services, social preferences shift	Commercialization and intensification
2. New sustainability paradigm *2a. Technological solutions*	Carrying capacity of the world increases through technologies	Widespread green technologies	High investments in green technologies	Engineered nature where needed, nature as nature where possible	Facilitating a transition to high-tech solutions	High-tech solutions are paired with increased valuation of nature	High-tech solutions and improvements
2. New sustainability paradigm *2b. Top-down governance structures*	The growing population changes its preference towards sustainable products	Increased green tech helps increasing sustainable use	Growth is sufficient to allow green investments	Strong environmental protection	Very effective, ensures and enforces sustainable practices	Global collaboration and strong stakeholder participation guide a shift towards sustainability	Governmental control and protection
2. New sustainability paradigm *2c. Bottom-up enforced shift*	A strong bottom-up enforced behavioral change	Technology development and transfer slow but key investments continue	Slowing growth and transformation away from capitalist model	Nature for culture dominates as people live with nature. There is a growing recognition of nature's intrinsic value, with wild animals regarded as sentient beings	Political collaboration around environmental issues	Living with nature ensures a sustainable use of wild species	Re-evaluation and respect for nature and wild species
3. Fortress world	Eventually a change towards local communities	The lack of global collaboration leads to case-based grounded, low-tech solutions	The lack of economic development takes off the pressure of global markets	Nature for society dominates, but demands are relatively low	Policies are national and relate to solving national issues effectively	Sustainability eventually as current structures first break down before change happens	Strong transition through bottom-up change
4. Inequality	Increased inequality provides possibilities for the poor	Technological change solved global issues and ensures quick transfer and high adoption rates	Sufficient growth to allow key investments, while demands are rather low	Environment is partly protected through the nature for society attitude of the elite and partly protected by local initiatives	Strong global policies ensure that global issues are controlled and solved	Eventually a strong bottom-up change is met by a globally enforced low carbon trend	Global-local joined forces

while also reducing the demand, in a world that moves towards nature as nature. The sustainable use of wild species is ensured by innovative high-tech solutions.

2b. Global sustainability paradigm-local carbon:

Context: In a globalized world, strong global policies in close collaboration with business opportunities open the door for strongly reduced greenhouse gas emissions. Against this backdrop, there is a strong top-down regulatory force towards sustainable use.

Sustainable use of wild species: A globally coordinated set of policies enforce a change in behavior towards a highly regulated and controlled use of wild species.

2c. Regional sustainability paradigm-ecotopian:

Context: In this regionalized, small is beautiful world, there is a strong trend towards reruralisation. This community-based foundation could lead to small local supply chains, but could also be the starting point for a transition towards broader collaborations. Eventually, solutions are upscaled.

Sustainable use of wild species: The bottom-up initiatives lead to a re-evaluation of nature with strong communities resulting in a central role for sustainable use of wild species across the globe.

3. Fortress world-transition:

Context: The phoenix rises from the ashes in this world where initial trade blocs and regionalization lead to a break-down, from which new structures might emerge that allow for a bottom-up transition.

Sustainable use of wild species: The strong bottom-up rebuilding of values includes a strong change towards sustainable use of wild species. The lack of regulatory frameworks helps a quick transition.

4. Inequality-ecotopian/low carbon:

Context: In a world that is characterized by a strong elite, there are opportunities for the masses to self-organize in smaller communities, while global policies ensure a successful combating of global issues. In a world with many challenges, there are many opportunities as well.

Sustainable use of wild species: The simultaneous efforts to combat global and local issues result in a strong path towards sustainable use of wild species with the combined strength of local knowledge and global technological know-how and collaboration.

Evidence from literature:

All papers in the literature review database were classified by labelling the scenarios that were used as belonging

Table 5 9 **Literature review database.**

	Archetype 1	Archetype 2a	Archetype 2b	Archetype 2c
Total papers	45	9	47	51
Logging (%)	64	22	38	22
Fishing (%)	22	33	40	35
Starting point scenario	Business-as-usual	Strong technological change	Business-as-usual	Transformative change
Main approach	Effect of single instrument/policy measures	Effect of single technology, when applied uniformly and globally	Effect of single policy measure, but role for integrated approaches	Integration, multi-use, cooperation, and community-based
Main method	Modelling study	Mixed, modelling and more qualitative	Modelling study	Mixed, importantly also qualitative
Most mentioned solutions	Carbon pricing, biodiversity offsets, price	Technology improvement	Restoration, management	Small-scale, decentralized, diversified strategies
Most important topics	Bioenergy, fish demand	Mixed, but often specialized, focusing on single species	Fish stocks, forest protection	Mixed, often integrated with human aspect and trade-offs
Comments	Strong link with climate change impacts and mitigation	Small group with relatively extreme solutions for specialized cases	Common element relates to a global, top-down approach and dominance of (existing) policy measures	Common theme is the ineffectiveness of current approaches and the need for local embedment

to the most appropriate scenario archetype. A total of 239 papers were thus related to one (or more) of the scenario archetypes. The other papers did not offer a clear link to the sustainable use of wild species. About two thirds of that set (152 papers) with concrete solutions related to an archetype were then used to characterize the archetypes. Results are presented in **Table 5.9**. Archetype 3 (2 papers) and Archetype 4 (0 papers) were excluded.

Some broad conclusions can be drawn from the analysis of this literature. Overall, there was a strong domination of logging and fishing papers, but with a marked shift from a very high contribution in business-as-usual-related studies to a much lower share when papers related to more extreme changes (Archetypes 2a and 2c). Furthermore, there were clear differences between the archetypes that all have their own identity. The dominance of logging and fishing papers might also in part be attributable to the choice of search terms.

Overall, the conceptually hypothesized archetypes **(Table 5.9)** were partly present in the literature, and partly (completely) absent. Archetypes 1, 2b, and 2c are all present with an almost equal share. They represent the three most important manners in which the future can be studied: business-as-usual; top-down, global measures; bottom-up local measures. Archetypes 3 and 4 are almost completely absent. A small number of papers relate to the exploratory archetypes “fortress world” and “inequality”, but with only a few exceptions, these scenarios are not linked to sustainable use.

The archetypes serve to categorize the multitude of sustainable use aspects across sectors, scales, topics, and types of solutions into a meaningful and clear – archetypical – overview. A main conclusion is that there is a strong focus on modelling single-measure effects for a single practice, particularly in logging (pricing, bioenergy) and fishing (fish demand/stock and management). Other, more integrated, solutions are studied, but often from a systemic viewpoint. This often implies a weaker link with (the sustainable use of) wild species. There is a clear gap related to studies that focus on wild species within broader systemic, integrated future changes.

5.7 LINKING THE ARCHETYPES TO THE PRACTICES

The information presented in section 5.4 and above allows to build towards an understanding of pathways of change, and how to link scenario studies from individual practices to archetype exploration. In section 5.4, existing studies on scenarios for the sustainable use of wild species were analyzed and evaluated by practice. This yielded a wealth of information and in-depth insights on possible solutions, from which generalities can be extracted. This section approached the issue from the angle of existing societal scenarios (i.e., focused on broad societal trends rather than sustainable use of wild species *per se*) and scenario archetypes, which allowed a set of conclusions specific for each archetypical future, but does not provide detailed practice-oriented concrete solutions. These two streams of information can be tied together to explore solutions that are both scenario- and practice-specific, while also being concrete. This furthermore allows to identify critical gaps in the literature on scenarios of sustainable use. **Table 5.10** presents examples of solutions and/or pathways elements for all combinations of scenario archetype and practice.

There are some conclusions that can be drawn from linking the practices to the archetype scenarios. In particular:

- **Multiple solutions:** The results show that there are multiple pathways and solutions that can lead to a more sustainable use of wild species. The market forces and new sustainability paradigm scenario archetypes (and sub-archetypes) contain promising solutions. Mechanisms by which this is reached are very different, but practices such as fishing and logging show that there is not a single path to sustainable use, and sustainable solutions for one practice might not work for others.

- **Limited exploration of transformative change in archetypes:** Radically different futures that would require fundamentally different solutions are not generally explored in the scenario literature. This suggests a knowledge gap, whereby leverage points and approaches to transformative change (see section 5.8) need further exploration within an archetypal scenario framework.

- **Generalities:** Many sustainable solutions would appear to benefit from market or policy support. Without favoring top-down approaches, even when solutions are sought through bottom-up initiatives or technological development, governments and markets might have a decisive role to play. In addition, bottom-up solutions are very integrative and essentially work for any practice;

Table 5 10 **Linking practices and exploratory archetypes through potential practice- and scenario-specific solutions.**

Note that solutions are only examples, and are not intended to be exhaustive or definitive. The bottom two rows are blank due to limited exploration in the sustainable use scenario literature.

		Practice				
Scenario	**Key direction of policy/approach for sustainable use of wild species**	**Fishing**	**Gathering**	**Terrestrial animal harvesting**	**Logging**	**Non-extractive practices**
Market forces and green economy	Commercialization (1) and intensification (2)	**1.** Adding value and food through fish byproducts (Stevens *et al.*, 2018) **2.** Valuation of tribal subsistence fishing (Morton *et al.*, 2017) Increasing the diversity and flexibility of small-scale fisheries, as well as gender recognition	**1.** Cultivation of commercially viable species (Cunningham *et al.*, 2017) **2.** Research into improved varieties to support cultivation (Chen *et al.*, 2016)	**1.** Increasing demand for sustainably harvested wild products (e.g., venison) **2.** Market incentives for sustainable use in hunting product labelling	**1.** Globally accepted and implemented high carbon price (Austin *et al.*, 2020) **2.** Increased agricultural intensification sparing land for forests (Ceddia *et al.*, 2014)	**1.** Novel financial instruments related to non-extractive practices (e.g., Rhino Impact Bonds; www.rhinoimpact.com; Debt for nature swap) **2.** Increased demand for wild species experiences influencing environmental attitudes (Lin & Lee, 2020)
New sustainability paradigm: *Technological solutions*	High-tech solutions and improvements	Technological advances for surveillance and compliance (Kroodsma *et al.*, 2018)	Technology to online monitoring of illegal online sales of wild species (Ticktin *et al.*, 2020)	More sophisticated anti-poaching measures (e.g., drones, lidar)	Aerial seeding by drones for reforestation (Lang *et al.*, 2018), improved efficiency of wood-biomass use for energy production (Proskurina *et al.*, 2019), product substitution and the digital era (McEwan *et al.*, 2020)	Increased use of technologies to enable virtual species viewing (Fennell, 2020)
New sustainability paradigm: *Top-down governance structures*	Governmental control and protection	Improving harvest control rules and recovery plans	Domestic and international regulation of harvesting and sales of wild species	Deploy policies designed to tilt sellers and buyers from wild meat towards consumption of other wild species (Wilkie *et al.*, 2016)	Sustainable forest management practices (Putz *et al.*, 2012), regulations to reduce illegal timber trade	Improved recognition and incorporation of non-extractive practices in governance systems (Chaudhary *et al.* 2019)
New sustainability paradigm: *Bottom-up enforced shift*	Re-evaluation and respect for nature and wild species	Community-based fisheries management, incorporating traditional ecological knowledge and customary tenures	Greater respect for traditional, local, and indigenous ecological knowledge around sustainable harvesting practices (Papageorgiou *et al.*, 2020)	Greater respect for traditional, local, and indigenous ecological knowledge around sustainable harvesting practices	Recognition of customary tenure rights in forest management	Increased wildlife watching tourism supporting conservation and local livelihoods (Dou & Day, 2020)
Fortress world (international authoritarian system)	Strong transition through bottom-up change					
Inequality	Global-local joined forces					

empowering local communities will help move towards sustainable use irrespective of the practice. In contrast, non-extractive practices have distinctively different example solutions in relation to extractive practices.

- **Knowledge gaps:** Important archetypes have not been explored at all in the sustainable use literature, and as per the previous section, in particular the fortress world and inequality archetypes. A full set of scenarios is needed to better understand what adaptation/mitigation options are needed and feasible. Similarly, as per the previous section, it is also easier to link fishing and logging practices to archetypes due to their greater prevalence in the relevant scenario literature.

- **Leverage points:** The scenario archetypes that are most commonly explored have some elements of the framework of the 3-horizons approach, with established practices giving way over time to transitional activities and ultimately a long-term shift to new innovations (Sharpe *et al.*, 2016).

  - **First horizon (market forces):** address current concerns and maintain essential features

  - **Second horizon (top-down governance/bottom-up enforced shift):** scale up current innovations and foster existing niches

  - **Third horizon (bottom-up enforced shift/top-down governance):** start new inspirational practices and link to future aspirations.

That is, transformative change may be reached by three concurring types of action: Phasing out existing practices (horizon one); fostering and strengthening current niches (horizon two); initiate novel transformational actions (horizon three). While the archetypes exploration here has shown that there are substantial knowledge gaps around transformative change, it is further explored in section 5.8.

5.8 APPLYING THE NATURE FUTURES FRAMEWORK CASE-STUDIES TO THE SUSTAINABLE USE OF WILD SPECIES

The nature futures framework (being developed by the IPBES task force on scenarios and models) provides a foundation for envisaging positive futures for sustainable use of wild species, since it places human-nature relations at its core and reflects the multiple ways in which both people and nature can benefit from the use of wild species (Lundquist *et al.*, 2017). Importantly, these visions are not mutually exclusive, but rather they offer a plurality of approaches for how sustainable use of wild species can be realized **(Figure 5.8)**.

The nature futures framework is a heuristic tool developed by the IPBES task force on scenarios and models that can help to explore and define positive relationships of humans with nature in order to create desirable nature scenarios (Pereira *et al.*, 2020). In the context of the sustainable use of wild species, the framework could be applied across different scales to target and achieve positive futures. When designing interventions to enhance sustainable use of wild species within the nature futures framework, a plurality of values needs to be included. Importantly, there is a need to "build on common interests between conservationists and [wild species users] wherever these occur, but also engage in honest discussion about genuine conflicts of interest where these exist and work towards negotiated solutions" (Newing & Perram, 2019).

Box 5.8 presents an example of a conceptual application of the nature futures framework to wild species use in a fisheries management context under the three most distinct nature perspectives identified by IPBES, i.e., the points of the triangle: nature for nature (intrinsic values of nature), nature for society (nature's benefits to people) and nature as culture (relational values with nature). **Box 5.9** shows an example of sustainable use in the Amazon as envisioned within the nature futures framework.

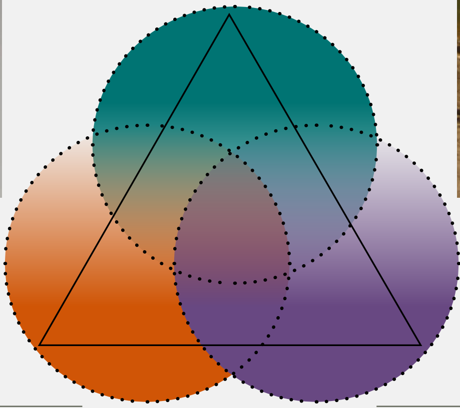
The three positive scenarios formulated for the Pará State in Siqueira-Gay *et al.* (2020) anticipate different positive outcomes. In the Pará minus scenario, land reform and regulation strengthen conservation values, social learning promotes collaboration between stakeholders and integrates their knowledge, and economic development does not depend on the extractive use of natural resources while traditional extractive activities continue in a sustainable manner. In the Pará consumo scenario, the food market motivates local production and consumption, reducing carbon emissions from transportation of goods and creating

NATURE FOR NATURE
Protection of some wild species, with non-consumptive use.

- Nature: Wild populations are not exploited, and therefore preserved. Wilderness and ecological processes kept intact.
- People: Benefit from existence value and non-consumptive use, such as photographic tourism.

E.g., The wildebeest migration in Serengeti National Park, Tanzania

E.g., Mentha pulegium (pennyroyal) in Southern Spain



E.g., Saltwater crocodiles in Australia

NATURE AS CULTURE
Socio-cultural interactions between humans and wild species, with meaningful experiences.

- Nature: Wild populations live in harmony with people.
- People: Benefit from meaningful connections with nature, including aesthetic, spiritual, recreational and cultural heritage.

NATURE FOR SOCIETY
Managed harvesting of some wild species, within bio-economically sustainable limits.

- Nature: Wild populations are maintained via sustainable management.
- People: Benefit from consumptive use values, such as food and income.

Figure 5 8 **A plurality of visions for sustainable use of wild species, based on the nature futures framework.**

Adapted from Pereira *et al.* (2020), under license CC BY-NC-ND 4.0.

Box 5 8 Nature futures framework in fisheries management for the sustainable use of marine resources.

This example **(Figure 5.9)** represents a simple conceptual illustration of the potential application of the nature futures framework to develop desirable future scenarios for both people (fishing activities) and nature (exploited wild species in marine ecosystems) under three different values perspectives (IPBES, 2021). This example aims to build different narratives related to fisheries management, focusing primarily on reference points. Here, these narratives have shared outcomes referred to as “common features” that are essential assumptions for achieving any of the positive visions embodied in the nature futures framework (e.g., application of the precautionary approach). The common features as shared elements aim to ensure a reference baseline for sustainable use. The specific features distinguish these narratives from one another. In this example, the differences between narratives were highlighted through three categories: (i) restriction strategies in mixed fisheries (output control in multispecies fisheries), (ii) management scale, and (iii) indicators of interest. These categories are not exhaustive and could be enriched to better describe different exploitation scenarios for marine species under the nature futures framework.

Box 5 8

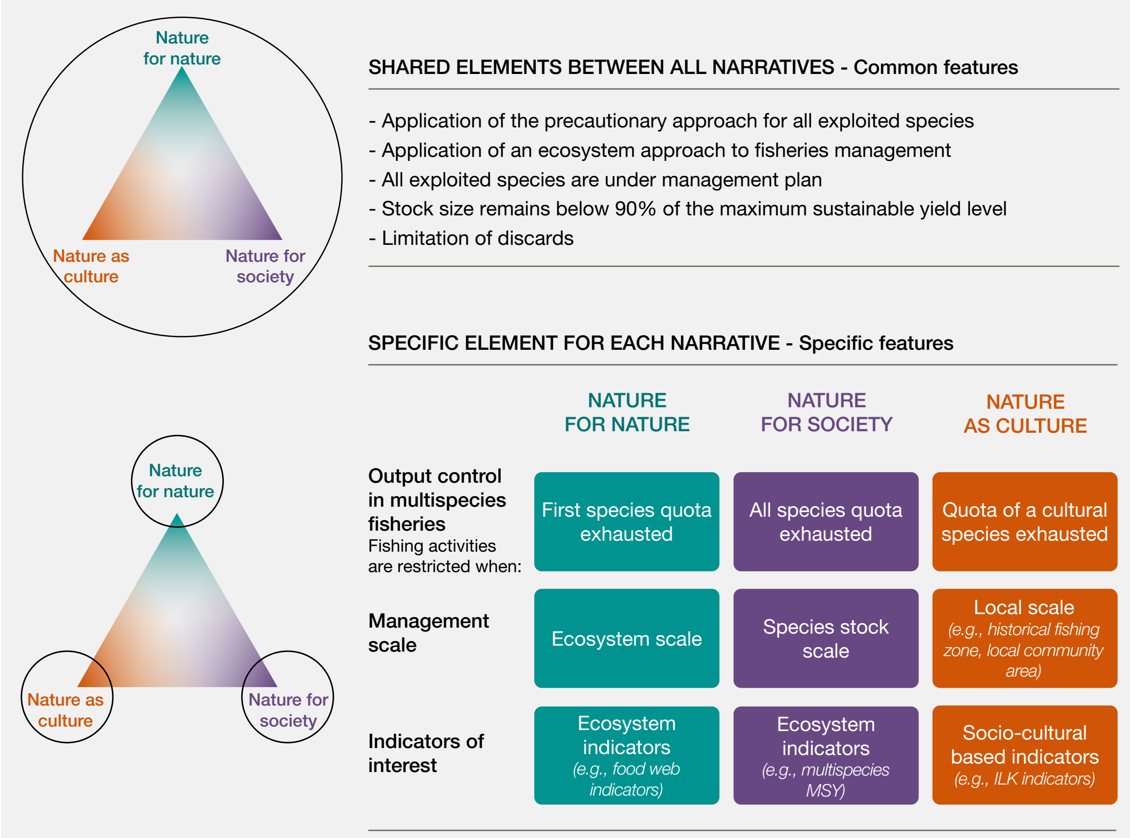


Figure 5 9 **Potential application of the nature futures framework in fisheries management.**

Source: Halouani *et al* (in prep). Abbreviations: MSY: maximum sustainable yield; ILK: indigenous and local knowledge.

Box 5 9 Nature futures framework scenarios for the sustainable use of forest resources in the Brazilian Amazon.

The nature futures framework promotes participatory and inclusive approaches to develop scenarios with stakeholders by co-creating narratives and modelling frameworks and co-identifying or developing indicators to inform decision-making (Pereira *et al.*, 2020; Kim *et al.*, 2021). By doing this, the goal is for the nature futures framework to facilitate and enable transformative change by helping people to reflect on different decision options from diverse value perspectives.

Using the nature futures framework and the framework on nature's contributions to people (Díaz *et al.* 2018), Siqueira-Gay *et al.* (2020) identified trajectories leading to positive futures in the Brazilian Amazon of Pará State, including indigenous peoples and local communities' perspectives. They created three positive scenarios addressing negative anthropogenic drivers:

1. Land management to tackle illegal deforestation (Pará minus)

2. Changes in consumption behavior (Pará consumo)

3. Combining (i) and (ii)

The Pará minus scenario includes policies that address rural land occupation, agriculture and pasture expansion, unofficial road building and forest degradation with co-management, and decentralized environmental governance with user-coordinated actions for sustainable management of natural resources. The Pará consumo scenario includes policies to reduce excessive meat consumption and clearing of forest areas for soy plantation for feeding animals through environmental education to modify consumption behavior (Siqueira-Gay *et al.*, 2020). The core actions for the implementation of policies in these scenarios are listed in **Table 5.11**.

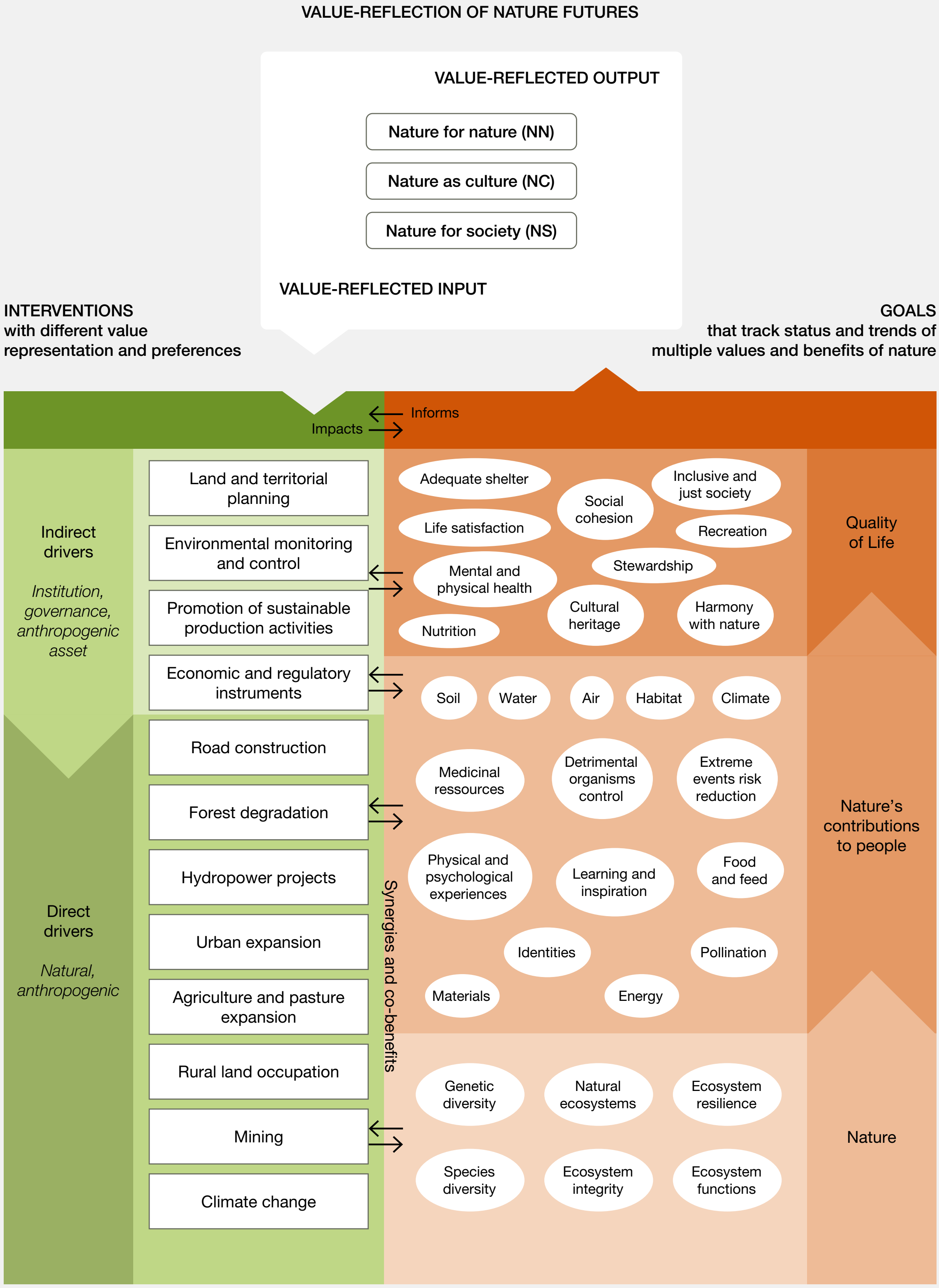


Figure 5 10 **An illustrative nature futures framework in the Brazilian Amazon of Pará State for assessing the potential consequences of different policies on nature and people.**

Based on Siqueira-Gay *et al.* (2020).

Table 5 11 **Core actions for policy implementation in two sustainable forest scenarios named Pará minus and Pára consume.**

Source: (Siqueira-Gay *et al.* 2020).

Pará minus scenario: *Land management to tackle illegal deforestation*	**Pará consumo scenario:** *Changes in consumption behavior*
i. Enforce forest decentralization efforts to allow small governance units to take decisions about their resources in a sustainable way **ii. Provide technological tools and training** to communities to facilitate sustainable development and monitoring efforts **iii. Enforce the protection of indigenous territories and protected areas** by creating an inheritance tax scheme and fines for illegally clearing forest areas **iv. Perform a land reform** to distribute underused or abandoned land to individuals or organizations committed to sustainability and conservation efforts or return the land to indigenous or traditional communities **v. Regulate for mandatory sustainable use** of undesignated public lands, and prohibit (with fines applicable) clearing of pristine forest areas **vi. Create new and strengthen existing alliances** to make forest monitoring and controlling efforts more effective, while facilitating social learning processes in local communities	**i. Create an educational program** to promote awareness on nature's contributions to people provision, the value of forest conservation, and damage caused by cattle ranching. This program would be integrated into the educational system by restructuring the curriculum **ii. Promote alternative options for protein consumption** instead of beef **iii. Create a tax incentive for large companies that join the beef moratorium** (an agreement not to buy meat from newly deforested areas) or that supports the educational program of awareness on nature's contributions to people provision (action i)

nature-based recreational opportunities for people. There is active urban farming and recycling to reduce waste, and values transformation through social welfare and innovation. In the scenario that combines the two, sustainable economic development is envisaged with green solutions and enhanced social empowerment through social learning and education. Overall, the policies implemented in these scenarios make positive steps towards sustainable land-use and land change, consider and help to mitigate climate change, and sustain natural resources (Siqueira-Gay *et al.*, 2020).

As illustrated in Pará State's scenarios, scientific and local knowledge, models, and indicators generate diverse and complementary evidence for evaluating the roles and impacts of different policy and management options in conserving nature and providing benefits to people (Kim *et al.*, 2021; Tengo *et al.*, 2014). The illustrative scenario and modelling framework for Pará State **(Figure 5.10)** could be developed for and applied to other places or systems to explore the consequences of nature- and people-positive visions in informing future policy and management decisions in a more solution- and action-oriented way. By bringing diverse value perspectives on nature (i.e., intrinsic, instrumental and relational values) into scenario development, the nature futures framework can help stakeholders recognize the multiple benefits of conserving nature and its ecological processes, while preserving and creating space for culture. In this sense, the nature futures framework becomes a heuristic and an entry point for visioning and assessing radical yet plausible pathways towards living in harmony with nature.

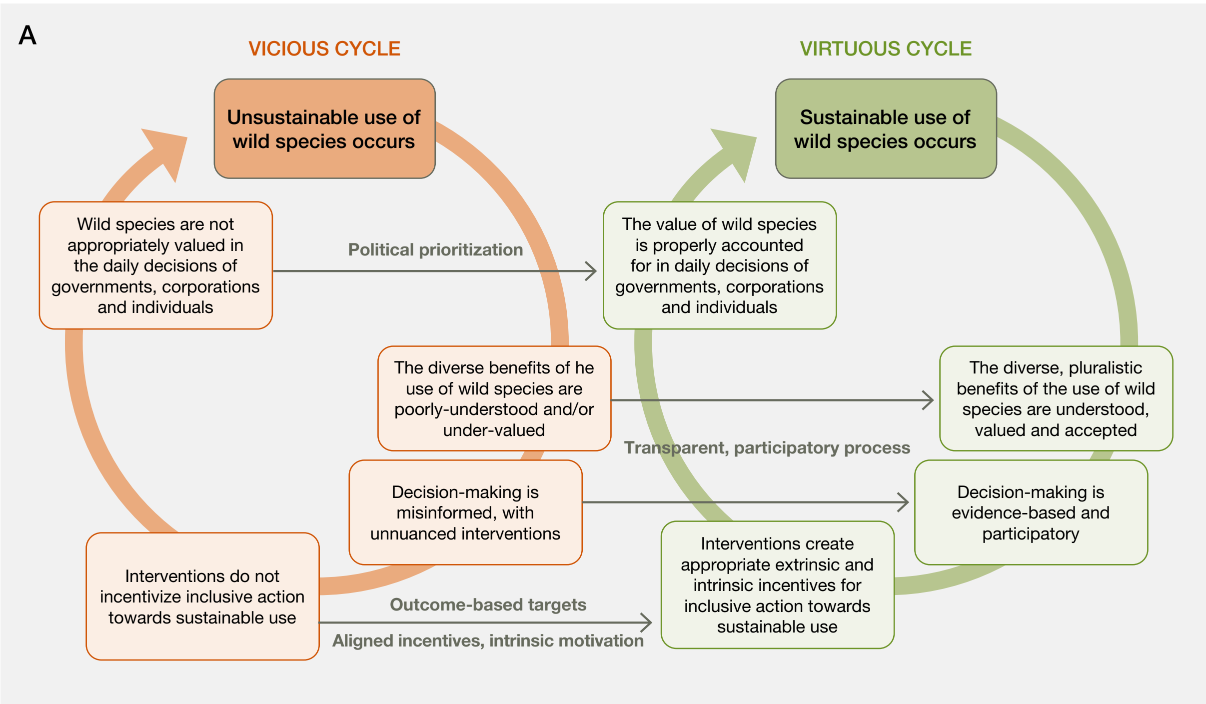
5.9 TRANSFORMATIVE CHANGE, LEVERAGE POINTS AND PATHWAYS TO ENHANCE THE SUSTAINABLE USE OF WILD SPECIES

Enhancing the sustainable use of wild species could provide benefits to both people and nature, but transformative change is needed if these benefits are to be realized. Given the vast diversity of life on earth, and the range of contexts and values that shape human uses of wild species, a pluralistic approach will be required, which recognizes and celebrates diversity in the relationships between people and wild species (see also section 5.8). As the previous section has indicated, the nature futures framework may also be a useful tool to help to envision these transformations and highlight leverage points and pathways. In this section some approaches towards transformative change are explored, as applied to scenarios of sustainable use.

5.9.1 Transformative change, scenarios and sustainable use

Transformative change through "deliberative transformations" (i.e., those caused by intentional interventions) very often involves a move towards collaborative adaptive management – which is precipitated by crisis or turmoil (Gelcich *et al.*, 2010). Actors such as policymakers, donor agencies, non-governmental organizations, private corporations, and scientists can play a catalytic role when acting in appropriate ways at the right place and at the right time (Olsson *et al.*, 2004).

Regulation has been a predominant approach to controlling wild species use. Regulations can take multiple forms, from strict spatial and species-specific prohibitions to rules for how and where species can be used (e.g., gear restrictions in fisheries, protected areas) and in what quantities (e.g., quotas). Some form of regulation is often necessary to support the sustainable use of wild species. However, it is not usually sufficient for positive transformative outcomes. Firstly, in order to be effective, regulations require appropriate compliance management, such as through monitoring and enforcement. Secondly, excessive and indiscriminate regulation can undermine incentives for sustainable use and lead to polarized narratives and an over-focus on illegality (Challender *et al.*, 2015). This may drive "vicious cycles" that constrain pathways to transformative change **(Figure 5.11)**. Yet if appropriately and anticipatorily governed via a mix of regulatory and economic instruments which are aligned with a plurality of values and visions, wild species can be sustainably used (noting that "use" can be associated to extractive and non-extractive practices, as per the nature futures framework, **Figure 5.9**). It can simultaneously support the pursuit of the Sustainable Development Goals **(Box 5.10)** and international conservation goals such as the Convention on Biological Diversity's new post-2020 global biodiversity framework, which is expected to be adopted at the 15th Conference of the Parties ('t Sas-Rolfes *et al.*, 2019).



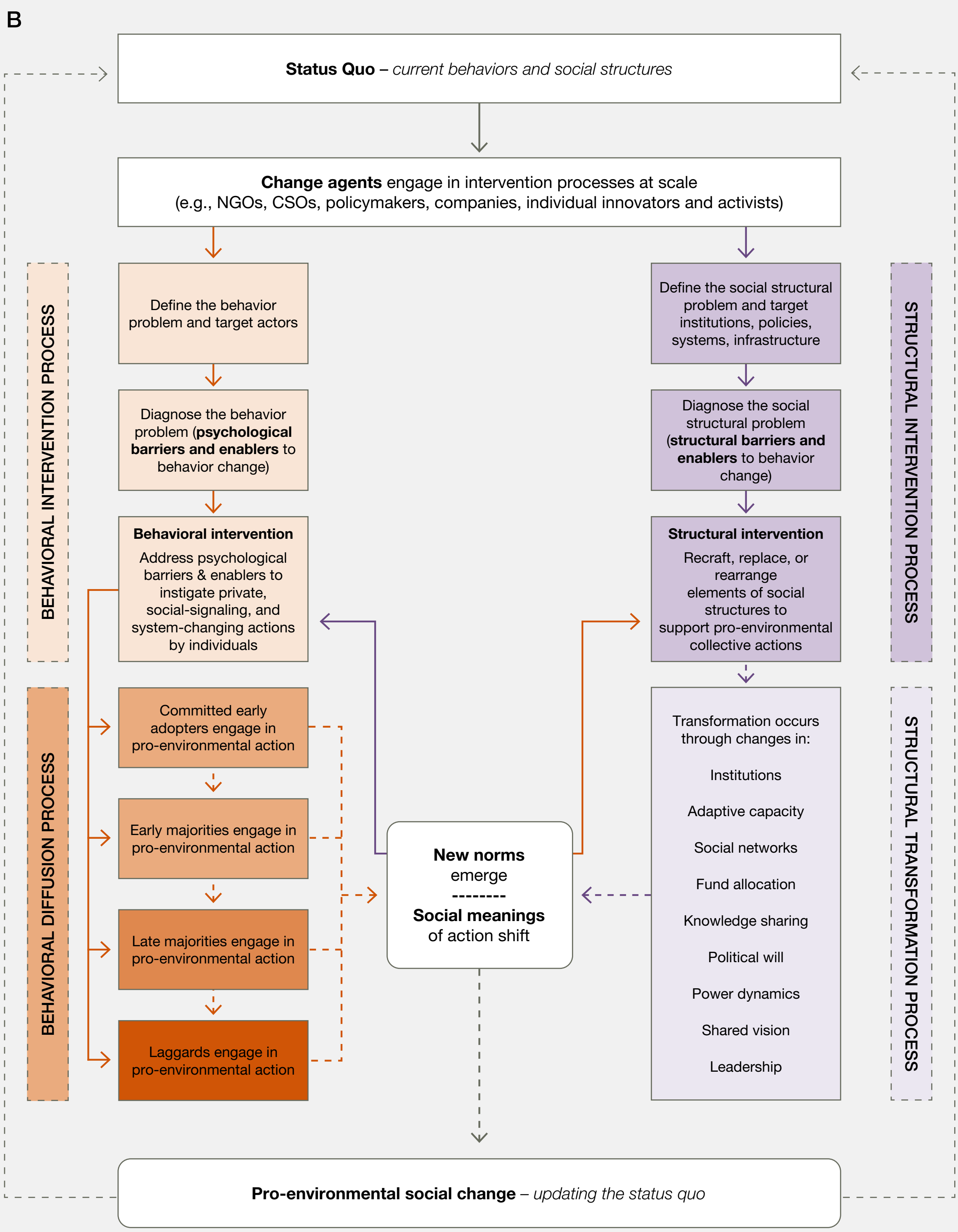


Figure 5 11 **(A) The vicious cycle of unsustainable use and the virtuous cycle of sustainable use, with illustrations of how leverage points can cause shifts between them.** These leverage points need to be applied in concert to obtain transformative change. One alone is unlikely to shift the system effectively. **(B) An integrative framework for pro-environmental social change.**

Abbreviations: NGO: Non-governmental organization, CSO: Civil society organization. Source: Naito *et al.* (2021).

Importantly, there is a need to understand trade-offs between the costs and benefits of different types of wild species use, how interventions might enhance or exacerbate them, and for whom **(Box 5.10)**. A plurality of values can be considered to understand these costs and benefits (e.g., economic, social, ethical), as per the nature futures framework (see section 5.8). In particular, the value systems of people who will be most

Box 5 10 **Wild species use and sustainable development.**

Enhancing the sustainable use of wild species requires a holistic understanding of how different use regimes can contribute to society. Moreover, by focusing on an outcome goal such as "sustainable development", heterogeneous pathways to this goal can be devised. **Figure 5.12** below shows illustrative examples of how interventions under differing value systems aligned with the nature futures framework can alter progress towards the Sustainable Development Goals relative to a business-as-usual framework.

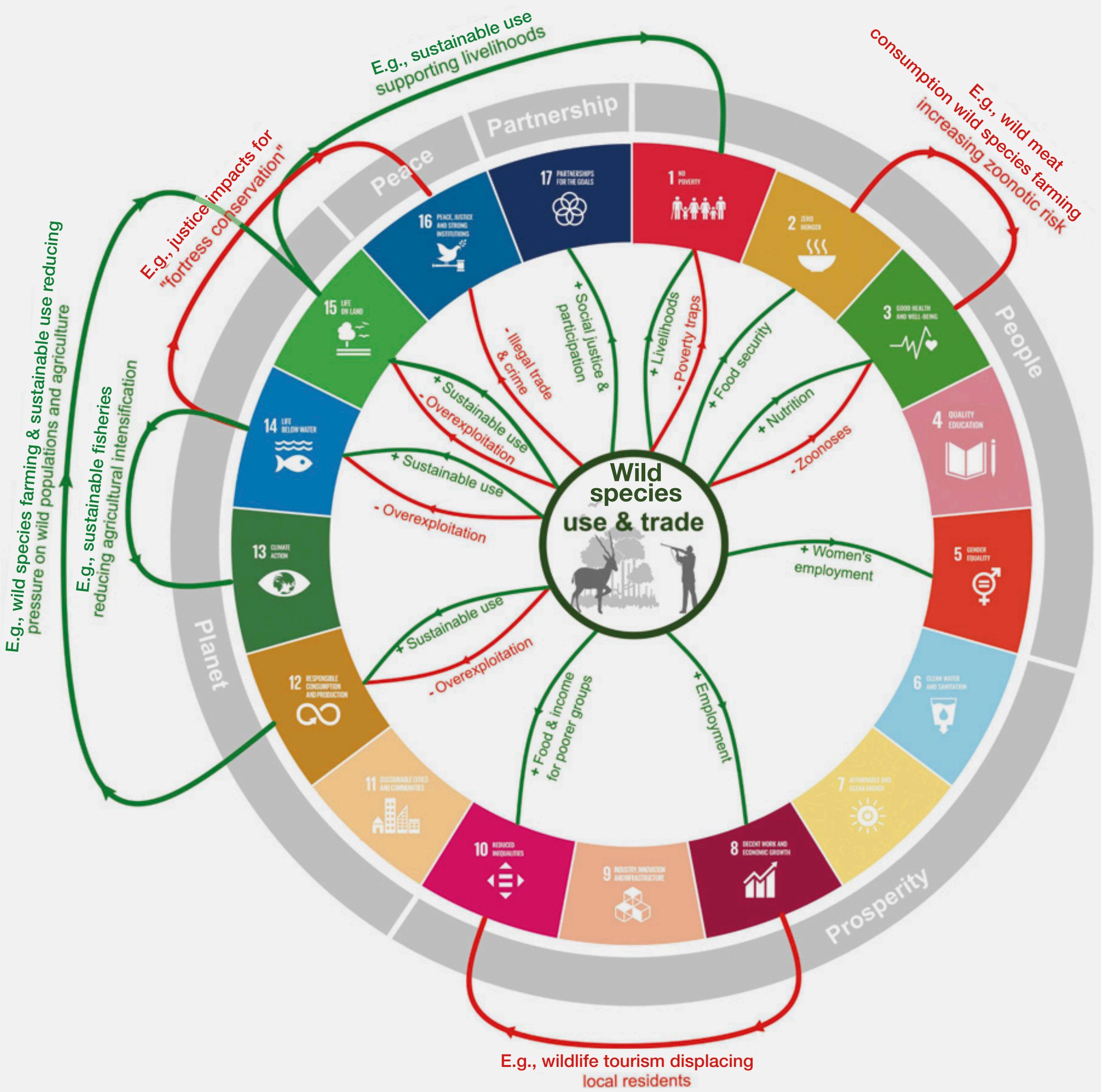


Figure 5 12 **Examples of positive (green) and negative (red) contributions of wild species trade to the Sustainable Development Goals.**

Source: Booth *et al.* (2021) under license CC-BY 4.0.

affected by interventions are foremost in the design of these interventions.

An appropriate mix of interventions, predicated on a good understanding of such costs and benefits, could promote a transition from vicious cycles of unsustainable use to virtuous cycles of sustainable use **(Figure 5.11a)**. In order to be effective, these interventions need to target both micro-level changes to transform individual human actions, and macro-level changes, which can transform social structures and norms (Naito *et al.*, 2021). For example, regulations can act as structural interventions which recraft the choice environment, while behavioral interventions, such as enforcement of regulations, positive economic incentives or promotion of goodwill values, can address socio-psychological barriers and act as enablers which promote pro-environmental social change **(Figure 5.11b)**.

A transformative shift to a virtuous cycle may be feasible under almost all of the IPBES archetype scenarios and positive visions (Lundquist *et al.*, 2017), provided certain enabling conditions and leverage points are in place.

Transformative processes may start with technological innovation which, if combined with social transformation, can signal a fundamental transition in a new direction. Enabling conditions (Pereira *et al.*, 2015) for transformations to sustainability include emancipation and empowerment, knowledge co-production, iterative learning and a political environment that encourages and nurtures innovations. Building blocks are intermediate conditions for transition. In small-scale fisheries, for example, five building blocks (local leadership, secure funding, support from local government, cooperation and awareness) were identified in a Vietnamese lagoon fishery (Andrachuk *et al.*, 2018; **Figure 5.13**).

To drive transformative change at scale, it will be necessary to set a united outcome-based vision for nature and people, which will provide an overarching "direction of travel" for other leverage points. These leverage points include: political prioritization (including coordinated policy at the international, national and local levels), aligned incentives and participatory processes (including transparent decision-making), which enable social change at micro- and macro-levels, supported by positively-framed approaches to adaptation and technological advances **(Box 5.11**, **Figure 5.14)**.

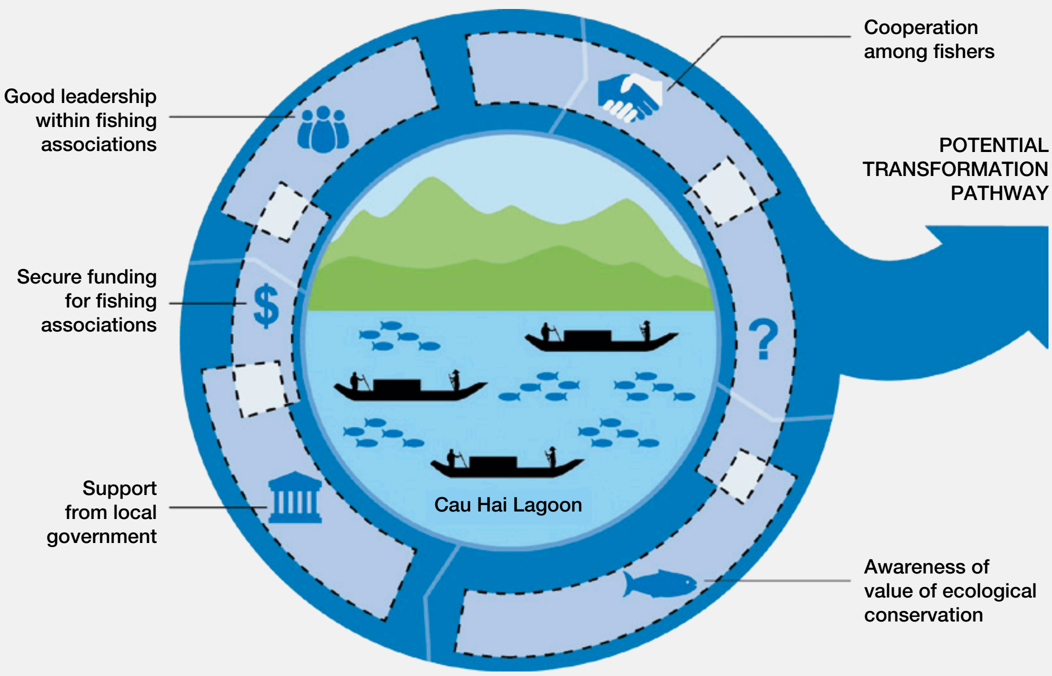


Figure 5 13 **Building blocks for social-ecological transformation in the Cau Hai Lagoon.**

Dotted blocks suggest supporting conditions for transformation; the nonlinear arrangements of blocks along the pathway is a reminder that building blocks will not be the same for all fishing associations.
Source: Andrachuk *et al.* (2018) under license CC BY-NC-ND 4.0.

Box 5 11 **Leverage points for transformation to sustainability.**

Drawing on the findings of the IPBES Global Assessment of Biodiversity and Ecosystem Services, Chan *et al.* (2020) highlight eight leverage points for transformation to sustainability, which may equally apply to sustainable use (**Figure 5.14**). These leverage points can be shifted, using five interrelated "levers". Chan *et al.* (2020) make the point that these elements are "non-substitutable", and, when used together, may lead to "synergistic benefits".

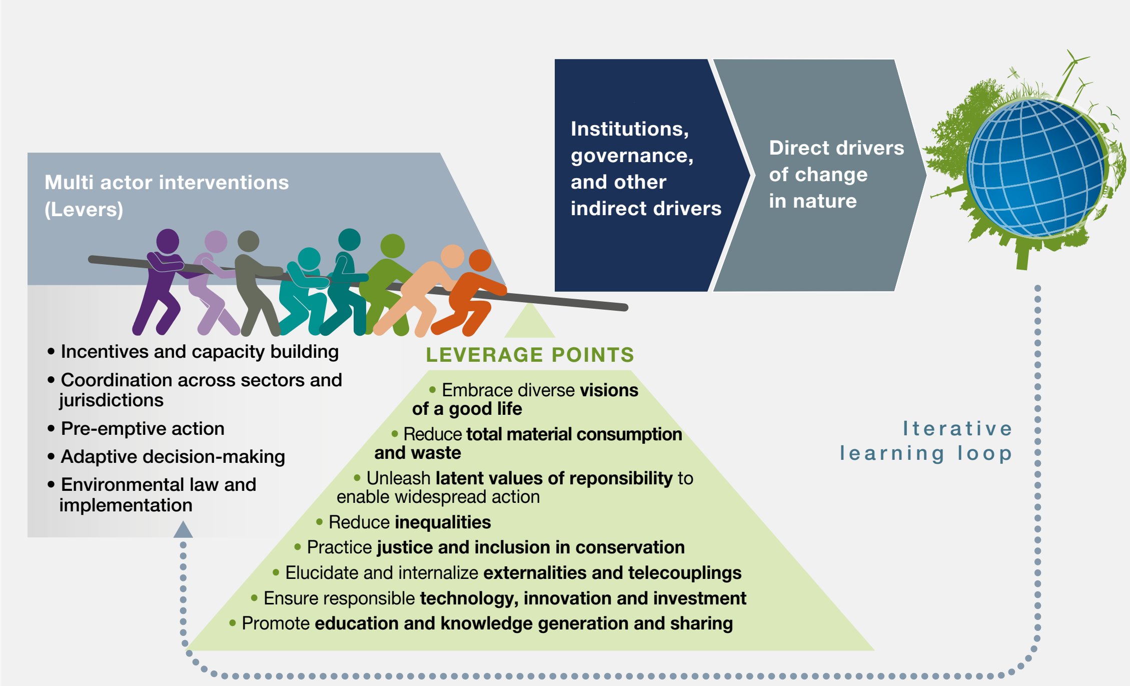


Figure 5 14 **Implementation of interventions (levers) targeting key leverage points to enable transformative change towards greater sustainability.**

A range of actors (such as intergovernmental organizations, governments, non-governmental organizations, citizen and community groups, indigenous peoples and local communities, donor agencies, science and educational organizations and the private sector) can apply the levers at multiple leverage points. Source: Chan *et al.* (2020), under license CC-BY 4.0.

5.9.2 Setting an outcome-based vision for nature and people

A key first step in enhancing sustainable use of wild species is to set a united and aspirational outcome goal for nature and people, which focuses on a desired end state (Bull *et al.*, 2020; Maron *et al.*, 2021). This is in contrast to process- or performance-based goals, which outline specific approaches or standards for achieving the end state (i.e., outcome goals focus on the ends, while process- or performance-based goals typically focus on the means).

In this case, the desired goal(s) may be, for example, sustainable use of wild species helping to "create a better and more sustainable future for all" and/or to "save lives, protect livelihoods and safeguard nature" (Booth *et al.*, 2021; Settele *et al.*, 2020). Similarly, the Convention on Biological Diversity's 2050 vision of "living in harmony with nature", underpinned by a target of nature recovery, could provide a broad aspirational outcome goal within which to embed diverse strategies for enhancing the sustainable use of wild species. Importantly, these outcome goals allow for a plurality of values (as per the nature futures framework), which can consider the multi-dimensional well-being of all living things, both humans and non-human.

Such outcome-based goals can provide a common vision towards which diverse stakeholders at multiple levels of society can work, whilst allowing for a plurality of approaches to get there. This means specific interventions can be designed to suit different species and contexts, allowing room for different values (i.e., as per the nature futures framework, nature for nature, nature for society and nature as culture), and integrating multiple international priorities **(Box 5.10; Box 5.11)** under different multilateral environmental agreements. It also limits potential perverse ecological outcomes, cost inefficiencies and social losses that can come from setting "one-size-fits-all" process-based or activity-based goals (e.g., for protected area coverage; Banks-Leite *et al.*, 2021).

However, ambitious outcome goals alone are not enough to drive transformative change. There is a need to "mainstream" nature, by translating high-level goals into meaningful and inclusive actions at multiple scales throughout society **(Box 5.11)**. Coordination between multilateral conventions and between different arms of government, business and civil society may lead to the "enabling" leverage points.

5.9.3 Political prioritization: embedding nature within high-level political targets

Enhancing sustainable use of wild species requires making the management of human-nature interactions a top political priority, with decision-makers committed to inclusive, equitable, and evidence-based policies and nature mainstreamed across all government sectors. Policy windows ("the emergence of junctures or openings for concerted action", Armitage *et al.*, 2011) are crucial to overcoming political inertia, particularly in the early stages of transformation, and may open new possibilities for incentive systems and new ways of allocating access rights.

In light of the COVID-19 pandemic, there have been calls for a "green recovery". Nature is also increasingly acknowledged as an economic priority, as reflected in the 2020 World Economic Risk Report and the Dasgupta review (Dasgupta, 2021b). This high-level prioritization and mainstreaming of nature into economic decisions could help to pave the way for enhancing sustainable use of wild species in the future. As reflected in the seven IPBES visions, to ensure a full societal shift towards sustainable use, this needs to be supported by shifts in high-level political targets, from growth-oriented goals which over-represent economic welfare (i.e., gross domestic product) relative to goals based on holistic social welfare and long-term sustainability. Changing this focus could help facilitate moves towards de-growth, ecological optimization and/or circular economy paradigms, which ensure that economic activities do not overexploit wild species.

5.9.4 Aligned incentives: ensuring people are not worse off via appropriate instrument mixes

Enhancing sustainable use of wild species will require behavior change and innovation across all sectors of society. Broadly speaking, there are two main types of instruments which can facilitate this transformational change: regulatory and market-based interventions (Young & Gunningham, 1997). Regulations are needed which consider both the bio-economics of the sustainable use of different species and ecosystems and the socio-economic costs and benefits of their use. Under the nature futures framework, in situations in which "nature for nature" is a dominant paradigm, extractive use of wild species can be prohibited while allowing for well-regulated non-extractive practices such as photographic tourism. In "nature for society" situations, regulations such as standards and quotas can help to ensure that use is compatible with the survival of wild species. Such regulations are effective safeguards for sustainability when they are also associated with robust monitoring and adaptive management, as well as with strong institutions which can insulate against poor governance (Young & Gunningham, 1997).

Regulations can also be supported by complementary rights- and incentive-based instruments for aligning socio-economic and sustainable use objectives, especially where indigenous peoples and local communities may be impacted. For example, in "nature for society" situations, where commercial use of wild species can be compatible with their survival in the wild, and with the economic welfare of society, mechanisms need to be put in place to ensure appropriate distribution of these economic benefits to people who are living in association with wild species, or who can act as stewards of wild populations and/or their habitats. An example is the commercial hunting of bighorn sheep in Mexico, where local people provide access and guiding services to hunters, and income from hunting permits supports habitat management and payments to communities (Cooney *et al.*, 2019). Another is the harvesting of saltwater crocodile eggs in the Northern Territory of Australia, where indigenous communities have use rights to benefit directly from egg harvesting, while outsiders can harvest eggs for an access fee (Fukuda & Webb, 2019). Appropriate interventions to enhance sustainability may include supporting local communities to achieve secure tenure of their resources, and promoting social justice and equity, such as implementation of conservation basic income schemes (Fletcher & Büscher, 2020).

In "nature for nature" situations, it may be necessary to directly reward or compensate people for protecting wild species and their habitats. Examples include shark reef in Fiji, where fisher communities are directly paid for protecting a no-take zone (WCS, 2020), and performance-based payments to protect endangered ibis in Cambodia (Clements *et al.*, 2010). Similarly, it may be necessary to develop negative incentives for unsustainable damage to wild species, for example through systems of "green" or "blue" taxes which are levied against corporations that exploit wild species (Zhou & Segerson, 2012).

In general, it will be important to set social outcome goals alongside nature outcome goals, such as ensuring people have higher well-being as a result of conservation interventions (Griffiths *et al.*, 2019).

5.9.5 Intrinsic motivations: driving behavioral tipping points though social norms

Intrinsic motivations, such as social norms, can interact with regulatory and market-based approaches and drive large-scale behavioral change across systems (Nyborg *et al.*, 2016). For example, leveraging social change through social marketing techniques could create positive outcomes for wild species, by both discouraging illegal and unsustainable use of wild species (e.g., products directly derived from protected or endangered wild species, and products that indirectly drive loss of nature such as industrial domestic animal production, Chaves *et al.*, 2018; Doughty *et al.*, 2020) and promoting behavioral shifts towards more environmentally-friendly diets (e.g., more plant-based diets and sustainably sourced animal products, Nyborg *et al.*, 2016). Novel approaches to producing social change include deploying social media and mobile technology, for example through targeted advertisements or inducing peer pressure via online social networks (Doughty *et al.*, 2020; Mani *et al.*, 2013), or through improved supply chain traceability and sharing of knowledge and data on the impacts of different actors on wild species (Österblom *et al.*, 2017).

Consumer awareness and social change can also drive corporate social responsibility for sustainable use of wild species or work in synergy with corporate activism. For example, a global science-business initiative for ocean stewardship has been created to enhance sustainable use of wild fish stocks by using data and transparency to drive corporate and consumer change (Österblom *et al.*, 2017).

5.9.6 Transparent, participatory processes and adaptive management

Good policy interventions and socio-economic instruments are co-designed with affected people, and consider in particular social justice and equity, both in terms of process and outcomes. To do so, participatory processes and transparency with respect to value-based judgements are useful (DeFries & Nagendra, 2017; Kenter *et al.*, 2011). They can in turn improve the social legitimacy of interventions promoting the sustainability of the use of wild species and their effectiveness in driving sustainability through behavior change (Bonwitt *et al.*, 2018; Levi *et al.*, 2009). In cases where the values of different stakeholders diverge, techniques such as describing and sharing mental models can help to improve common understanding about complex issues (Biggs *et al.*, 2011), while positive message framing can promote inclusive action (Jacobson *et al.*, 2019).

All interventions to enhance sustainable use of wild species will also require adaptive management. For complex, dynamic issues like wild species use, there is rarely one static universal solution. This requires that the impacts of interventions are assessed, with room for "optimistic" and "fail safe" adaptation, that provides room for learning from failures, and allows challenges to contribute to institutional knowledge (Catalano *et al.*, 2019). Horizon scanning may also be a useful component of an adaptive approach to transformative change in dynamic systems, which can be used to inform scenario-building and policy formulation **(Box 5.12)**.

Box 5 12 A horizon scan of the illegal trade in wild species.

To help inform proactive policy responses in the face of uncertainty, Esmail *et al.* (2020) conducted a horizon scan of significant emerging issues for the illegal trade in wild species. This covers the hunting and gathering practices discussed above, with a focus on international trade. Building upon existing iterative horizon scanning methods, they used an open and participatory approach to evaluate and rank issues from a diverse range of sources. The top 20 issues fell under three overarching themes: (i) Geographic (political, demographic and socio-economic) shifts and influences; (ii) Scientific and technological innovation, and (iii) Changing trends in demand and information (see **Figure 5.15**). Issues under the first theme include changing geopolitical processes and the rising global influence of East Asia. Political, demographic and economic changes could facilitate greater access to wild species and stimulate growing demand for wild species products, but also opportunities for sustainable use. For example, the political and cultural revival of traditional Chinese medicine, the increasing role of China in developing countries, and the rapid expansion of new international trade routes, particularly in the context of the Belt and Road Initiative, could bring both new threats and new opportunities for sustainable wild species trade (Esmail *et al.* 2020).

Issues under the second theme fell into two broad categories: biotechnology and information technology. For example, genetic technological advancements could enable rapid, cost-effective assessments and traceability of product identity and source at the species and individual levels. This could lead to better enforcement of regulations, and potentially promote sustainable sourcing. Cross-thematic issues which touch on the vicious-virtuous cycle of **Figure 5.15** included that, in the modern age of networked communication, misinformation (from market participants, intergovernmental bodies, non-governmental organizations, policymakers and/or the media) can rapidly influence policy and practice. This can be difficult to correct and can undermine conservation efforts by skewing policy responses and potentially misdirecting scarce resources. Horizon scans are meant to be repeated at regular intervals or when circumstances have changed. A post-COVID-19 scan would pick up some of the same issues (potentially intensified) as well as bringing in new ones (Esmail *et al.* 2020).

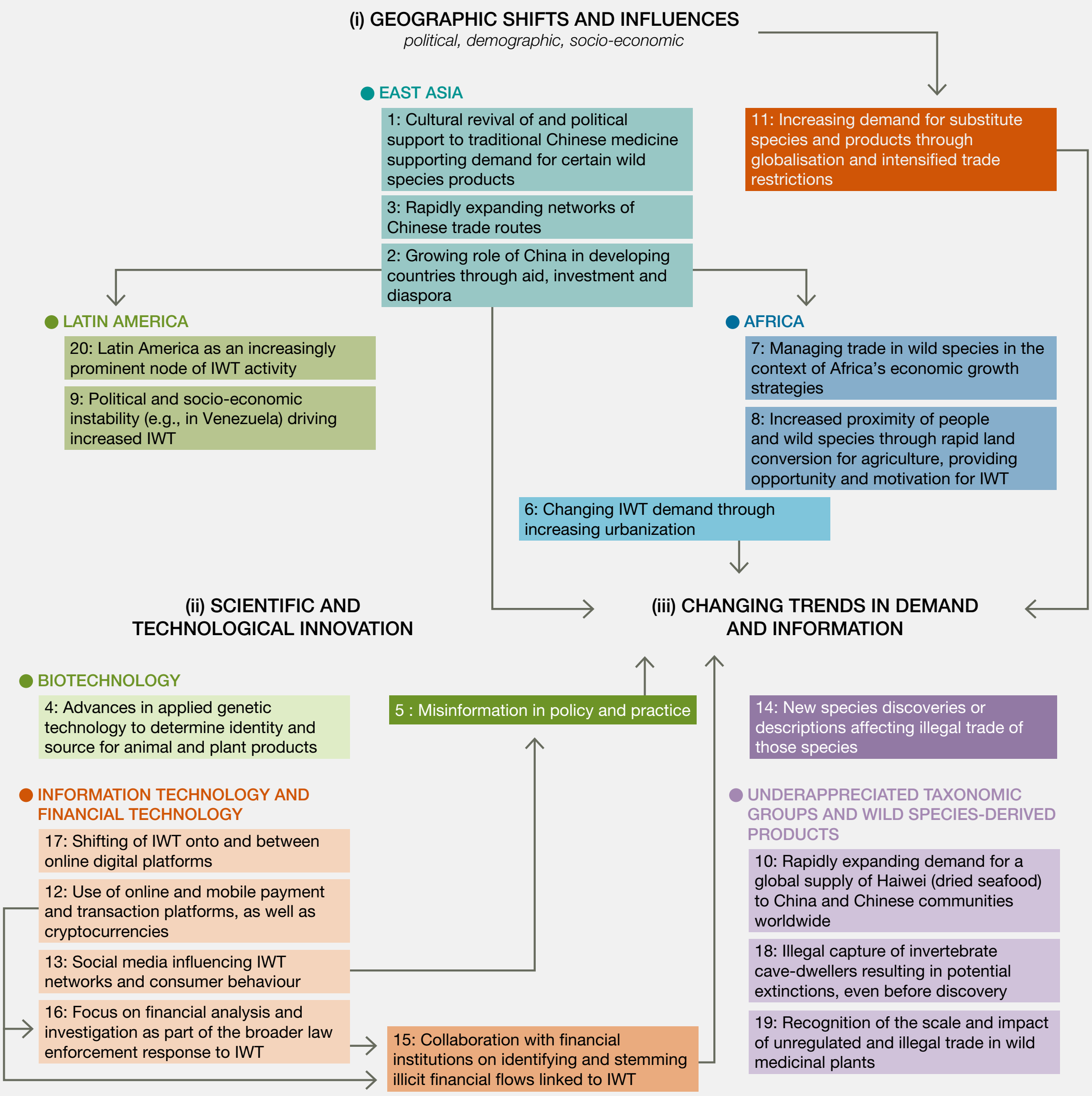


Figure 5 15 **The top 20 emerging illegal wild species trade issues, illustrating linkages between them.**

Numbering represents the rank order of the issues (referred to in the text as Horizon scan issues 1-20). Those outlined in black are cross-thematic issues. Abbreviations: IWT: International wild species trade.
Source: Esmail *et al.* (2020) under license CC-BY 4.0.

5.10 A CRITICAL REFLECTION ON INEQUALITY ISSUES WITH RESPECT TO THE SUSTAINABLE USE OF WILD SPECIES

Rising inequality is a major concern for the sustainability of economies, societies, and communities and necessitates an urgent research agenda to improve understanding of and responses to inequality (UNDESA, 2020). The sustainable use of wild species also requires particular attention to social inequalities, as was highlighted in each of the sectoral scenarios and pathways illustrated in this chapter and the vision for transformative change (section 5.8). Inequalities can be of opportunity, income, food access or other issues, and can be both within countries and between countries. They may also reflect gender and intergenerational issues. Inequality is one of the main drivers of social tension. The direct and indirect effects of the COVID-19 pandemic are strongly conditioned by inequality between countries and within countries, and as such, COVID-19 will likely worsen these inequalities (Naidoo & Fisher, 2020; Dasgupta, 2021b).

A critical reflection on social equity issues is crucial for the interpretation of the different types of scenarios that explore the future of wild species use and the trajectories that are proposed to move society towards more sustainable uses. Overall, vulnerable groups that depend on wild species have not been properly addressed in integrated assessments, models and forecasts (Gasalla, 2011, 2015; Martins & Gasalla, 2020). Although there are numerous studies that explore high-level, aggregate economic and environmental data, there is still a need for an examination of the specific underlying pathways linking different kinds of inequalities to behaviors that affect the sustainable use of wild species positively or negatively (Berthe & Elie, 2015; Hamann *et al.*, 2018).

As an example, natural capital stocks as a whole are shrinking and the consequent social costs of these changes have not yet been well assessed (Dasgupta, 2021a). When wild species resources are overexploited, people in vulnerable situations who depend on them for their livelihoods are usually disproportionately affected. The loss of earnings and opportunities also feeds into rising inequality within countries, as illustrated by **Figure 5.16**, where the mechanisms of transmission of wild species degradation into inequality within countries is shown.

Inequality is also characterized by social marginalization and exclusion. Social exclusion manifests primarily through unequal access to resources, limited political participation and voice and the denial of opportunities (UNDESA, 2016). Pastoral and fishing livelihoods have been severely undermined by decades of marginalization from policy and investment decision-making processes, violence and displacement, as well as insecure tenure rights and access (Gasalla, 2011). The lack of alternatives to the use of wild species has been critical, despite the human right to food being considered as a universal value and accepted as an international ethical standard (A. Sen, 2004; D'Odorico *et al.*, 2019).

Markets play a critical role in the demand for wild species. Scenarios showing market concentration, i.e., the dominance of a few actors within a specific natural resource management system, suggest that the consequences for marginalized groups can be severe. As the status of natural resources improves (e.g., healthier fish stocks), higher profits allow for further accumulation of capital, as well as investment in improving extraction or harvest technologies (Hamann *et al.*, 2015). When such investments allow firms to exploit cost advantages due to an increased scale of production, they further reinforce the trend towards market concentration (Martin *et al.*, 2012). This concentration of wealth and influence also leads to higher lobbying power, which can be used to sway policy decisions, thus strengthening the feedbacks between market concentration, capital accumulation, and management of the resource. In resource management systems with a high level of market concentration, a small number of powerful firms or actors therefore tend to dominate the total production of a certain resource (Hamann *et al.*, 2015). High market concentration thus implies a high level of inequality between firms or actors

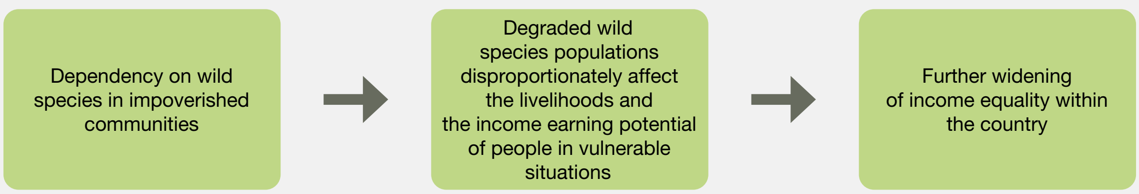


Figure 5 16 **A conceptual scenario chain for the relationship between poverty, inequality and wild species dependence.**

that use and manage the resource. Whether such inequality results in actions that are beneficial or detrimental to the sustainability of the use of wild species is highly context-dependent.

As an example, the implementation of certification schemes, such as the Marine Stewardship Council, can promote the sustainable harvest of marine wild-species through the implementation of rules and monitoring (Gómez Tovar *et al.*, 2005), but can also exclude marginal actors given the cost of compliance with the certification regime (Bush *et al.*, 2013; Cumming, 2007; Jacquet *et al.*, 2010). Hence, certification can directly influence resources and promote sustainability, but it can also reinforce market concentration and increase social and economic inequalities.

In a globalizing world, wealth will inevitably be appropriated by a very small fraction of the population unless effective wealth-equalizing institutions emerge at the global level (Scheffer *et al.*, 2017). Wealth inequality may have emerged as far back as the Neolithic era but the relative amount of wealth appropriated by the richest has increased as societies have scaled up. It happens due to the scale effect itself, and because installing effective institutions to dampen inequality becomes more challenging as scale increases (Scheffer *et al.*, 2017).

Excessive concentration of wealth is widely thought to hamper economic growth, concentrate power in the hands of a small elite and increase the chance of social unrest and political instability (Piketty & Saez, 2014). Whether the pathways for effective governance can now be achieved at the global level and, if so, what this new form of governance might look like, remain unclear (Scheffer *et al.*, 2017).

Nevertheless, several studies suggest that the reduction of inequality will have an important role in achieving environmental sustainability as a whole, including the use of wild species. Reduction of inequality is challenging. Within a country, the national government can take various fiscal and asset redistribution policies to reduce inequality. Fiscal policies involving taxes and cash transfers are more politically feasible than asset redistribution policies are. In most developed countries a significant portion of the national income (sometimes exceeding fifty per cent) is indeed taxed and redistributed, so that the distribution of "net" (or disposable) income is much less unequal than the distribution of "market" (or gross) income. Such extensive and deep redistribution of income however is yet to be instituted in most developing countries (Islam, 2015). Reduction of inequality at the international level is difficult to achieve, because there is no "global government" with redistributive power similar to that of a national government. However, the international inequality situation is changing as a result of the operation of spontaneous economic forces. The "rise of the South" and formation of "the Group of Twenty (G20)" are manifestations of these changes. An important task for the future is therefore to harness these changes and consider how to apply them towards the sustainable use of wild species.

All these considerations are critical to improving social justice and human rights issues and incorporating them into future scenarios of the sustainable use of wild species, especially with consideration of the roles of indigenous peoples and local communities. Hamann *et al.* (2018) explains the interactions between inequality and the use of wild species in social-ecological systems. These pathways of interaction represent a subset of possible interactions and a starting point for further research on inequality issues in scenarios.

5.11 KNOWLEDGE GAPS AND PRIORITIES FOR FUTURE RESEARCH AND ACTION

Critical knowledge gaps have arisen from evaluating the literature around scenarios of sustainable use of wild species. These include gaps for specific practices, scenarios types, and social-ecological aspects.

Beginning with individual practices, across almost all practices there is a deficit of scenarios that explore cultural aspects. The scenario literature on sustainable use predominantly pertains to fisheries and logging, and the impacts of climate change and/or management interventions and interactions with climate change. Other practices are under-represented, particularly for non-business-as-usual scenarios, as are scenarios and projections of cultural aspects, the role of indigenous peoples and local communities and rights-based approaches, and the intersection of broad top-down management and governance regimes with equity issues.

In addition to these gaps, there are specific gaps for each practice. For fishing, projections of climate change impacts are relatively common, but the translation of climate impacts coupled with governance and equity storylines to quantitative projections is limited, though scenario narratives exist at global scales (Maury *et al.*, 2017). Thus there is a need for more holistic scenarios. Projections for aquaculture and freshwater systems also remain more limited. Furthermore, scenarios of recreational fisheries in the future remain less common.

For gathering, many species have limited empirical data on production, trade volumes and revenues, making future projections of use challenging. In general, there is a lack of projections, scenarios and generalizations, though there are numerous studies on community-based management, which could perhaps be evaluated using a scenario-based approach.

For hunting, few scenario studies exist at all and they are difficult to generalize. A further exploration of comparative studies may help in building the evidence base necessary to produce more scenarios (e.g., Dobson *et al.* 2019). Other specific gaps are scenarios on the effects of environmental change, particularly climate-driven change, as a driver of changes in hunting practice, and on the role of hunting, including trophy hunting, in conservation.

For logging, as with fishing, there are a number of studies on the challenges of sustainable use brought about by climate change. However, these can be fairly narrow and need to be more integrative, suggesting the need for scenarios on the sustainable use of natural forests given the interactions between climate change, development, biodiversity, and poverty, and how differing contextual factors such as biomes can affect these interactions. Furthermore, as for all practices, projections of cultural aspects remain sparse.

For non-extractive practices, there are few scenario studies at all, and even fewer focused on a non-extractive practice in isolation. There is also almost nothing on economic aspects beyond tourism.

Going beyond individual practices, broadly speaking, there are numerous scenarios and projections on environmental sustainability writ large, biodiversity conservation and climate change, but wild species use is not often explicitly considered within these. There needs to be a greater focus on sustainable use within the context of more integrated solutions, and consideration of how sustainable use interacts with conservation and other elements of a broadly sustainable society. Furthermore, when sustainable use is considered, it is less frequently under archetype scenarios corresponding to fortress world and inequality. Broad studies on these scenario types do exist, but again need to explicitly link to the sustainable use of wild species.

Finally, vulnerable groups who depend on wild species are not well represented in scenarios and projections, nor are issues around inequalities more generally, and how these inequalities affect the sustainable use of wild species.

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Chapter 6

POLICY OPTIONS FOR GOVERNING SUSTAINABLE USE OF WILD SPECIES[1]

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Chapter **6**

POLICY OPTIONS FOR GOVERNING SUSTAINABLE USE OF WILD SPECIES

EXECUTIVE SUMMARY

This chapter reviews the range of policy options available for the sustainable use of wild species. Four broad and overlapping categories of instruments are considered: i) legal and regulatory, ii) economic and financial, iii) social and information based, and iv) customary and rights based. Evidence for their effectiveness in supporting the governance of socio-ecologically sustainable use is evaluated, and key enabling and constraining conditions determined. This information is intended to support decision-makers and society in steering towards a desirable future (see Chapter 5).

A mix of instruments tends to be used in combination and applied across different social and ecological contexts *(well established)* {6.4; 6.5}. Furthermore, evaluations of policy instruments are seldom systematic or controlled, making it difficult to fully disentangle policy effectiveness {6.5.1} or establish causality between implementation of a policy instrument and resulting social-ecological sustainability {6.5.1}. Where effectiveness is evaluated, there is a risk that evaluations are based on normative interpretations of those involved. In order to minimize bias, Chapter 6's experts therefore define effectiveness as 'the ability to support sustainable use', which by necessity includes analyses of the governance context {6.3}. Below are the key messages emerging from Chapter 6, that are expanded in detail in the chapter.

1 **Ensuring 'inclusive participation' is an underlying principle of governance and can support more effective sustainable use policies *(well established)* {6.5.4; 6.5.5.1; 6.6.1}.** Specific actions to promote inclusive and participatory processes include enacting policies with clear guidance on procedures for decision-making and representation (e.g., specifying membership roles and responsibilities) and building capacity that enables all parties to participate fully *(well established)* {6.5.1.1, 6.6.1}. When processes and procedures support and enable the inclusion of all actors, traditions, knowledges, and contexts, transformative change in sustainable use is possible *(well established)* {6.4.4, 6.5.2, 6.6.1}. Full and effective participation in the sustainable use of wild species can support effective learning and reduce redundancy (e.g., *via* knowledge brokers, mediators, facilitators). Outcomes are also likely to be better supported by communities and all stakeholders, and damaging power dynamics can be illuminated and navigated *(well established)* {6.5.1.1, 6.6.1}. Such participatory mechanisms are more effective when implemented through inclusive processes that integrate customary and statutory laws, include participation of indigenous peoples and local communities in policy design, recognize gendered differences in the knowledge and practices of uses of wild species and include close follow up through monitoring *(well established)* {6.5.2.2}. Conservation instruments such as protected areas or other effective conservation measures can also contribute to the sustainability of the use of wild species *(well established)* {6.5.1.1}. However, to be effective, protected areas should be inclusive of indigenous peoples and local communities and other people involved, avoid displacing indigenous peoples, local communities, and dependent livelihoods, and be embedded in larger planning processes, and have a full implementation strategy *(well established)* {6.5, 6.5.1.1}.

Legal and regulatory, and economic and financial policy instruments are more effective, when developed through democratic, and participatory processes, that involve representative leaders, transparent institutions, community-based approaches, and collective rights *(well established)* {6.5.1.1, 6.5.2.2, 6.6.1}. Legitimate participatory processes that involve a more equal balance of power, tend to support more effective policies because they draw on diverse perspectives and forms of knowledge, support collaboration, and increase buy-in leading to better self-regulation {6.5.1.1.}. This is especially the case for high value species *(established but incomplete)* {6.5.2.1, 6.5.3.1}.

2 **Elevating 'respect for multiple forms of knowledge' and 'protection of human rights' as values and principles that underpin governance, can lead to more effective sustainable use policies *(well established)* {6.5.2.2; 6.5.3.3; 6.6.2}.** The knowledge of indigenous peoples and local communities, such as on wild species is often undervalued and underrepresented in policy documents *(well established)* {6.4.4.3, 6.5.2.2, 6.6.2}. Yet, this knowledge can provide extensive, additional information about the relationships between living beings and the environment, especially with regards to natural resources and ecosystem services that indigenous peoples and local communities depend on *(well established)* {6.4.4.3} (also see Chapter 1). Retention and contributions of indigenous

and local knowledge is necessarily linked to their rights to natural resources and their access to these resources. The cultural, linguistic, spiritual, and material survival of these knowledge systems is also tied to their recognition *(well established)* {6.4.4.3}. Coproduction of knowledge by indigenous peoples and local communities and scientists can also create robust information about social and ecological conditions and enhance decision-making *(well established)* {6.5.1.1, 6.5.1.2.}. Inclusion of indigenous peoples and local communities in the development and implementation of policies for sustainable use of wild species requires sustained commitment and recognition of both systems as authoritative, but in doing so can be mutually beneficial. It is also important that engagements with indigenous peoples and local communities observe free, prior and informed consent and follow international protocols on access and benefit sharing, for example based on the Nagoya Protocol *(well established)* {6.4.4.2, 6.5.2.4, 6.5.3.3}. Legal and regulatory instruments are more effective when they take into account indigenous and local knowledge and science *(well established)* {6.5.3.3}. The failure to include indigenous and local knowledge and indigenous languages in policy processes and their implementation results in the loss of languages, weakened community cohesion, and diminished indigenous and local knowledge related to species and sustainable use, that can erode sustainable use practices *(well established)* {6.4.3, 6.4.4, 6.4.4.2, 6.6.2}. The sustainable use of wild species is integral to people living well and within their means and also supports human rights, including access to food, work, leisure, and a clean, healthy and sustainable environment *(well established)* {6.4.4}. Thus, international laws, guidelines, and commitments exist to protect local food systems and livelihoods of indigenous peoples and local communities in recognition of both a moral obligation, and pragmatic reality that these can help support the sustainable use of wild species *(well established)* {6.4.4.4}.

3 Embedding 'benefit sharing' and 'equity' as central elements of governance, can lead to more effective sustainable use policies *(well established)* {6.4.3.1; 6.5.2.1; 6.6.3}. The fair and equitable distribution of benefits from the sustainable use of wild species needs is increasingly promoted in voluntary, state, and private legislation; but its implementation is often incomplete and needs greater support *(well established)* {6.4.1.1, 6.4.3.1; 6.5.2.1; 6.6, 6.6.3}. People's perceptions of fairness and justice shape their willingness to comply with regulations that govern sustainable use {6.4.3}. Small producers, who lack political or economic power, can easily lose out if measures are drafted in a way that primarily promotes the interests of the advantaged *(well established)* {6.5.2}. There are often gender inequities in how costs and benefits of wild species uses are distributed, with women bearing more of the costs and receiving fewer benefits of use *(well established)* {6.4.3, 6.4.4, 6.5.4.1}. Although penalties can be effective in some cases, such as hunting fines *(well established)* {6.4.4.3, 6.4.5}, financial and economic policies tend to be more effective when based on incentives (e.g., tax breaks, certification, market access or compensation) rather than penalties (e.g., taxes, fines, or restrictions). Specific actions and plans could include enacting guidelines on access and benefit sharing that are currently common in voluntary agreements, applying governance and institutional frameworks that ensure fair and equitable distribution of costs and benefits. This may ensure that policies do not inadvertently criminalize or deprive local communities or marginalized individuals of access and equitable distribution of costs and benefits, and identify measures that may ensure preventing the misappropriation of genetic resources and associated traditional knowledge *(well established)* {6.4.4, 6.6.3}.

4 Effectiveness of market-based incentives, such as certification and labelling, is mixed and mostly limited to high value markets *(established but incomplete)* {6.4.3.1}. Certification and labelling schemes operate on the premise that providing information to consumers will result in a market shift that favors sustainable products, thereby incentivizing and rewarding sustainable practices by producers through price premiums and increased market share *(well established)* {6.4.3.1, 6.5.1.2}. In general, certification and labelling, when carefully designed and implemented, can promote ecological, economic and to a lesser extent social sustainability, but benefits have largely been for large scale operations and where there is a high market demand *(established but incomplete)* {6.4.3.1, 6.5.1.3}. Mechanisms, such as certifications or regulation, are most effective when they enable the equitable sharing of both monetary and non-monetary benefits, include marginalized communities and indigenous groups, and when the administrative costs of such systems do not exceed their benefits *(well established)* {6.4.3.1, 6.5.2}. Certification and labelling are widely used in large-scale commercial fishing, logging, and non-extractive recreational practices. In the cases of fishing and logging, certification and labelling frequently have been successful in securing and increasing market share, but it is unclear how often certification supports transitions from unsustainable to sustainable practices *(established but incomplete)* {6.4.3.1}. Certification may also lead to a specialization around a few value chains. Furthermore, market-based incentives have generally not delivered price premiums for producers *(well established)* {6.4.3.1}. Relatively high costs to obtain certification, satisfy ongoing reporting requirements and realize market benefits, often place certification beyond the reach of small-scale producers, including indigenous peoples and local communities *(established but incomplete)* {6.4.3.1, 6.5.2}. The viability of market-based incentives such as certifications and labelling, depend also on appropriate design in line with international trade regulations *(established but incomplete)* {6.4.3.1}.

5 Governance processes that are designed to coordinate interactions across scale, including across the spectrum of customary to statutory forms of governance, support more effective sustainable use policies *(well established)* {6.5.1.2, 6.5.2.3, 6.5.3.3, 6.6.4, 6.6.6}. When policy instruments are aligned (i.e., across scales, incentives, or allowable activities) or designed to reinforce one another they result in more positive outcomes *(well established)* {6.5.1.2}. Governance processes that pay attention to coordinating interactions between approaches, actors, and scales can result in more effective outcomes *(well established)* {6.5.2.3, 6.5.1.1}. Policies that are aligned at international, regional, national, sub-national, and local levels can be more effective at supporting sustainable use of wild species, with fewer negative and unintended consequences *(well established)* {6.5.1.2, 6.6}.

6 Governance institutions that are adaptive to changes in social and ecological conditions and robust with clear conflict resolution mechanisms support more effective sustainable use policies *(well established)* {6.5.1.3, 6.6.7}. Institutions that are structured around collaborative and decentralized learning and shared interests in sustainable use can create accountability through social norms, compliance and self-monitoring *(established but incomplete)* {6.3, 6.6.7}. Whereas, centralized systems, that often rely on legal and regulatory approaches, require sufficient investment of resources and capacity for monitoring and enforcement to ensure institutions are robust, which in turn results in more effective sustainable use policies *(well established)* {6.5.1.3}.

The social and ecological conditions under which uses of wild species occur are always dynamic. Consequently, policy instruments and management tools are most effective when they address causes of unsustainable use and adapt to changing circumstances *(well established)* {6.5.2}. Adaptive processes are enhanced by collaborative learning and governance. Successful co-learning is characterized by comprehensive, continuous, iterative and transparent engagement between key actors, including governance institutions and those who depend on wild species for their livelihoods and wellbeing *(well established)* {6.5}. Moreover, adaptive and dynamic institutions, capable of adjusting to changing circumstances are more likely to support the sustainable use of wild species in the face of current and future drivers *(established but incomplete)* {6.6.1, 6.5.1.2}. The integration of conflict resolution mechanisms can make institutions more effective, while transparency initiatives connected to legally mandated measures of accountability can enhance trust in institutions, resulting in more effective policies *(well established)* {6.5.4.1, 6.6.3}. Facilitators trained in conflict resolution can help formulate equitable and viable policies *(established but incomplete)* {6.5.2.3}.

7 Policies that are tailored to the context can support effective policies for sustainable use of wild species *(well established)* {6.4.1, 6.4.1.2, 6.4.3, 6.4.4, 6.5.1, 6.5.2.3, 6.5.2.1, 6.5.3.1, 6.6.4}. Policies are more effective when tailored to local ecological, social and governance contexts *(well established)* {6.4.1, 6.5.2.1, 6.6.4}. Such approaches are more likely to be designed to support equitable benefit sharing, thus providing an enabling environment for indigenous peoples and local communities to benefit *(established but incomplete)* {6.5.1}. For example, the diversity of contexts in which small-scale fisheries operate have often made conventional data-driven fisheries management inadequate and unsuccessful, but when the involvement, participation and empowerment of indigenous peoples and local communities are maintained or promoted, the sustainability of small-scale fisheries can be achieved *(well established)* {6.5.1.1, 6.5.3.1}. In contrast, policies based on assumptions or frameworks from outside a region or local context may lead to unanticipated outcomes *(well established)* {6.4.3, 6.5.2.1, 6.5.2.3}. For example, bans are more effective when they take into consideration species characteristics (e.g., reproductivity, status), local customs, and traditional use *(well established)* {6.4.1.2}. In contrast, policies and regulations that fail to recognize and account for the diversity of uses and benefits associated with a practice, particularly differences between commercial and subsistence or small-scale actors, can lead to negative social and ecological outcomes *(well established)* {6.4.1.2, 6.4.3.1}. Similarly, customary and rights-based approaches can provide a more nuanced and effective approach to regulation where commercial demand is low, and practices and uses diverse *(established but incomplete)* {6.4.4, 6.5.1.2}. The need for policy "fit for purpose" is widely acknowledged but incompletely pursued *(well established)* {6.5.2.1, 6.5.4.2}. For example, community-based and nature-based tourism standards that combine legal and regulatory approaches with social and information-based approaches provide livelihood benefits to communities while protecting indigenous and local cultures and environments *(established but incomplete)* {6.4.1.3, 6.4.4.5}.

8 Policies that are clearly aligned with goals, and that clarify ownership and access rights and responsibilities, support more effective sustainable use policies *(established but incomplete)* {6.4.4.1, 6.5.1.1.2, 6.5.2.2}. For successful policy formation and implementation, policy goals and instruments need to be clearly identified, aligned, and shared with stakeholders *(well established)* {6.5.2.2}. Yet, often legal uncertainties, opaque policies, and a lack of resources inhibit the effectiveness of sustainable use policies *(well established)* {6.5.2.2}. Yet, when land tenure and resource rights are secure, customary law tends to be strong, and local capacity to manage the resource base and deal with commercial pressures exist *(established but incomplete)* {6.4.4, 6.5.2.2}. In contrast, where customary law has broken down to a significant degree, Governments can offer important and necessary complementary levels of regulation -often requested by local groups *(well established)* {6.4.4, 6.5.2.2}. When policies have clearly stated rather than generic goals, whether short or long term, they can be more effective (6.5.2.2). For example, restrictive hunting regulations are generally most effective at supporting sustainable use (i.e., through species recovery) when used in the transition to a new arrangement such as when conducting population studies for the establishment of harvesting (trade) quotas (e.g., in the case study of bighorn sheep in Mexico **(Box 6.10)**. In other cases, bans are established temporarily while populations recover, and later on, sustainable harvest limits are set.

9 Broader, national, policies that align with sustainable use policies and objectives, can support more effective sustainable policies. Broader policies, including poverty alleviation, national education, and linguistic policies can support sustainable use of natural resources amongst indigenous peoples and local communities, while laws protecting their local food systems and livelihoods will help sustainable use of wild species *(well established)* {6.5.2.3}. National education, communication, public awareness and linguistic policies could positively contribute to the sustainable use of wild resources but are seldom prioritized as policy options *(established but incomplete)* {6.4.3.2}. If well designed, strategic combinations of policies can simultaneously alleviate multiple drivers of unsustainable use and create a supportive environment for sustainable use of wild species *(well established)* {6.5.3, 6.6.4}. Moreover, the representation of livelihoods of indigenous peoples and local communities in schools could promote inter-cultural understanding and respect, community pride and desire to continue with traditional practices *(well established)* {6.4.3.2, 6.4.2.1, 6.5.2.3, 6.6.2}.

10 An over reliance on regulatory policies can impede sustainable use *(well established)* {6.4.5, 6.5.3.1}. A diversity of policy approaches exists and can be applied to various species, practices, and sets of actors or geographical areas *(well established)* {6.5.3.1}. However, Statutory legal and regulatory based instruments are the most commonly applied instruments to regulate wild species use *(well established)* {6.4.5, 6.5.3.1}. These are often applied as single-species regulations without wider ecosystem considerations and in some cases are applied without adequately considering existing customary laws and practices, the *de facto* practices of users, or what other approaches may be more effective {6.5.3.1}. Furthermore, legal and regulatory based instruments, most frequently target high value species, in particular within fishing and gathering practices, despite tending to be less effective than social or information based and customary and rights-based instruments *(well established)* {6.4.5}.

11 Policies that are too narrow or overly focused on economic or ecological outcomes, thus neglecting social and cultural contexts, can constrain sustainable use of wild species {6.4.3.1, 6.4.5, 6.5.1, 6.5.1.3}. Policies developed for a specific practice, user group, sector, species, or habitat will have impacts beyond the target of the policy that may be undesirable or unexpected {6.5.1}. Yet, policies tend to have a narrow focus, and as a result multispecies interactions, local context, and scale are seldom taken into account *(well established)* {6.5.1}. Indeed, policy instruments are most frequently targeted towards improved ecological, and at times economic, sustainability rather than social, or linked social-ecological sustainability *(well established)* {6.4.5}. For example, economic and financial instruments that secure access rights to land, water bodies, territories, and resources have been widely employed (e.g., individual transferable quotas) {6.4.5}, but are mostly motivated by economic efficiency and often overlook social equity. Similarly, social and information-based certifications have largely focused on large scale operations and where there is a high market demand, but can be successful at promoting ecological, economic and to a lesser extent social sustainability although policies and benefits thus far *(established but incomplete)* {6.4.3.1, 6.5.1.3}. Consequently, negative social outcomes and elite capture that concentrates benefits in the hands of few are common *(established but incomplete)* {6.5.1}.

12 Overlooking customary practices, rights, and indigenous and local knowledge can constrain sustainable use of wild species *(well established)* {6.5.3.3}. Policies that support secure tenure rights and equitable access to land, fisheries and forests as well as poverty alleviation, create enabling conditions for sustainable use of wild species *(well established)* {6.4.4.1}. When national sectoral policies are aligned with targeted policies to support local tenure of land, fisheries and forests, the synergy creates enabling conditions for the sustainable use of wild species. For example, policies that alleviate poverty, can also empower local customary institutions that, in turn, support sustainable use of wild species *(well established)* {6.5.1}. Historical policies on land tenure, land rights, and rights contain inadequate protection of access and rights to indigenous lands and water but national policies seldom align with customary laws and policies; which negatively affects sustainable use of wild species {6.5.3.3}. This precludes indigenous peoples and local communities from securing greater social-ecological benefits, reduces incentives for sustainable use, ultimately undermining policy effectiveness. Furthermore, the knowledge of indigenous peoples and local communities, such as on wild species, is often undervalued and underrepresented in policy documents {6.5.3.3}. This knowledge can provide extensive and additional information about the relationships between living beings and the environment, especially with regards to natural resources and nature's contributions to people that indigenous peoples and local communities depend on. Continuity and contributions of indigenous and local knowledge is necessarily linked to rights, access, recognition, and survival (cultural, linguistic, spiritual, and material). The failure to include indigenous and local knowledge in policy processes results in loss of language, community cohesion, and indigenous and local knowledge related to species and sustainable use.

13 Strengthening customary institutions and rules often contributes to the sustainable use of wild species *(well established)* {6.4.4.2}. Attention to customary institutions and rules governing uses of wild species can reduce conflicts and increase policy effectiveness *(well established)* {6.5}. Customary approaches can lower transaction costs for monitoring and enforcement compared with formal governance systems. For example, taboos limit use of individual species. Such customary approaches can support the ecological and economic dimensions of sustainability but are particularly effective at supporting its social dimensions. However, historical and cultural systems, such as taboos, have seldom been incorporated into policies for managing use of wild species *(well established)* {6.4.4.3}.

14 Policies that fail to adequately account for historical context can undermine sustainable use. The historical context into which a policy is developed and implemented affects policy outcomes *(well established)* {6.6.4}. Yet most laws are built incrementally and lack an overall strategy or clear objectives, consequently seemingly unrelated areas of law directly and indirectly impact the use of wild species, their management, and trade. New policy instruments that are added to a mix of existing instruments may work differently depending on historic and current conditions *(well established)* {6.5.3.2, 6.6.4}. Implementation can exacerbate pre-existing tensions, creating conflicts even where other enabling conditions are present *(well established)* {6.5.4.2}. A lack of alignment between current and historic polices undermines their effectiveness in supporting sustainable use {6.5.4.2, 6.6.3}.

15 Power imbalances can undermine sustainable use policies, creating conflicts and allowing corruption and abuse of power to persist *(well established)* {6.5.2.3, 6.5.4.3, 6.5.2.6}. Power imbalances need to be addressed and conflicts managed to guard against elite capture or the domination of a few powerful actors that undermine policy effectiveness. Power imbalances between different actors can shape their involvement in decision making, creating barriers to participation. For example, processors and traders often control sectors with small-scale producers and harvesters having limited power over, and access to, commercial trade and pricing. Small producers and harvesters, who lack such political or economic power, can easily lose out if measures are drafted in a way that does not fairly represent their interests *(established but incomplete)* {6.5.4.3}. Legitimate participatory processes that involve a more equal balance of power support more effective policies because they draw on diverse perspectives and forms of knowledge, support collaboration, and increase buy-in leading to better self-regulation *(well established)* {6.5.2.3, 6.5.4.3}. This is particularly important for species that are heavily traded with strong economic interests *(well established)* {6.5.4.3}. For example, regulations that follow voluntary codes of conduct, can have positive social effects but are dependent, for example, on the existence of strong norms, which are strengthened by actor participation {6.5.2.3}. Inequities and inequalities both within governance structures and across sustainable use actors can undermine sustainable use policies. For example, where corruption is allowed to emerge within governance processes this creates conflict and hampers implementation of regulatory measures.

16 Policies can inadvertently criminalize vulnerable people and local communities, which in turn constrains sustainable use policies. Policies may inadvertently criminalize harvesting activities, further marginalizing producers and constraining effective outcomes *(well established)* {6.4.1.2. 6.5.4.3}. Lack of clarity of regulations and the field knowledge give negative impacts to policy enforcement and effectiveness. In many countries, violations of many sustainable use regulations, such as the abuse of quotas, are treated as administrative offenses or misdemeanors, rather than as criminal offenses {6.4.1.2}.

6.1 INTRODUCTION

People are an integral part of nature and depend on its resources for survival. Therefore, for millennia, societies across the world have used a wide variety of wild species, from a range of ecosystems, and in different ways (see Chapter 1 and Chapter 2). However, increasing land use changes and subsequent degradation of natural habitats, as well as recent trends in the use of wild species (see Chapter 3) raise concerns for the future sustainability of these practices (IPBES, 2019b). In each region, different direct and indirect drivers influence those desired and undesired patterns (see Chapter 4). A greater understanding of the effectiveness of governance and policy options (Chapter 6) can support the transition towards more sustainable and desirable future trajectories (see Chapter 5) for the sustainable use of wild species.

According to the Convention of biological diversity, states are responsible for ensuring biological resources are valued and used in a sustainable manner. States, together with stakeholders, are expected to establish and implement biodiversity management policies. An improved understanding of the direct and indirect drivers behind these trends (see Chapter 4), should be used to inform the governance of wild species use. Biodiversity policy options and strategies implemented by a State, must co-exist with a broader set of strategies initiated by a range of actors from grassroots users and citizens through to inter – and multinational institutions, with varying levels of interaction and co-ordination between them. Consequently, the broader social (i.e., governance, economic, cultural, technological), and well as historical, and ecological contexts of each locality, influences how effective policies are likely to be in enhancing the sustainable use of species. This chapter explores the governance context, policy options, and responses available (Section 6.4) for the sustainable use of wild species. In doing so, it identifies key governance elements that support sustainable use, as well as enabling and constraining conditions (Section 6.5). The overarching goal is to elucidate levers to changes and policy options (Section 6.6) that hold promise or pose challenges to a sustainable future.

Evaluating the effectiveness of policies for the sustainable use of wild species requires an understanding of the governance landscape in any given setting. Chapter 6 draws on interactive governance theory (Section 6.3) to support its analyses of policy effectiveness with a particular focus on the interactions that occur among multiple actors. Building on an understanding of interactive governance, section 6.2 describes the methodological approach used for evaluating effectiveness.

Section 6.4 presents the range of policy instruments available to support the sustainable use of wild species, at a range of spatial scales (local, national, international), and across five key practices (fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices). Four groups of policy instruments are explored: i) legal and regulatory, ii) economic and financial, iii) social and information based, and iv) rights-based and customary instruments.

Section 6.5 synthesizes evidence on the governance context and effectiveness of policy instruments to identify key enabling and constraining conditions. Evaluating the impact and effectiveness of available policy instrument is crucial to ensure that limited financial and human resources available are used to maximize outcomes (Karousakis, 2018). The options explored include a combination of policy instruments and their integration with other environmental policy tools for promoting the sustainable use of wild species and their habitats. This includes consideration of the interests and rights of multiple actors including indigenous peoples and local communities, and ways in which conflict can be managed between different actors. Enabling and constraining conditions to policy effectiveness are identified, such as existing and emergent limitations, challenges, and opportunities.

Section 6.6 presents levers of changes learned of in the policy assessment and presents options for tested and emergent solutions for ensuring the sustainable use of wild species in diverse contexts.

Section 6.7 summarizes knowledge gaps identified in the assessment of policy effectiveness for the use of wild species.

6.2 METHODOLOGICAL APPROACH

Three iterative strategies and approaches were used to identify and assess relevant literature through which the status of knowledge on policy use and effectiveness was evaluated. This section therefore describes the methods used in this chapter in order to: i) assess what policy instruments are available to support the sustainable use of wild species; ii) determine how effective the policy instruments that have been used are across different practices; iii) establish what are key enabling and constraining conditions, including those that relate to governance contexts; iv) illuminate levers of change and policy options, and; iv) identify knowledge gaps.

1. General Review: Three strategies were pursued in tandem. First, all lead authors conducted an expert led review of the literature to gather, and synthesize available information on the application and effectiveness of policy options for the sustainable use of wild species. This broad search of the literature continued for the entire duration of the assessment. This was primarily used to summarize information on the availability and characteristics of policy instruments, and patterns of use (section 6.4). However, literature gathered was also used to supplement information on the effectiveness of policy options (section 6.5).

2. Mixed methods (systematic) review: Understanding what policy options are available, and evaluating the effectiveness of these options is an important stage in the policy cycle (Giorgi, 2017; E. Young & Quinn, 2002). Effectiveness refers to whether a policy works as intended and meets the purpose for which it was designed (Sadler, 1996). Policy effectiveness can be assessed in terms of objectives, outcomes and impacts (Broc *et al.*, 2018). Establishing when and why particular policy approaches are most likely to succeed is key to enabling the sustainable use of wild species. Because effectiveness is context specific, variables through time, practice, place, and culture, are considered to establish the conditions enabling or constraining policy effectiveness. The concept of "enabling conditions" centers on conditions that facilitate approaches to addressing social and ecological challenges. They can be defined as factors that increase the likelihood of an intended change in the governance approach, strategy, or management regime. The presence of enabling conditions can facilitate the emergence of a particular environmental policy, whereas the absence of key enabling conditions can present a barrier to management or sustained policy action (Huber-Stearns *et al.*, 2017). Assessing policy effectiveness contributes to understanding what worked as planned and providing inputs to the redesign or improvement of policies at the stage of policy evaluation. It contributes to narrowing a knowledge gap given the science-based justification for policy decisions (Artelle *et al.*, 2018). A systematic review process follows four steps: identification, screening, eligibility, and inclusion (Moher *et al.*, 2009). Chapter 6's experts followed, and where necessary adapted, the IPBES guidelines for a systematic review of the literature.

The initial literature search was conducted in English, in March 2020, in a bibliographic database, SCOPUS, which is one of the largest citation databases, but it does not include grey literature and is geographically biased to industrialized countries. Chapter 6's experts chose SCOPUS for its broad scope and accessibility across all experts, although other sources were used at a later date. Search fields included article title, abstract, and keywords. The search strings were a combination of the two major topics: use practices of wild species (terrestrial animal harvesting, fishing, etc.) and policy instruments (legal & regulatory, economic & financial, etc.) and designed in order to capture all forms and derivatives of the root word (e.g., fish* would capture fishing and fisher) (see data management report at https://doi.org/10.5281/zenodo.4663236). The search included all articles published during the whole period provided by database, which spanned the years 1975 to 2019. 1975 was the year when the experts found the firstly published article from the database.

Once articles had been identified from the search, the abstracts, and where necessary full article, were screened in April 2020 for initial eligibility by experts. Articles were retained if they: i) addressed the use of wild species; ii) were about one of the practices (terrestrial animal harvesting, fishing, gathering, logging, and non-extractive practices), and iii) contained information on the effectiveness of a policy response that fell under one of four policy instrument categories (legal & regulatory, economic & financial, social & information based, rights-based & customary); and, iv) reflected a positive example.

The initial systematic review identified a total of 4729 articles by practice and policy instrument. There were a number of duplicate articles due to the nature of our search terms. For example, a single article or case study could evaluate two or more policy instruments in which case it was picked up twice.

Following the initial screening of articles focusing on their relevance for policy effectiveness and use of wild species, only a few **(Table 6.1)** were selected as appropriate. This number indicated a lack of articles focused on assessing or measuring policy effectiveness in use practices of wild species. Because of lack of articles focused on evaluating policy options, or potential bias (Estes *et al.*, 2011; Isaksen & Richter, 2019), the experts conducted a supplementary expert review to supplement the initial list of articles with additional key cases.

Experts supplemented papers gathered in the first search with an additional expert led search of the field drawing on expert experience, extensive reading, and the collective network of international collaborators. This second phase included literature published in languages other than English, including Spanish, Portuguese, Russian, and Hindi.

Cases were selected from the systematic and expert review for further systematic analysis based on three criteria; i) causal leverage, ii) diversity, and iii) data accessibility. Causal leverage captures the extent to which effectiveness is demonstrated (Seawright & Gerring, 2008). The cases should include relevant information on the influence of policy effectiveness under the research framework. In this assessment, the cases should offer information on positive impacts and effects of policy instruments in use on practices or wild species and specific governance mode. Second, diversity is a major criterion of selecting cases (Seawright & Gerring, 2008). Diversity can reduce bias of selection. In this assessment, the cases were selected to consider geographical balance. Experts sought for representation across continents, climate zones, countries, policy characteristics, and characteristics of the practices (e.g., within fisheries we included industrial and small-scale case studies). A number of cases were cross scale- e.g., reflected two or more of local, national, regional, international or transnational issues. Third, data accessibility was for practical reasons a criterion for inclusion. Experts were only able to use case studies that were accessible in online databases, whether peer reviewed, grey literature, or open access databases.

Through the combination of systematic and expert searches the experts identified 100 policy-relevant cases, across all practices, spanning the range of policy approaches, for in-depth systematic analysis **(Table 6.1)** of the application and effectiveness of policy instruments across practice for the sustainable use of wild species. Each case study represented a body of knowledge, and therefore could contain a number of articles from the peer reviewed or grey literature.

The experts coded the 100 selected case studies, to allow for a systematic analysis to compare individual cases across policy instrument, practice, and geography **(Table 6.2)**, allowing them to postulate that certain attributes can be taken as criteria for assessing causality, e.g., (1) strength of association between the policy instruments application and sustainable use outcomes; (2) consistency of association in various conditions across ecosystems, practices and local contexts; (3) plausibility of causal explanations; (4) coherence with paradigms and knowledge of each practice;

Table 6 1 **Articles identified through systematic and expert review guide case study selection for systematic analysis.**

The number of articles searched, screened, and selected in systematic and expert review.

Practice	Instrument	Identification (Systematic Review)	Retained (Systematic Review)	Added (Expert Review)
Fishing	Legal and regulatory	321	4	9
	Economic and financial	151		
	Social and information-based	148		
	Right-based and customary	326		
Gathering	Legal and regulatory	51	5	28
	Economic and financial	50		
	Social and information-based	19		
	Right-based and customary	82		
Terrestrial animal harvesting	Legal and regulatory	275	7	8
	Economic and financial	166		
	Social and information-based	164		
	Right-based and customary	360		
Non-extractive practices	Legal and regulatory	773	7	21
	Economic and financial	212		
	Social and information-based	258		
	Right-based and customary	1114		
Logging	Legal and regulatory	77	0	11
	Economic and financial	41		
	Social and information-based	46		
	Right-based and customary	95		

and (5) temporality, where presence of attributes preceded success) (see data management report et https://doi.org/10.5281/zenodo.4663236).

Experts read all 100 case studies and coded them qualitatively, or based on a 3 points scale, to capture three case study characteristics, evaluate how effective the policy is at supporting four dimensions of sustainable use, specify enabling and constraining characteristics, comment on dimensions of the governance systems, and include any additional comments **(Table 6.3)**. Case study characteristics include: i) the most dominant practice it relates to (i.e., fishing, gathering, etc.); ii) policy instruments being evaluated (at least one of legal and regulation, economic and financial etc.); iii) relevant policy scale(s) (temporal, governance, and spatial).

Chapter 6's experts drew on the sustainable use indicators reviewed in chapter 2, criteria for effectiveness from selected publications (Alatorre-Frenk *et al.*, 2016; Arnstein, 1969; Diaz *et al.*, 2015; EUROSTAT, 2017; Gagnon & Berteaux, 2009; Lakon *et al.*, 2008; Ostrom & Ahn, 2003; Putnam, 2000), and the experts review to identify four dimensions of sustainable use and define effectiveness as 'the extent to which a policy supports sustainable use, whilst minimizing any adverse effects to external systems. Sustainable use was evaluated along four dimensions:

A. **Ecological sustainability** is where ecological objectives are met, including maintaining or improving species, habitats, diversity, and abundance.

B. **Social sustainability** is where social objectives are met including supporting equity, material, relational, and subjective wellbeing.

C. **Economic sustainability** is where economic objectives are met including sustaining income, livelihoods, and trade.

D. **Institutional sustainability** is where institutional objectives are met including enabling cost effective, participatory process, incorporation of indigenous and local knowledge, and integration between international and national regulations.

Each sustainable use dimension- ecological, social, economic and institutional- were coded as positive (+1) (i.e., policy manages to maintain or increase dimension), neutral (0) (i.e., mixed or no effect of policy on dimension), negative (-1) (i.e., despite, or because of policy dimension declines) or not enough evidence (n/a). Social and economic dimensions were separated for the purpose of analysis to illuminate common trade-offs and evident bias.

Effectiveness of a specific policy approach is likely to be influenced by enabling, constraining, and governance conditions. Enabling and constraining conditions, increase or decrease the likelihood of policy effectiveness, and we include social, ecological, technological, and cultural factors (e.g., resources, indigenous and local knowledge, species life history characteristics). For governance conditions the experts drew on our adapted interactive governance theory framework, to evaluate: i) interactions among actors; and, alignment is the ii) values, iii) rules, and iv) tools (Huber-Stearns *et al.*, 2017). This coding system allowed us to analyze policy effectiveness across all practices, policy instruments, and contexts, to evaluate effectiveness and determine common enabling and constraining conditions.

After coding all 100 cases, Chapter 6' experts found that 16 cases did not reflect a positive value in any aspects of sustainability. Because the focus of the assessment is on policy effectiveness, rather than ineffectiveness, these 16 cases were excluded from further evaluation of effectiveness. Consequently, all practices included

Table 6 2 **Number of cases by practice and region that were analyzed in chapter 6.**

Practice	Region							
	Asia	Africa	Europe	Oceania	North America	Central & South America	Other	TOTAL
Fishing	1	4	1	1	2	2	2	**13**
Gathering	12	6	6	0	1	6	2	**33**
Terrestrial animal harvesting	2	3	1	2	1	6	0	**15**
Non-extractive practices	6	8	2	7	0	3	2	**28**
Logging	3	1	4	0	1	1	1	**11**
TOTAL	**24**	**22**	**14**	**10**	**5**	**18**	**7**	**100**

more cases with positive effectiveness than with negative effectiveness. In total 84 cases of effective sustainable use policy, covering any aspect of sustainability, all practices and a range of geographies **(Table 6.3)** were coded, ready for analysis.

The systematic review focuses on providing evidence-based knowledge, acknowledging that not all wild resource practices are equally well covered, as for example the large discrepancy between the large-scale and small-scale fisheries practices. The systematic review followed IPBES guidelines and drew on the broader literature on systematic reviews (see the data management report at https://doi.org/10.5281/zenodo.4663236). The focus of studies that address policy effectiveness – be it implicitly or explicitly – is often focused on a subset of the three aspects of sustainability (ecological, economic, social), with the ecological natural science literature often looking more at the effects on the stock status or habitat protection, while more social science versatile authors are more likely to include information about economic and especially social consequences of an implemented policy. Thus, the measure of success is often discipline biased and the full information on any particular case study may also be dispersed across many different publications with differing levels of visibility and accessibility. The assessment depends on authors' evaluation and interpretation from the selected cases.

A variety of policy options have been introduced to control, or support, sustainable use of wild species. These are reviewed in section 6.4. Experts used the mixed methods review to first add to this evaluation by establishing the prevalence of application of each policy instrument based on the proportion of case studies across each practice that included each policy instrument (see section 6.4, **Table 6.6**). Section 6.5 next synthesizes the evidence gained on effectiveness of policy for the sustainable use of wild species, to pull out the key enabling and constraining conditions, including how governance characteristics support or enable these processes.

3. Illustrative boxes. Finally, similar to previous chapters, experts drew on the evidence they had compiled through the two review processes, and their expert knowledge in different geographies, policies, and practices, to identify a range of illustrative boxes. These boxes span different geographies, practices, policy instruments, and time, and illustrate key aspects of policy responses, contexts, and enabling conditions relevant to Chapter 6.

Table 6 3 **Policy effectiveness coding framework.**

Coding applied to 100 selected case studies (see the full dataset in the data management report at https://doi.org/10.5281/zenodo.4663236).

Category Group	Sub-Category
Practice	Fishing
	Gathering
	Terrestrial animal harvesting
	Non-extractive practices
	Logging
Policy instruments	Legal and regulatory
	Economic and financial
	Social and information-based
	Right-based and customary
Scale	Temporal
	Spatial
Effectiveness	Ecological
	Social
	Economic*
Enabling conditions / **Constraining conditions**	Economic/technological/cultural/ecological condition and interactions
Governance	Interactions among actors and alignment among values and tools
Reference	Information of the article

* Economic and Social are treated separately to identify whether policy options create trade-offs between different subcomponents of sustainability.

6.3 GOVERNANCE

Governance is commonly understood as ways of organizing government and other public institutions, civil society, and private actors in order to create opportunities or solve problems (Kooiman & Bavinck, 2005; Meuleman, 2008). Governance has recently taken center stage in efforts to understand threats to biodiversity and its loss, with growing consensus that inadequate or inappropriate governance is the most significant obstacle to achieving sustainable development and the sustainable use of natural resources (Allison *et al.*, 2012; Cahill, 2010; Cronkleton P. *et al.*, 2008; Ribot, 2004; Sowman & Wynberg, 2014). Closely related, governability is the capacity of a system to govern or to be governed. Governability is influenced by the interactions that exist between the system to be governed and the governing system. Analysis of policy effectiveness requires the interrogation *inter alia* of the nature and role of all actors involved in natural resource use, the way in which these actors interact, and the nature of those interactions. It also requires analysis of the evolving systems of rules, norms, values, knowledge, and incentives that shape different actions. Many different social and legal systems exist, often alongside one another, ranging from statutory through the customary regulation, with multiple approaches along the spectrum, including informal arrangements **(Figure 6.1)**. These plural governance systems have introduced complex tools and frameworks that actors must navigate to access and use wild species.

Various modes of governance exist and have been conceptualized in different ways, from hierarchies (state-centric governance), networks or co-governance (a constellation of actors in varying partnership arrangements), markets (market-based instruments and incentives), voluntarism (non-binding agreements and instruments) and self-governance (including customary governance) (Sowman & Wynberg, 2014). However, elements of one form of governance are often found in another, such that categorization is fluid and ideal rather than actual (Treib *et al.*, 2007). An overriding common element among these frameworks, which distinguishes governance from

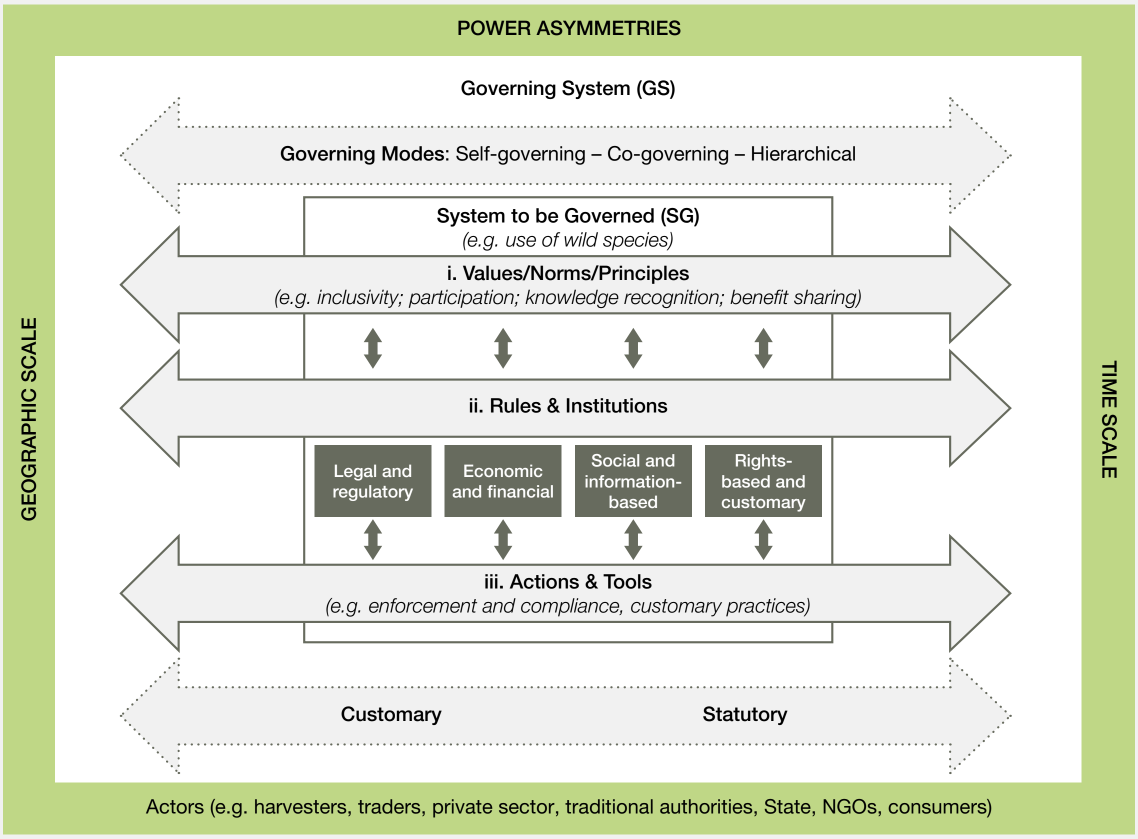


Figure 6 1 **Conceptualizing the interactive governance of wild species use.**

In the context of this IPBES assessment, the system to be governed includes the social-ecological system within which wild species are used (e.g., gathering in a forest, fishing in the ocean). Adapted from (Jentoft & Bavinck, 2014) under license number 5260851125678 CC-BY NC.

government and management (which is the day-to-day activities (e.g., monitoring) designed to achieve objectives), is that governance is concerned with interactions and processes which occur between a diverse group of actors, including non-state actors often with diverging interests (Bavinck *et al.*, 2005; Kooiman & Bavinck, 2005; Torfing *et al.*, 2012).

Interactive governance theory presents a useful approach to the analyses of governance focused on these interactions. Interactive governance theory divides societal systems into three parts: a system-to-be-governed, a governing system, and the interactions that take place within and between them (Jentoft & Bavinck, 2014) **(Figure 6.1)**.

All three parts of the system (system to be governed, governing system, interactions) are understood to be structurally diverse, complex, and dynamic, and operate at various scales. Interactive governance theory therefore encompasses multiple modes of governance, involving the market, state, civil society, and hybrid forms of these. Such a conceptualization captures the polycentricity of actors and arrangements, but also the plurality of the forms of governance (Bavinck & Gupta, 2014). This approach can recognize both *de facto* practices and rules in use, whether formal or customary, and *de jure* practices and rules in law. This is beneficial because customary *de facto* modes of governance developed to guide the use of wild species are often not recognized or accommodated in formal state-centric systems state (Kozanayi, 2018; Sowman & Wynberg, 2014; Sunde, 2014; R. Wynberg & Laird, 2007). Indeed, in many contemporary settings, local or customary forms of law emerge in response to largely ineffective forms of formal law (Karnad, 2017). An approach that can simultaneously analyze statutory and customary governance is needed for evaluations of the governance and use of wild species.

The governing system *(de facto)*, whether formal or informal, is comprised of three core orders (Jentoft & Bavinck, 2014):

1. The **values, norms and principles** that underlie governance, and can be understood as ethical principles linked, for example, to social justice and environmental sustainability. The values, norms, and principles related to the sustainable use of wild species are those which would reflect both the range of world views and different ways of knowing among users and communities, as well as the scope of use – which might vary from subsistence use through to recreational use or local or global trade.

2. The **rules and institutions** of governance, including for example, the rights that people have to access resources, their entitlements, and the rules or policy instruments prescribing access and use. The rules and institutions of relevance to the sustainable use of wild species can be categorized into four categories of policy instruments: legal and regulatory, economic/financial, social and information based, and rights-based and customary approaches typically employed under different governance configurations that are not mutually exclusive.

3. The day-to-day **actions and tools** taken to implement rules, including customary or formal management actions or harvesting regulations. The actions and tools, relevant to the sustainable use of wild species refer to the day to day legal and illegal actions that are used to either enforce or navigate the rules.

Power is a core consideration of interactive governance theory, for power reflects the ability to influence or control the beliefs or actions of others. Power is thus central to understanding interactions within and between the governing system and system to be governed. Power can be exerted in overt (e.g., state control) or diffuse (e.g., hegemonic ideas) ways, shaping the interactions. In interactive governance theory, Jentoft and Bavinck (2014) characterize power differentials as symmetrical or asymmetrical, using these terms to explain the coherence between components of the system. Symmetrical power exists where actors hold equal influence, whereas asymmetrical power exists where one can exert control over the other with no consequence. Where there is compatibility, and symmetrical power differentials, between norms, values and principles, rules and institutions, and the day-to-day actions and tools, conflict is less likely and there are increased opportunities for mutual support. The corollary is that where these elements differ legally, there are fewer opportunities for cooperation and harmonization.

Multilevel governance includes the implementation of public policy across diverse spatial scales from subnational and national to global (Forsyth, 2009). Vertical links could connect actors at the national and subnational levels according to international framework for achieving the shared goals such as climate change mitigation and biodiversity conservation (Forsyth, 2009). The structure and operation of nested governance across the scales can fortify more effective natural resource management (Hudson, 2011). Nested governance can contribute towards the robustness of social-ecological systems involving large-scale common pool resources (Marshall, 2008).

The actors involved will similarly vary depending on the type of use, the value of the resource, and the context. These may involve, state and parastatal organizations (e.g., government agencies, United Nations agencies, and intergovernmental bodies), market and commerce (e.g., small business and, multinational corporations), and various civil society (e.g., community groups, non-governmental organizations, and harvesters).

Against this background, and mindful of the legal pluralism that characterizes the use of many wild species, an interactive governance theory approach was adopted to analyze the effectiveness of policy instruments applied to support the sustainable use of wild species **(Figure 6.1)**. Governance was broadly conceptualized to involve various combinations of and interactions between customary law and statutory legislation, as well as everyday approaches in-between, that vary according to the geographical and temporal context, as well as between the three orders of governance (values, norms and principles; rules and institutions; and actions and tools). The analyses of governance thus focus on interactions between the actors, including the state, market, and civil society, involved in the various forms and stages of governance, whether in the system to be governed, the governing system, or both. Chapter 6's experts pay attention to both the symmetries and asymmetries of power as they influence and are influenced by the shape and form of governance arrangements, interactions between statutory and customary approaches, and alignment between the three orders of governance.

6.4 POLICY INSTRUMENTS ADOPTED FOR THE USE OF WILD SPECIES

A policy option reflects a combination of instruments strategically selected and implemented to achieve a specific policy goal. Policy instruments can be defined as "the set of tools and techniques by which governmental authorities wield their power in an attempt to ensure support for an effect or to prevent social change" (Vedung, 2017). Although governments often exert their power independently to introduce and implement policy, governments govern in existing and emerging contexts where grass roots and customary systems of governance co-exist with formal systems of government, multilateral governance, and emerging private, public, and market-based systems. Policies are thus adopted within a governing system, as a set of rules and institutions **(Figure 6.1)**. As highlighted in the previous section, governance is a critical determinant of policy effectiveness and thus forms the overarching framework within which policy effectiveness was evaluated in section 6.5. To begin, the experts review the range of policy options available to support the sustainable use of wild species. In doing so the experts draw on examples from across five practices (fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices) to describe common policy instruments and interventions, across four policy categories (legal & regulatory, economic & financial, social & information based, and rights based & customary instruments) at international, regional, national and subnational scales **(Table 6.3)**.

Importantly, this separation of governance, policy, and practice supports the analysis, whereas it is recognized that in reality:

1. Categorizations of policies may overlap with governance, for example community-based management can be viewed as a policy instrument or as a governance approach.

2. Categorizations of policies may overlap across categories, for example ecolabels and certification schemes reflect both economic financial instruments as well as social and information-based instruments.

3. Categorizations of policies may overlap within categories, for example, some fees can be thought of as payment for ecosystem services schemes – therefore policies in one category can relate to others – however, here each policy option are dealt primarily under one category.

4. Although policies are often developed with a particular practice in mind, they can affect other practices (e.g., a

national park legally designated to limit terrestrial animal harvesting, may also limit non-extractive practices).

5. Finally, policies are often designed to be applied together and thus reinforce one another; however, here the experts present and examine them independently.

The experts therefore acknowledge that the treatment of policy options and the categories they fall into is more ridged and reductive than occurs in reality.

6.4.1 Legal and regulatory instruments

Legal and regulatory-based approaches comprise interventions that formally influence social and economic action through binding rules or 'regulations' (Krott, 2005). Legal and regulatory approaches traditionally comprise the most commonly used instruments of government for solving social and economic conflicts (M. S. Park, 2009), or regulating patterns or intensity of use. Legal and regulatory based approaches develop rules for acceptable behavior and limit certain activities in a society (Lemaire, 1998). Legal and regulatory-based instruments include agreements, legislation, regulations, rules, standards, and planning, and are developed and applied at international, regional, national, and local scales **(Table 6.4)**. Although some scholars consider planning a separate type of policy instrument (Jang *et al.*, 2015; M. S. Park, 2009), here planning instruments was included with other regulatory based instruments because of their focus on statutory obligatory guidance. At an international scale, the use of wild species can be regulated through international treaties, pacts, agreements, conventions, and laws or legislation. At all scales (international, regional, national, local) the use of wild species can be further regulated through laws or legislation, standards, regulations, rules, and planning.

6.4.1.1 International agreements and conventions

A treaty is a written international agreement, between states, governed by international law, whether embodied in a single instrument or in two or more related instruments regardless of designation (Article 2 of the Vienna convention). Treaties contain conventions and agreements. An international environmental agreement (sometimes environmental protocol) is an intergovernmental document intended to be legally binding, with a primary stated purpose of preventing or managing human impacts on natural resources (Mitchell, 2019). An international convention is an agreement which becomes legally binding to a particular state when that state ratifies it. If an environmental agreement is among three or more nations, it is referred to as a multilateral environmental agreement. A recent analysis of multilateral environmental agreements found 90% with fewer than 10 signatory parties, and only 30 agreements with more than 100 parties (Mitchell *et al.*, 2020). Of 1,300 agreements analyzed, one third was directly related to species (e.g., regulating overharvesting of wild animals), the rest indirectly through pollution and energy, or other issues (Mitchell *et al.*, 2020).

Voluntary guidelines are non-legally binding documents, often developed in extended consultation with rights holders, and can be powerful in moving policy discourse and practice towards desired or aspirational goals for sustainable use. For example, in fishing, the voluntary guidelines for securing sustainable small-scale fisheries (FAO, 2015) were co-developed through extensive engagement, over ~20 years, with diverse groups of actors. Voluntary guidelines can lay the foundations, resulting in the enactment of, legally binding multilateral agreements. For example, in gathering, voluntary guidelines on access and benefit sharing preceded the development of the Nagoya protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization to the Convention on Biological Diversity (Nagoya Protocol).

Many of these international efforts to promote sustainable use or protect wild species relate to multiple practices or take an integrated view of species use. Although some have a greater relevance to individual practices. For example, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on Biological Diversity (CBD) include policy statements on the sustainable use of wild species that affect fishing, gathering, terrestrial animal harvesting, logging, and non-extractive uses. In contrast, the United Nations convention of the law of the seas primarily affects fishing, with lesser effects on gathering (at sea), and non-extractive uses.

Trade is one of the primary channels through which practices involving wild species are regulated at an international scale. The Convention on International Trade in Endangered Species of Wild Fauna and Flora is the premier international instrument, which through species listings in its Appendix I, II, or III, has the capacity to monitor, limit, or prohibit international trade of specimens of wild species to ensure that it does not threaten the survival of the species. Through these mechanisms, the Convention on International Trade in Endangered Species of Wild Fauna and Flora is heavily involved in regulating terrestrial animal harvesting, and logging practices, but is also relevant for fishing and gathering practices (see Chapter 2). Other international agreements that exist, and can together with the Convention on international trade in endangered species of wild fauna and flora, work to control the trade of wild species include the Convention on the Conservation of Migratory Species of wild animals, the Agreement on the conservation of African-Eurasian migratory waterbirds, the Convention on Biological Diversity, and the Forest Law enforcement, Governance and Trade action plan.

Table 6 4 **Examples of policy instruments for each practice (fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices).**

Pictograms represent (from left to right): fishing, gathering, terrestrial animal harvesting, logging and non-extractive practices. Abbreviations: CBD: Convention on Biological Diversity, CBT: Community-based tourism, CITES: Convention on international trade in endangered species of wild fauna and flora, CMS: Convention on the Conservation of Migratory Species of Wild Animals CMT: Customary Marine Tenure, FAO: Food and Agriculture Organization, FLEGT: Forest Law enforcement, Governance and Trade, FSC: Forest Stewardship Council, HRBA: Human rights-based approach, IWC: International Whaling Commission, MSA: Magnus-Stevens Fisheries Conservation Act, MSC: Marine Stewardship Council, MSP: Marine Spatial Plans, PA: Protected Areas, PES: Payment for Ecosystems Services, REDD+: Reducing emissions from deforestation and forest degradation, SSF: Small-Scale Fisheries, UNCLOS: United Nations Convention on the Law of the Sea, UNDRIP: United Nations Declaration on the Rights of Indigenous Peoples, US: United States of America.

Category	Instruments	Description and scale (if relevant)					
Legal & Regulatory	Treaty/ Agreement/ Convention	International legally binding (or with intent) commitment by states to prevent or manage human impacts on wild species, to be enacted by national and regional bodies	*CITES*				
			CBD's Nagoya Protocol				
			UNCLOS/CMS		*CMS*	*FLEGT*	
			CBD				
	Legislation/ Law/ Act	International, regional, national, or local legislation for the sustainable use of wild species	*Magnus-Stevens Fisheries Conservation Act*	*Forestry Law*	*Wildlife Restoration Act*	*Forest code*	*Park Management Act*
	Rule/ Regulation	Rules and regulations used to enact legislation	*Restrictions on gear, species, or place*	*Novel food regulation*	*Harvesting and/or Trade bans*	*Logging Ban*	*Visitor Limit*
	Standard/ Planning	Quality standards and planning tools to support and coordinate decision making around sustainable use	*MSP*	*Food Safety Regulation/PA*	*PA*	*Forestry legislation Quality standards/PA*	*CBT/PA*
	Enforcement & Sanctions	Sanctions are intended to deter future violations, reducing repeat offenses and signaling to the broader population that illegal action has repercussions	*Fines, imprisonment, asset forfeiture, revocation permits, law suits*				
Economic & financial	Tax/ fee	Instruments seek to incentivize sustainable use or disincentivize unsustainable use through penalty, while generating funds for improved management	*License fee*	*Tax (medicinal plants)*	*Tax (ammunition)*	*Penalty (illegal logging)*	*Entrance fee*
	Subsidy/ Incentive/ Compensation	Instruments seek to incentivize sustainable use or disincentivize unsustainable through reward	*On fuel*		*Damage compensation*		
	PES/ Bonds/ Offsets	Instruments aim to internalize externalities through new financial transactions for environmental goods and make sustainable use economically logical, while generating funds for improved management	*Blue bonds*	*PES*	*Livestock insurance to avoid hunting wild predators*	*REDD+*	
Social & information-based	Certification	Instruments use information to shift consumer choice to demand more sustainable products and hence practices	*MSC*	*FairWild*		*FSC PEFC*	
Rights-based & customary	Customary law	Customary laws are intended protect customs, ensure over-use is prevented, and that sufficient wild species will be left for future generations	*CMT*	*Native lands*	*Communal forest rights*	*Water rights*	
	Tenure, Access, Rights	Communal ownership of land and wild species is widespread among indigenous peoples and local communities who have developed practices, TEK, and social norms	*Tambu*	*Taboos*			*Right to roam*

The Convention on the Conservation of Migratory Species of wild animals is the global environmental treaty specialized in the Conservation of Migratory Species. Parties to the Convention on the Conservation of Migratory Species of wild animals "strive towards strictly protecting these animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them" (CMS, 2021). Although the Convention on the Conservation of Migratory Species of wild animals does not specifically address sustainable use of these species, the Convention text, Article III paragraph 5 specifies that Parties that are range states of a migratory species listed in Appendix I (migratory species that are endangered) shall prohibit the taking of animals belonging to such species. It can also contribute to sustainability of fishing and terrestrial animal harvesting of migratory species through its joint work program with the Convention on international trade in endangered species of wild fauna and flora, and on the frame of the memorandum of understanding signed between the secretariats of both conventions and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Res. Conf. 13.3 in this regard).

The Agreement on the Conservation of African-Eurasian Migratory Waterbirds is an intergovernmental treaty dedicated to the conservation of migratory waterbirds (AEWA, 2018; Madsen *et al.*, 2015) and has the sustainable use of the wild species it targets as one of the main objectives of its strategic plan for 2019–2027 (objective 2: To ensure that any use and management of migratory waterbird populations is sustainable across their flyways) (AEWA, 2019). The Conference of the parties to the Convention on Biological Diversity encourages parties to the convention to develop, revise or update, as appropriate, their regulatory systems to differentiate among subsistence uses, illegal hunting, and domestic and international trade of specimens of wild species and products. Through resolution 2/14 on illegal trade in wild species and wild species products the United Nations environment assembly (2016) urged member states to prevent, combat and eradicate the supply, transit and demand related to illegal trade in wild species and wild species products (United Nations Environment Assembly of the United Nations Environment Programme (UNEA), 2016). Decision XII/18 of the Conference of the parties to the Convention on Biological Diversity (CBD, 2014) emphasizes sustainable use of biodiversity in the context of both hunting of wild meat and sustainable wild species management (see Chapter 2).

Although voluntary partnership agreements are developed on a voluntary base, they are legally binding on both sides. The new concept of Forest Law enforcement, Governance and Trade emerged to control illegal timber-harvesting and international trade in illegally harvested timber in 2000s (Brack, 2005). For implementing Forest Law enforcement, Governance and Trade (FLEGT), voluntary bilateral agreements between producer and consumer countries were introduced. European union adopted the Forest Law enforcement, Governance and Trade action plan including voluntary partnership agreements. The voluntary partnership agreement require that producer countries develop verifying systems to exclude illegal timber and consumer countries import only licensed timber from that country. The voluntary partnership agreement, as a voluntary scheme, supports to avoid biodiversity loss by illegal timber-harvesting. Forest Law enforcement, Governance and Trade has a strong emphasis on the central government and the privileging of regulatory instruments over market-based forms of governing (Van Heeswijk & Turnhout, 2013).

A number of international agreements exist that focus on logging or gathering practices including the International Convention on Temperate and Boreal Forests (Montreal Process) and the Pan-European Forest Process (formerly the Helsinki Process). Furthermore, and as seen above, several global environmental conventions contain provisions to regulate certain activities related to wild forests and logging. For example, the Convention on Biological Diversity contains provisions related to logging, and gathering, in particular where traditional practices and local communities are concerned. The United Nations convention to combat desertification addresses deforestation and reforestation, the Bern convention on the conservation of European wildlife and natural habitats where planning of the Emerald network is concerned or the Economic Development Partnership act which improves management (including logging) in protected areas.

People have been fishing the oceans for centuries. However, in the years following the Second World War fishing effort on the high seas increased greatly, facilitated by technological advances in vessel construction, fishing gears, navigation, and on-board fish processing, and by development of international chains for processing. marketing, and sales. The resultant increase in overfishing was an important factor in negotiation of the United Nations Convention on the Law of the Sea (UNCLOS). The United Nations Convention on the Law of the Sea and the United Nations agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and management of straddling fish Stocks and highly migratory fish Stocks are the most relevant international agreements pertaining to fishing **(Box 6.14)**. The United Nations Convention on the Law of the Sea, signed in 1982 and ratified by 186 countries since, provides the overarching international legal agreement under which activities at sea are regulated. The United Nations Convention on the Law of the Sea *inter alia* determines the sovereign rights of coastal States and outlines the obligation to conserve and manage living resources and the marine environment (Art. 192). The Fish Stocks Agreement elaborates on these provisions of the United Nations

Convention on the Law of the Sea in relation to straddling stocks and highly migratory stocks. Article 5 of the Fish Stocks Agreement gives conservation and management principles, including the promotion of optimal utilization (i.e., intended to be sustainable), management that is based on scientific evidence, and uses precautionary and ecosystem-based approaches.

The United Nations Convention on the Law of the Sea includes provisions that entrenched national jurisdiction of the Exclusive Economic Zones (EEZs) for 200 miles from coastlines. However, neither United Nations Convention on the Law of the Sea nor the Fish Stocks Agreement cover inland fishing, which comprises over half of all fish species and nearly 30% of global catches (Funge-Smith & Bennett, 2019). Furthermore, areas beyond the 200 nautical miles (nm) exclusive economic zone from shore are considered by the United Nations Convention on the Law of the Sea as international waters, or areas beyond national jurisdiction. The regulation of uses of biodiversity (including harvested wild fish) in these areas has been discussed in a lengthy process under the auspices of the United Nations, starting in the early 2000s and resulting in an agreement to hold intergovernmental conferences on the topic starting in 2018. A long-term effort has been underway to get better regulation for the high seas through an internationally legally binding instrument, with negotiations being held in an intergovernmental conference on the topic, with the first session held in 2018 and the second in 2019.

However, the United Nations Convention on the Law of the Sea did include provisions under the duty to cooperate (Article 117) that facilitated development of Regional Fisheries Management Organizations (RFMOS) in areas beyond national jurisdictions, and laid out the mandates and requirements for operation of Regional Fisheries Management Organizations. The guidance and constraints on Regional Fisheries Management Organizations operations laid out in the United Nations Convention on the Law of the Sea were refined and clarified in the United Nations Fish Stocks Agreement of 1995. The Food anf Agriculture Organization (FAO) notes at least 50 different regional fisheries bodies have been established.

Under the United Nations Convention on the Law of the Sea and the Fish Stocks Agreement, Regional Fisheries Management Organizations have the mandate and competence to adopt legally binding conservation and management measures, which have to be implemented and translated into actions at the country and regional levels, as appropriate, by the member states. The measures should ensure long-term sustainability and promote optimum utilization of fishery resource, be based on the best scientific evidence available; and decisions must apply the precautionary approach. Correspondingly, Regional Fisheries Management Organizations routinely have science advisory bodies comprising experts largely drawn from the member states' secretariats which coordinate reporting, over-sight and enforcement of regulations, and annual meetings where Parties discuss compliance and regulatory issues, consider the science advice, and adopt measures for regulating harvest levels and methods (Garcia *et al.*, 2014).

The FAO reports that there are now more than 20 Regional Fisheries Management Organizations, of which 12 are generic, 5 consider tuna and tuna-like species, 3 manage anadromous stocks, 1 manages halibut and 1 manages cetaceans (FAO, 2020). Regional Fisheries Management Organizations coverage of oceans in the northern hemisphere is much greater than coverage of oceans in the southern hemisphere, particularly for fisheries for species other than tuna (Figure 3.15). The track record of Regional Fisheries Management Organizations for effectively deterring overfishing and illegal, unreported and unregulated fishing is spotty and contested, but there is evidence of successes and overall improving trends in performance (see section 3.3.1 in Chapter 3). The ongoing negotiations of an implementing agreement for the United Nations Convention on the Law of the Sea to deal more broadly with biodiversity beyond national jurisdictions may further alter the mandate and measures of Regional Fisheries Management Organizations. Currently all of them discuss issues such as bycatches and impacts of fishing gears in the fisheries they manage, but universal performance standards have not been adopted.

The International Whaling Commission was set up in 1946 under the International Convention for the Regulation of Whaling and is the global body charged with the conservation and management of whales, thus relating to both fishing and non-extractive practices of whaling. Three different types of whaling are recognized by the International Whaling Commission; subsistence whaling, commercial whaling, and scientific whaling. Subsistence whaling for traditional purpose is allowed in some places, but the International Whaling Commission put in place a moratorium on commercial whaling since 1986. A small number of countries have expressed reservations or objections to this moratorium (Norway, Iceland, and Russia), and some continue to catch whales commercially. The International Whaling Commission includes the regulation of whale watching and measurement of the impact of this activity in species population (Sitar *et al.*, 2016). Whale watching is taken as a general description of any marine mammals as indicated by the International Whaling Commission (Parsons, 2012).

6.4.1.2 Legislation, regulations, and rules

Legislations, regulations and rules are implemented at the local, national, and regional level as a means for states and organizations to work towards fulfilling their international obligations. Local, national, and regional bodies, some of which are advisory and others that have a legal mandate, support this work by enacting legislation through regulations. Regulations are measures undertaken to influence people by means of formulated rules and directives which mandate receivers to act in accordance with what is ordered in these rules and directives (Vedung *et al.*, 1998). National legal and regulatory rules, that apply to the sustainable use of wild species, include bans or limits on what, when, where, how, and by whom extraction can take place. Legal and regulatory instruments often exist alongside, or reinforce other instruments, such as economic and market based, social and information-based, and customary and rights-based. Furthermore, national scale instruments are often supported by, or integrated with international instruments **(Box 6.1)**.

A body of regulation centered on quality control, and safety and efficacy standards, increasingly influences the harvesting, use, and trade of products from particularly fishing and gathering practices, especially those associated or connected to markets in high income nations. Such policies may be determined at international (e.g., FAO's Codex Alimentarius), regional (e.g., European Union Novel Foods Regulation) or national levels (e.g., United States Food and Drug Administration requirements). This means that wild algae, plants and fungi producers may be required to institute sophisticated procedures for tracking materials that end up as medicinal, cosmetic, personal care products, food and beverages. Although these are intended as standards to protect consumers, particularly in high income nations, there is a risk of these regulations diverting scarce resources away from domestic food safety issues and towards international standards (FAO *et al.*, 2021).

Food safety legislation such as FAO's Codex Alimentarius has often proved a formidable obstacle to international trade for food products particularly affecting fishing and gathering

Box 6 1 **Non-lethal harvesting: aquarium trade.**

The small-scale and multi-species non-lethal fishing that supply the marine aquarium trade represent important livelihood opportunities for coastal communities, especially in exporting, mostly lower income nations where resources and alternative options for generating income can be limited (Rhyne *et al.*, 2012; Wabnitz, 2003). Species that are part of the marine aquarium trade also provide valuable benefits to hobbyists, and play a role in educating the general public about coral reef ecosystems (Rhyne *et al.*, 2014). The aquarium industry as a whole is of relatively low volume yet very high value, thus potentially providing an incentive to conserve reef habitats from which most species are harvested. Marine aquarium fisheries are extremely selective, with fish for instance typically harvested by hand, snorkeling or using, where permitted, an underwater breathing apparatus such as SCUBA. Sustainable fish harvest involves the use of small mesh nets that seek to not damage the target fish or non-target species, or the habitat (Wabnitz & Wood, 2017). However, the use of cyanide has been widely reported in aquarium fishing, which damages the broader ecosystem and results in mortality rates of up to 90% (Dee *et al.*, 2019; Madeira *et al.*, 2020; Militz, Kinch, *et al.*, 2018; Raghavan *et al.*, 2018; Vaz *et al.*, 2017). Furthermore, reports of over-harvesting, high mortality levels, disease and trade of invasive species remain, raising concern for this trade (Madduppa *et al.*, 2018; Militz, Foale, *et al.*, 2018).

Management of the trade is daunting due in part to the wide diversity of fish, coral, other invertebrate species, and live rock involved in the trade (Dee *et al.*, 2014) as well as the need to contextualize fisheries management to local conditions. Globally, many strategies to monitor, regulate and manage the aquarium trade exist including, for instance, closures, banned-species lists, quotas, gear restrictions, size limits, licensing, limited entry into the fishery, and regulations on imports. However, monitoring remains challenging, particularly for small scale aquarium trade (Biondo & Burki, 2020; Biondo & Calado, 2021). As aquarium fishing is export-oriented, Pacific Island Countries and Territories involved in the trade have experienced relatively good enforcement of management measures at the point of export.

In Fiji, for example, current aquarium trade policies include a ban on the export of live rock, a (possibly temporary) ban on the export of coral; a quota system for coral; and a requirement for companies to have an environmental impact assessment, a harvesting area management plan, an export permit from the ministry of fisheries, an export permit for species covered by the Convention on International Trade in Endangered Species of Wild Fauna and Flora from the ministry responsible for the environment, a fishing license for the operator of a harvesting vessel, and to regularly submit statistics to the ministry of fisheries. While no official national aquarium fishery management plan currently is in place, existing regulations and policies pertinent to the marine aquarium trade essentially can be considered as a *de facto* management plan (Gillett & Halford, 2020).

Harvesting and export of species for the marine aquarium trade in Australia are managed at state level by a well enforced policy framework, including fisheries management measures such as catch limits; logbook systems; size limits and seasonal closures for certain species; regularly undertaken assessments to evaluate the environmental performance of fisheries as mandated under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and to promote the ecological sustainability of target fisheries; permits; limited entry; list of no take species; legally defined harvest/special management areas as well as types and specifications of gear allowed; and export controls.

practices (Brown, 2005; Burgener, 2007; Iqbal, 1993; Pierce & Burgener, 2010). However, governments tend to act quickly when these obstacles arise. For example, in the 1990s when the European Union and the United States of America set maximum acceptable levels of aflatoxins that threatened gathering for the Brazil nut (*Bertholletia* spp.) trade, the Bolivian government jumped into action, passing a series of food safety measures that created norms for Brazil nut classification, sanitation practices and aflatoxin sampling, drawing upon the FAO's Codex Alimentarius (Cronkleton P. *et al.*, 2008; Soldán, 2003). These steps allowed Bolivian Brazil nuts to maintain access to international markets.

Under Article XIV of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, signatory governments are recommended to establish stricter domestic measures on the international trade of the Convention on International Trade in Endangered Species of Wild Fauna and Flora-listed species. This includes regulations on the international trade of species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix II, for which non-detriment findings studies are required, in order to demonstrate that legal international trade will not threaten the survival of the species. The Convention on International Trade in Endangered Species of Wild Fauna and Flora also enables national scale trade bans for species listed in Appendix I (Conrad, 2012). These measures tend to focus on species in commercial trade, or form part of national efforts to protect endangered or indigenous species or regulate trade under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Section 6.4.1.1). Although the impact of these measures can be controversial, some unexpected and undesired conservation outcomes have been documented (Weber *et al.*, 2015). The goal of trade bans is usually to reduce harvesting pressures, such as when fishing, gathering, terrestrial animal harvesting, or logging involves threatened wild species (Fischer, 2010). A well-publicized trade ban clearly specifies when a species is no longer legally available. This splits demand, removing the demand of law-abiding consumers, and leaving only illegal demand. To encourage law-abiding behavior, governments can ensure availability of substitutes to absorb the previous demand, impose consequences for non-compliance (fines and penalties), and that a stigma become associated with consuming products obtained illegally (Conrad, 2012; Fischer, 2010). However, the idealized trade-bans described here tend not to happen as bans have often been mismanaged, they struggle to regulate illegal trade, and potentially spur trade by increasing scarcity (e.g., Rivalan *et al.*, 2007).

Most countries, particularly with abundant natural resources, where fishing, terrestrial animal harvesting, and logging practices occur have dedicated sector specific legislation (e.g., Forestry Act in the United Kingdom of Great Britain and Northern Ireland, Magnus-Stevens Fisheries Conservation Act in the United States of America), as well as public bodies regulating the economic, technical, environmental and sometimes social affairs of those sectors. In some cases, countries with very large-scale forestry practices (e.g., Brazil, Russia) all forest-related issues are harvested under the same cover and adopted as a single fundamental legal act, such as a forest code. Although historically developed for logging, forestry legislation, reflecting international policy trends, increasingly covers all activities that occur in the forest (e.g., gathering and terrestrial animal harvesting). Importantly, bodies of forestry legislation of major global forest importers, such as the European Union and the Unites States of America are not only concerned about national or supranational forestry practices, but also about the legality of imported timber. In the absence of global intergovernmental arrangements regulating logging, the European Union Timber Directive and United States of America National Forest Act effectively play this role in some respects.

The rules and laws in forestry legislation that relate to gathering, intersect with economic and financial instruments to include permits, quotas, management plans, royalties, and taxes. However, the track record for implementing such policies remains poor (Ortiz, 2002; Pierce & Burgener, 2010), largely due to the inappropriate use of timber-based approaches for the diverse, complex and perhaps less lucrative gathering practice (Laird *et al.*, 2010). The scope and definition of the products covered have remained unclear, and few specific actions have been stipulated (Fiji Islands, 1992; Republic of Cameroon, 1994; Republica de Bolivia, 1996). Increasingly, countries have begun to fine-tune such policies to reflect the socioeconomic, ecological and cultural realities of using gathered products. This has resulted in a number of specific improvements in the ways these products are regulated, including re-thinking the use of costly and complex inventories and management plans for gathering, and revising quota and permitting systems (Areki & Cunningham, 2010; Cronkleton & Pacheco, 2010; Kluppel *et al.*, 2010; Laird *et al.*, 2010). Some forestry laws have also included gathering in management plans for logging operations to minimize negative impacts on locally valuable products. In Brazil, national and state governments have passed laws prohibiting the logging of high-value plant, algae and fungi species (Kluppel *et al.*, 2010), and in Bolivia prohibitions on felling Brazil nut trees arrived in 2004 as part of a decree addressing property conflicts (Cronkleton & Pacheco, 2010).

There are many parallels in how fishing and terrestrial animal harvesting practices are regulated across the world. In general, regulations differ based on whether harvesting is for commercial, traditional, subsistence, or sport purposes (Emery & Pierce, 2005). In most of Africa, wild animals are either owned by the state (e.g., in Kenya), or have no ownership (Lindsey *et al.*, 2013). Fishing and terrestrial animal harvesting are therefore regulated through legal instruments, which stipulate restrictions on who, when, where, what, and how activities can take place. These restrictions are often controlled through licensing, permits, and quotas (Cirelli & Morgera, 2009; Lindsey *et al.*, 2013). Although, in some places, subsistence fishing or hunting does not require a license or permit (e.g., Zambia, Tanzania, Botswana, Malawi, Mozambique) (Cirelli & Morgera, 2009).

Many countries combine legal and regulatory instruments with economic and financial instruments. For example, allocation of ownership or user-rights to private and communal landholders is often under specific conditions, such as building fences that support sustainable use (Barnett & Patterson, 2005; Cirelli & Morgera, 2009; P. A. Lindsey *et al.*, 2013). User-rights in addition allow land owners, or fishing quota holders, to fish or hunt for themselves or to sell these rights to private fishing or hunting operators or tourists (Bond *et al.*, 2004; P. A. Lindsey *et al.*, 2007). However, hunting which is in disagreement with specific permissions is considered illegal in most contexts (P. A. Lindsey *et al.*, 2013).

Yet, in hunting the lack of legal and regulatory approaches has been associated with unsustainable use. For example, for 50 years there was an absence of hunting regulations in Brazil, which led to the unregulated use of wild species, and a general scenario of lack of data on the activity (Fernandes-Ferreira & Alves, 2017). Hunting is allowed when the hunter or their family are hungry and when conducted by indigenous and traditional peoples, but management is generally lacking throughout the country (Vieira de Mattos *et al.*, 2019). In the Malaysian state of Sarawak, the 1998 Wild Life Protection Ordinance banned all commercial sales of wild species.

National regulations of non-extractive, recreational use practices are often centralized, drawing on international guidelines and research, to limit the number of users that the environment can sustain or control their behavior (Avila-Foucat *et al.*, 2013; Parra-López & Martínez-González, 2018). For example, in line with the International Whaling Commission guidelines many national legal regulations concerning whale watching have evolved from voluntary, to formal, to participatory and adaptive (Mallard, 2019) to control the speed and noise from boats, distance from whales, acceptable behavior, and time spent whale watching (Avila-Foucat *et al.*, 2017; Sitar *et al.*, 2016). Specific methods for calculating and regulating the number of visitors are diverse and contested (Avila-Foucat *et al.*, 2013; Wall, 2020). Carrying capacity regulations based on establishing a specific number of visitors and standards have evolved into other management frameworks such as limits of acceptable change, visitor impact management, visitor experience and resource protection, and visitor activities management process that integrate different management options, are more dynamic and involve different stakeholders (Farrell & Marion, 2002).

International guidelines (e.g., United Nations declaration on the rights of indigenous peoples, see section 6.5.1), national regulations (e.g., native American graves protection and reparation act), and locally developed codes of conduct exist to guide non-extractive use practices at spiritual and cultural sites to ensure sacred sites and practices are protected and norms adhered to (C. Negi, 2013). Many of these regulations protect spiritual practices that involve wild species, or protect wild species that are sacred or found in sacred places. For example, in the United States of America, the Fish and Wildlife Service can issue permits to indigenous peoples allowing them to obtain feathers from endangered bird species for spiritual/ritual uses, the genus *Ficus* is protected in many parts of the world because of cultural and spiritual beliefs, and the sacred species of Shiling *(Osmanthus fragrans)* is found in temples located in the Garhwal hills and Kumaun Himalayas (C. Negi, 2013).

The binding nature of a formal, regulation-based approach to wild species governance relies heavily on the enforcing the rules, including the use of sanctions against violators, such as fines, imprisonment, asset forfeiture, revocation permits and warning letters (Pascual *et al.*, 2021). Such sanctions are intended to deter future violations, reducing repeat offenses and signaling to the broader population that illegal action has repercussions, although the criminological literature highlights the complexities of deterring illegal behavior (Wilson & Boratto, 2020).

For example, penalties and fines can act as a deterrent against unsustainable practices or trade in banned species, and revenues from penalties and fines charged can be allocated to habitat and biodiversity protection (Klasen, 2018). Penalties and sanctions can be applied to all extractive practices, including terrestrial animal harvesting, fishing, gathering, and logging. However, payment is not always allocated exclusively to environment protection or management.

International agreements, conventions and guidelines can support monitoring to ensure compliance with domestic regulations. For example, the Convention on International Trade in Endangered Species of Wild Fauna and Flora Database reports the details of >850,000 legal export and imports across the signatory countries, helping to monitor legal, sustainable trade (CITES, 2021). However, such international instruments have notably few opportunities to enforce against violations.

National legislation and domestic government agencies are primarily responsible for enforcement, including monitoring for compliance, pursuing violators and imposing sanctions. In many countries, violations of many sustainable use regulations, such as the abuse of quotas, are considered comparatively less serious and are treated as administrative offenses or misdemeanors, rather than as criminal offenses. Such violations are typically dealt with by the relevant agencies, such as forest departments, which can often directly issue fines and seize illegal harvest (Pascual *et al.*, 2021). However, some violations, such as those involving protected species, are criminal offenses in many countries that are formally prosecution *via* the court system and result in both fines and lengthy imprisonment. In some jurisdictions, violations of wild species legislation may also be the object of environmental lawsuits that can provide unique ways to enforcing environmental rights (see below).

The types and scales of sanctions for violating wild species regulations vary widely around the world. For example, the maximum allowable imprisonment term for illegally hunting a protected species in Brazil is 1.5 years, while in Kenya it can result in life imprisonment (Pascual *et al.*, 2021). Approaches to financial sanctions are similarly diverse, with fines ranging from 0 to 200,000 United States dollars, variously set based on default values, market prices of specimen, number of individuals involves, and local salary scales (Pascual *et al.*, 2021). Differences in sanctions handed out can limiting the efficacy of these deterrents (Pascual *et al.*, 2021).

Amidst widespread calls to increase sanctions for wild species violations, there are long-standing debates about which approaches are most likely to improve environmental outcomes in ways that are socially acceptable (Wilson & Boratto, 2020). Indeed, there is widespread evidence that enforcement and sanctions are often disproportionately on those involved in harvesting, rather than trading and consuming wild species, and that conservation enforcement disproportionately affects indigenous, poor and other marginalized communities (Duffy *et al.*, 2019; Paudel *et al.*, 2020; L. Wilson & Boratto, 2020).

Despite the formal nature of government enforcement, informal sanctions are also important in the context of wild species use. This is especially true because, in many countries, wild species conservation, management, use and violations occur beyond the sphere of formal government control (Sjöstedt & Linell, 2021). Social norms can serve to reinforce (or active oppose) government enforcement of regulations, depending on whether the underlying regulations are aligned with local priorities, customs and needs (Kinzig *et al.*, 2013).

Alongside traditional sanctioning approaches based on fines and imprisonment, environmental liability lawsuits can help enforce wild species regulations. Such environmental liability legislation forms part of national legislation in a great many countries. These laws hold responsible parties liable for the environmental harm they cause, and thus responsible for providing remedies. Environmental liability legislation is important to sustainable use because, where legal trade is violated (illegal trade, quota abuse, inappropriate standards, etc.) there is a need for appropriate enforcement responses that not only punish violation, but provide remedies that meaningfully address conservation impacts and values of nature (Pascual *et al.*, 2021).

Although laws and procedures vary widely, many countries allow different stakeholders to bring environmental lawsuits to court (Pascual *et al.*, 2021), seeking remedies such as:

1. Injunctions to stop harmful activities from continuing, such as the suspension of harvest licenses;

2. Orders for government agencies to act in accordance with the law or review their procedures, such the processes for setting harvest quotas, or the ways in which government agencies chose to enforce wild species legislation (e.g, (Brosi & Biber, 2012).

3. Orders that the parties responsible for causing environmental harm be liable for providing remedial actions, such as species reintroductions, clean-up or reforestation (Pascual *et al.*, 2021).

As such, environmental lawsuits can be used to seek compensation from illegal traders of wild species resources, or to challenge quotas, the (mis)allocation of permits, failure to implement the Convention on International Trade in Endangered Species of Wild Fauna and Flora Non-Detriment Findings, failure to list a protected species, or government failure to allow for traditional harvest of a species. Related litigation can thus not only support sustainable use, but also act as a means of "making nature's value legible" (6.4.2) and for recognizing human rights (6.4.4.4) through court actions that formally recognize different types of rights that are frequently overlooked or violated in policy processes.

6.4.1.3 National standards and planning

Standards have been developed in several countries that relate to non-extractive uses, including wildlife watching, and other forms of sustainable nature-based tourism. For example, community-based tourism standards, combine legal and regulatory approaches with social and information-based approaches, and in doing so seek to create local enterprises that provide livelihood benefits to communities while protecting indigenous cultures and environments (Simpson, 2009). The aims of community-based tourism include equitable participation in efforts to enhance sustainable use of natural resources and social well-being (Stone, 2015). However, Iorio and Corsale (2014) indicate that communities are not homogenous, and involvement in community-based tourism depends on the resources and skills of the community. National legislation, such as forestry legislation normally sets standards for logging practices. These include the setting of environmental quality objectives (including forest rotations, logging rules etc.), threshold values, liability rules, impact regulations, technical requirements etc. Other practices covered under standard setting include food quality standards that relate to gathering and fishing.

Planning instruments such as marine spatial plans and land use planning including systematic conservation planning and protected areas have been applied to various ecosystems, covering terrestrial animal harvesting, fishing, gathering, logging and non-extractive use practices. Protected areas are a cornerstone of biodiversity conservation, one of the objectives of the Convention on Biological Diversity. Thus, protected areas play a major role in maintaining key habitats, providing refugia, allowing for species migration and movement, and ensuring the maintenance of natural processes across the landscape. The Conference of the Parties to the Convention on Biological Diversity, at its 7th meeting in 2004, adopted the Programme of Work on Protected Areas. The Programme of Work on Protected Areas enshrines the development of participatory, ecologically representative, and effectively managed national and regional systems of protected areas, stretching across national boundaries where necessary. The Programme of Work on Protected Areas can be considered as the core framework for the designation and management of protected areas. It offers a system for cooperation between multiple actors, including governments, donors, non-governmental organizations and local communities (J.-Y. Park *et al.*, 2019).

6.4.2 Economic and financial instruments

Economic instruments are all those political means of intervention that formally influence social or economic action through the exchange of "economic values" (Krott, 2005). Economic policy instruments involve either the handing out or the taking away of material resources, be they in cash or in kind (Vedung *et al.*, 1998). Economic and financial instruments include any policy option that uses price as a basis for the governance of wild-species, and can be further categorized into centralized instruments and decentralized instruments (see Hahn *et al.*, 2015). Evidently, there is overlap here with some regulatory instruments, in particular sanctions (e.g., fines). Centralized policy approaches include traditional fiscal instruments such as taxes (and tax reliefs), subsidies, fees, charges, and budgetary allocations; whereas, decentralized instruments create new markets for services and goods to guide environmental governance such as through conditional and voluntary incentive schemes (e.g., payment for ecosystem services), compensation payments, and new financing streams (e.g., blended finance and blue/green bonds) (Hahn *et al.*, 2015) **(Table 6.4)**. What generally characterizes the broad range of economic policy approaches is that they supplement approaches that outright ban resource use. Financial instruments use market signals to control or direct resource use, as well as to generate flows of finance that can be used to subsidize research, management, monitoring, local livelihoods and initiatives to protect terrestrial vertebrate species.

6.4.2.1 Taxes and Fees

Taxes and fees are economic instruments, whereby users pay to use or access wild species, are designed to incentivize sustainable use or disincentivize unsustainable use while generating funds that can be redirected towards conservation, or the sustainable management of wild species. Taxes can be effective if they are set at an appropriate level, can be administered, and adequately monitored. Although taxes can be perceived as overly top-down and might not be supported by all actors, which can result in problems with implementation due to lack of buy-in or political lobbying (Bräuer *et al.*, 2006). Fees are often applied to non-extractive use practices, particularly when the activity takes place in a natural protected area or when a private company charges for a service, through entrance fees or for example, for conducting safaris on national parks. Fees are similarly applied to wildlife watching, for example whale watching generates 2.1 billion United States dollars in expenditures (including charges for the trip) and 13,000 jobs worldwide (O'Connor *et al.*, 2009), however, standards, codes of conduct, and regulations are more important instruments for regulating non-extractive use practices than price.

Taxes, fees, and royalties are some of the most frequently applied financial instruments to hunting practices, often in conjunction with quotas and permits, such as for wild species capture, hunting, and trade. Similar to fees, taxes and royalties can be used to generate revenue and to support the sustainable use of wild species (Bräuer *et al.*, 2006; Klasen, 2018). One example of such a mechanism has been implemented for hunting, sport shooting or personal defense in the United States of America, through the Federal Aid in Wildlife Restoration Act, popularly known as the Pittman–Robertson Act (1937) (Spidalieri, 2012). The Act provides funding for habitat preservation, harvest management, hunter safety education, research, restoration, and monitoring, not only for game species but for many other species. Funds for the act come from an 11% federal tax on sporting arms, ammunition, and archery equipment, and a 10% tax on handguns (Pack *et al.*, 2013; USFWS, 2013). These funds are collected from the manufacturers and are distributed each year to the states and territorial areas by the Department of the Interior. The state covers the full amount of an approved project and then applies for reimbursement through federal aid for up to 75% of the project's expenses; the state is responsible for the other 25% of the project's cost (USFWS, 2019). Each year, nearly 200 million United states dollars in hunters' federal excise taxes are distributed to state agencies (USFWS, 2013).

Another example of a fee is that of the federal duck stamp in the United States of America. This is the result of the migratory bird hunting stamp act (or duck stamp act), which specifies that all waterfowl hunters 16 years of age and over must annually buy and carry a migratory bird hunting and conservation stamp. Ninety-eight cents of every duck stamp dollar go directly into the migratory bird conservation fund, which seeks to protect wetlands vital to the survival of migratory waterfowl. Since 1934, some 800 million United States dollars have gone into that fund to protect over 5.7 million acres of wild habitat (USFWS, 2017). One of the reasons for the duck stamp's success is that anyone can purchase the federal duck stamp, not just hunters, so it has become a collector's item.

As these examples demonstrate, through a tax model, hunters have made large contributions to conservation. However, as the United States of America continues to urbanize, and as hunting has drawn criticism from conservationists and animal rights advocates, hunting participation rate has declined over the last decades and average age of hunters has increased (Heffelfinger *et al.*, 2013; Spidalieri, 2012) – although notable increases occurred during the COVID-19 pandemic. Maintaining this system of conservation will require a broader scope. This tax model is referred to as a "user-pay, user-benefit" system, as extractive users (as hunters) both pay and benefit. However, this model has been heavily criticized around the world, for being thought to allocate access to nature on an ability to pay basis. Furthermore, other groups, that engage in non-extractive use practices, such as campers, hikers and wild species watchers (non-extractive users) also benefit from the presence of wild species and conservation programs, yet do not traditionally pay into the system through federal taxes (Pack *et al.*, 2013). However, the duck stamp is now becoming a strong societal norm, and is also the basis of a famous artistic contest (for who will draw the stamp of the year), so that many non-hunters also buy duck stamps. An expansion of the tax model has been proposed, through a new tax on outdoor recreation equipment, which would contribute to wild species conservation. This way, non-extractive users might directly fund conservation efforts. Said additional tax would supplement funding and provide new economic support for the conservation of game and non-game. However, the legislation needed to implement the new tax proposal has not been enacted (Pack *et al.*, 2013; Spidalieri, 2012).

Taxes can also be used to kick-start innovative sustainable use programs. For example, in crocodile/alligator farming, many of the technologies now used were developed by government research expenditure, and governments had to invest significantly in management and for example in obtaining support from the Convention on International Trade in Endangered Species of Wild Fauna and Flora to be able to export (CONABIO, 2021b). That support was gradually withdrawn as industries came on line, and in some countries, even the monitoring programs are funded by industry. Louisiana and Florida in the United States of America with alligators, Northern Territory in Australia with saltwater crocodiles, Zimbabwe with Nile crocodiles, are all examples. Innovative new industries in many fields, considered high risk initially, often depend on interim subsidies to get established. With larger crocodiles (and likely many other predators on people and livestock), a key role of sustainable use programs is to provide commercial incentives for landowners and the public to tolerate crocodiles, representing a pragmatic intervention.

Taxes are equally applied to gathering, to enable the sustainable use of wild species. Through taxes, governments can earn revenue from what is perceived as a lucrative business, or as an incentive to stimulate the practice. Such efforts have had variable effects. For example, in Cameroon, the government instituted new taxes on medicinal plants in the 1990s in response to a widespread belief that the medicinal plants were 'green gold' (Laird *et al.*, 2010). In India, tendu *(Diospyros melanoxylon)*, which provides as much as 74% of Orissa state's total earnings from forests, was nationalized in several states in the 1960s and 1970s due to its high value and the interest of government bodies in benefiting from its trade (Lele *et al.*, 2010).

Taxation as a policy tool can thus have significant consequences, especially with regard to influencing behavioral change. In some cases, tax relief can help to stimulate the gathering practice, but when used as a tool to collect revenues, government taxation has more often than not led to bureaucratic and confusing gathering measures. This can leave communities and government authorities unclear about proper procedures, providing government officials an opportunity to request additional 'unofficial payments' (Arquiza *et al.*, 2010; Laird *et al.*, 2010; Ndoye & Awono, 2010). Inappropriate and burdensome measures can also make unofficial payments or bribes preferable to following regulations.

'Unofficial taxation' (i.e., bribery) is a very real cost of doing business in many countries. Bribes are tolerated, and even encouraged, by some governments, and they work like any other policy stick to change behavior. In a number of countries, roadblocks set up by government officials to 'control' the transport of goods from rural to urban areas, and check required documents, divert profits from traders and have knock-on effects for hunters, fishers, gathers, and loggers (Arquiza *et al.*, 2010; Ndoye & Awono, 2010; Sunderland *et al.*, 2010). In the Philippines, one study showed that unofficial payments, or "SOPS" (standard operating procedures), significantly impact the already meagre livelihoods of indigenous peoples' dependent on wild algae, plants and fungi (Arquiza *et al.*, 2010).

6.4.2.2 Subsidies and incentives

Like taxes, subsidies can work to incentivize sustainable use or disincentivize unsustainable -and illegal- use of wild species (Hahn *et al.*, 2015). However, unlike taxes, subsidies seek to influence behavior through reward, rather than penalty. Subsidies are often used to enable entry into a practice, by reducing the costs of entry or operation, and in doing so enable greater resource extraction.

Beneficial subsidies are those that promote resource conservation (Milazzo, 1998; Sumaila *et al.*, 2016), for example, in Brazil, fishermen receive a salary (minimum wage) for 4 months during the fish reproductive period in order not to fish, and in other instances subsidies are paid to marine protected areas, fisheries management, or research. However, because of the nature of subsidies, they can create perverse environmental outcomes. Such subsidies are referred to as harmful subsidies because they drive overexploitation, include for example through fuel or boat subsidies that lower the cost of unsustainable (Milazzo, 1998; Sumaila *et al.*, 2016).

In a recent global analysis, estimates of beneficial fishing subsidies were found to be are considerably smaller than harmful capacity enhancing subsidies (30% *versus* 63%), furthermore, these harmful subsidies were found to be growing (Sumaila *et al.*, 2019). Global subsidies in fishing, amounts to 35 billion United States dollars, the majority of which are harmful fuel subsidies that drive overexploitation (Sakai *et al.*, 2019), with beneficial subsidies that support sustainability through management and surveillance, accounting for as little as 5% of all subsidies (Sakai *et al.*, 2019). Accordingly, pressure is mounting on the need to remove harmful fishing subsidies, an item that is currently under negotiation in the World Trade Organization talks (WTO, 2018).

However, the removal of subsidies can be challenging. Once subsidies are established, market prices adjust accordingly, and removal is likely to significantly impact the social wellbeing of many local communities, in hitting the poorest fishers hardest (Cisneros-Montemayor *et al.*, 2020; Hicks *et al.*, 2014). Consequently, in discussions around removal of harmful subsidies, exceptions to the rules- or special and differential treatment is recommended to minimize these social impacts (Sumaila *et al.*, 2021).

Compensation payments, which can also be conceptualized as a conservation subsidy, are frequently applied to encourage sustainable hunting. The most-often mentioned compensation approach in the literature regarding wild species hunting is that of damage compensation (Bulte *et al.*, 2003). A damage compensation scheme is a tool used to mitigate human- wild species conflict, and might, in many cases, deter illegal hunting of conflicting species. It reimburses individuals who have suffered the costs of wild species – damage (to crops, livestock, property or personal safety) through monetary payments or non-monetary compensation such as replacement animals or food and supplies (Nyhus *et al.*, 2005; Ravenelle & Nyhus, 2017). Most compensation programs aim to increase tolerance towards wild species, thereby reducing "retaliatory killing" of wild species and resistance to conservation management actions (Maheshwari *et al.*, 2014; Shilongo *et al.*, 2018). According to an analysis of global patterns and trends in human- wild species conflict compensation, a majority of programs focus on carnivores (large cats, bears, wolves and crocodiles), and livestock losses represent the most common reason for wild species compensation (Ravenelle & Nyhus, 2017). Similarly, there are payments for compensation for damage caused by attacks to people by carnivores, as has been documented in several cases of crocodile attacks in different areas where these species live (Das & Jana, 2018).

A large majority of compensation schemes are based on ex-post compensation (Ravenelle & Nyhus, 2017; Schwerdtner & Gruber, 2007). However, even when they are effective, they have been widely criticized because compensation is not tied to incentives (Maheshwari *et al.*, 2014; Nyhus *et al.*, 2005). This criticism has led to the development of payment in advance and performance payment approaches (Nyhus *et al.*, 2005; Schwerdtner & Gruber, 2007). The key difference between these approaches and ex-post compensation is that the affected receives compensation in advance (prior to predation damage on livestock or agricultural loss) with a grant or subsidized loan (Schwerdtner & Gruber, 2007). Therefore, this approach creates incentives for locals to seek technical support and acquire materials (e.g., electric fencing) to improve husbandry practices and to maintain carnivores in the landscape (Maheshwari *et al.*, 2014; Zabel & Engel, 2010). Positively valuing a species or habitat is a prerequisite for investing in conservation action. Hence, a species or habitat is more secure, if it is valued by as many people in the community as possible for a diversity of different reasons/values, both intrinsic and utility (Webb, 2015).

6.4.2.3 Sustainability finance mechanisms

The last two to three decades have seen an increase in development and application of market-based policy instruments that aim to create new transactions for environmental goods and services, in efforts to merge conservation with profitability (Bresnihan, 2016). Policy approaches that consider managing nature as a question of managing natural capital are controversial and diverse spanning approaches that aim to make nature's economic value legible to stakeholders to approaches that try to establish novel economic transactions (Bresnihan, 2016; Dasgupta, 2021). Approaches are designed to complement traditional command and control instruments and make sustainable use more attractive to users (Engel *et al.*, 2008; Wunder, 2007). Efforts to make nature's economic value visible include payments for ecosystem services, offsets, and emissions trading, which are most commonly applied to gathering and logging practices and natural capital accounting. Whereas, novel transactions including new financing mechanisms such as blended finance, insurance, and blue/green bonds are increasingly applied to fishing (Christiansen, 2021a; Christiansen & Schutter, 2019).

Payments for ecosystem services are a specific class of approach, used to facilitate voluntary transaction between a provider and a user of a service, conditioned on natural resource management rules for dealing with environmental externalities (Wunder, 2015). Payments for ecosystem services are created to deal with market failures, environmental externalities, property rights problems and asymmetric information between economic actors. Market failure arises due to high transaction costs, uncertainty, and short-term solutions. Two of the most well-known examples of payments for ecosystem services systems are Costa Rica's Pago por Servicios Ambientales and the United Nations-REDD Programme, which both aim to support sustainable use of wild forest species by decreasing logging practices and also impact on gathering practices (Bresnihan, 2016). Payments for ecosystem services differ from other conservation incentives because the payment is direct to the provider but conditional on sustainable use outcomes internalizing the cost (Ezzine-de-Blas *et al.*, 2016).

Even though payments for ecosystem eervices were originally designed as a market instrument, there exist a variety of institutional arrangements, where private and public sectors cooperate (Ezzine-de-Blas *et al.*, 2016). In some countries, programs are financed and managed by public institutions, as it is the case of the payments for ecosystem services national program in Costa Rica (Pagiola, 2008) and the payments for hydrological services program in Mexico (Giron-Nava *et al.*, 2019) which incentivize sustainable logging. In others cases they have been created as an exchange between private institutions such as the profafor carbon payments for ecosystem services in Ecuador (Wunder and Alban, 2008). However, hybrid or mixed schemes also exist where non-governmental organization, landowners, government and users are part of the institutional arrangement such as the matching funds in Mexico (Giron-Nava *et al.*, 2019). In general terms, it has been highlighted that public sector payments for ecosystem services are more common in Europe and Asia, and in Latin America a high diversity of schemes exists.

Payment in the form of access or entrance fees (see 6.4.2.1 on fees) for wildlife watching – a key non-extractive use practice – or for cultural ecosystem services (Church *et al.*, 2017; Cook *et al.*, 2020) is seldom considered as a payment for ecosystem service, highlighting both overlap between instruments and knowledge gaps in the role payments for ecosystem services can play in non-extractive uses (Bigger & Dempsey, 2018; Christiansen, 2021a, 2021b; Dempsey *et al.*, 2022; Frost & Bond, 2008; Ouma *et al.*, 2018).

6.4.3 Social and information-based instruments

It is generally accepted that the general public should be involved in decision-making processes that relate to the sustainable use of wild species. Consequently, social and information-based instruments have been developed to promote greater accountability and influence, through public attitudes and involvement. Social and information-based instruments are thus interventions that seek to influence practices through greater provisions of information (Krott, 2005). Approaches can be applied in isolation, but are more often either overlap with, or are applied in conjunction with legal and regulatory, economic and financial, rights based and customary approaches to steer attitudes, preferences, and demand and thus shape resource use. Common categories of instruments include certification schemes, (eco)labelling transparency & initiatives education and training and stakeholder engagement and consultations.

However, the development and implementation of social-based instruments needs to also pay careful attention not to bias public perceptions and support towards certain species at the expense of understanding key functions and roles in the broader ecosystem. Such a focus on flag species, common with especially large-sized mammals, can lead to unexpected and undesirable outcomes. Although it is very important to guarantee these species protection, they are not the only ones which need this protection.

6.4.3.1 Certification schemes and eco-labelling

Certification schemes and associated (eco)labelling are social and information-based as well as economic instruments since they are intended to operate, through the provision of information, to exert a market pressure to incentivize more sustainable use practices. They achieve this by developing a transparent process that signals to the market a product is sustainable (Pascual-Fernández *et al.*, 2019). For example, an ecolabel is an official symbol that verifies a product has been evaluated, against a set of environmental criteria by a third party. Certifications and labelling work on the basis that given the necessary information, consumer preference will shift to demand more sustainable products; in turn, incentivizing and rewarding, more sustainable practices. However, evidence for certification driven shifts in consumer demand is limited. Several types of certifications and labels have been developed and applied that target different dimensions of social and ecological sustainability (e.g., environment, equity, and benefit sharing). When successfully designed and implemented, certification schemes can support more sustainable practices, more equitable distributions of benefits, the development of new skills, more stable markets, and sustainable sources of finance (Cetinkaya, 2009). However, ecolabels have been criticized for setting up parallel systems of policy for sustainable use, and diverting government funds away from, rather than supporting existing structures and processes. This is exacerbated, in lower income settings where the cost and infrastructure requirements mean certifications, may need Government or external support.

Certification and labelling schemes are well established and widely used in large scale commercial fishing, logging, and recreational non-extractive use practices. The Marine Stewardship Council is one of the oldest and well-known certification schemes that covers fishing and is increasingly recognized by industry as an indicator of success in achieving sustainable fishing. The Marine Stewardship Council was formed in the aftermath of the 1992 collapse of the cod stocks, initially in an alliance between the Worl Wildlife Fund and Unilever. By 2000 the first fishery, the Australian rock lobster, had been certified, and in 2006, the Marine Stewardship Council achieved consistency with the FAO of the United Nations's voluntary guidelines on ecolabelling. Currently, over 20,000 Marine Stewardship Council certified products are available, with entire supermarkets (e.g., Sainsbury's) and even countries (e.g., Netherlands) having pledged to sell only 100% Marine Stewardship Council certified fish products.

However, 80% of fisheries certified by the Marine Stewardship Council are large scale fisheries, despite these accounting for only ~50% of global catches (Le Manach *et al.*, 2012; World Bank, 2012). Furthermore, Marine Stewardship Council certifications have been criticized for certifying already sustainable fisheries rather than supporting unsustainable practices to transition to sustainable ones, and for predominantly (83%) certifying fisheries that employ active gears, despite their greater environmental footprint (Le Manach *et al.*, 2012). Consequently, the harvesters and buyers/processors from fisheries, such as the United States of America west coast albacore tuna, Brittany sardines, and Portuguese sardines' fisheries reportedly seek out certification primarily to expand or maintain their market share, rather than improve sustainability (Anderson *et al.*, 2021).

Within logging, certification and labelling emerged in the early 1990s in an effort to incentivize more sustainable use. Certifications have since been widely adopted and well-respected, although the anticipated price premiums associated with certification have not materialized. The success of logging is due to consumers' (both primary, i.e., companies acquiring and processing timber and secondary ones at higher segments and at the end of a supply chain) sensitivities to environmental concerns (this is related, in its turn to the effectiveness of information and opinion forming), and legitimacy of certification bodies labelling in ensuring transparency and inclusiveness.

The two largest international forest certification schemes, the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification seek to incentivize more sustainable logging practices, through greater information transparency, actor engagement, and corporate social responsibility, but have adopted different governance strategies. The Forest Stewardship Council, is a hierarchical organization with its roots in environmental movements, and similar to many certification schemes, engages a broad range of private sector actors, and open society organizations. The Forest Stewardship Council was first conceptualized after the 1992 Earth summit, after it failed to reach agreement to halt deforestation, with 1994 seeing the first Forest Stewardship Council certified product in the United Kingdom of Great Britain and Northern Ireland.

In contrast, to the Forest Stewardship Council, the Programme for the Endorsement of Forest Certification works primarily with national quality control and certification bodies, such as the Nordic Swan ecolabel and many national forestry certification schemes offering a relatively flexible compliance framework. Many governments (e.g., in Argentina and Indonesia) prefer the Programme for the Endorsement of Forest Certification model, but some have resorted to double certification to increase international market appeal. Both the Forest Stewardship Council and the Programme for the Endorsement of Forest Certification are well respected, but some argue that, where national forest and biodiversity governance frameworks are robust and well-functioning, certification does not bring any added value.

More recent certification schemes include the Union for Ethical Biotrade (https://www.ethicalbiotrade.org/about-uebt) and FairWild (https://www.fairwild.org/our-story), born in 2007 and 2008 respectively. Both FairWild and Union for Ethical Biotrade aim to promote biologically and socially sustainable trade through transparency and accountability, and cover the gathering and harvest of wild species and products.

Certifications and labelling are also widely adopted to support more sustainable non-extractive use practices, by providing the consumer with environmental, safety, or ethical information about the company characteristics, that supports more informed consumer choice. These instruments guide individual choices towards specific types of markets that match their values. For example, the "Whale Sense" label was created in the Gulf of Maine, to indicate which whale watching tour companies have taken a training course, and have a certificate, to ensure their practices align with obligations set out by the International Whaling Commission (Avila-Foucat *et al.*, 2013; IWC, 2020). However, various nature-based tourism labels have been criticized for failing to adequately account for environmental impacts of for example carbon emissions from travel (Buckley & Shakeela, 2013; Gosling *et al.*, 2017; Margaryan & Stensland, 2017).

In addition to certification, many non-extractive use activities have developed codes of conduct to guide use that are implemented by the sector or the communities. One third of the regulations on non-extractive uses are mandatory with two-thirds entirely voluntary (Garrod & Fennell, 2004). Most codes specify a minimum approach distance (e.g., 50–100m or more), but other aspects such as prescriptions on no feeding or touching cetaceans are not necessarily included. Codes of conduct in birdwatching are also used as an instrument by birdwatchers' societies or tour companies (Walther & White, 2018).

Certification requires traceability such Forest Stewardship Council in logging and Seafood Business for Ocean Stewardship (SeaBOS) in fishing. Sophisticated traceability system of certification schemes is a barrier for indigenous peoples and local communities to comply with. Although the certification ensures traceability, complexity hampers execution of certification process in the supply chains. For effective implementation of the certification which secures traceability, clarifying and informing the certification process and the required competencies is crucial for active participation by indigenous peoples and local communities.

6.4.3.2 Education, training, stakeholder engagement and consultation

Social and information-based instruments can also be useful to increase knowledge, skills, and awareness, to promote involvement, stimulate control, and generate public pressure which are all important drivers of change in the use of wild species.

Education and training can help move towards more sustainable use of wild species. Education generally has a strong and functional relationship with practice, holding considerable potential for influencing actions. However, education and training are seldom prioritized as policy options, more often appearing as a complementary activity. In many regions, ocean and forest management historically prioritized logging and commercial fisheries, orientated towards maximizing economic yields. This focus resulted in peoples, including indigenous peoples and local communities, and practices, including gathering, being overlooked. Furthermore, because education and training is a knowledge-intensive field involving topics from many bordering disciplines, that involve considerable amounts of monitoring, technology and policy innovation, education has historically not been very inclusive. This is especially true in countries where education is structured within multiple institutions, and this can be regarded as a challenge. Thus, associated academic fields have historically failed to include the diversity of disciplines (though this is rapidly changing), knowledges (e.g., indigenous and local knowledge), and languages of relevance.

Stakeholder participation, engagement, and consultation are increasingly recognized as essential components of environmental decision-making and policy, often legally mandated in processes (Mease *et al.*, 2018). Ample guidance is now available and effective stakeholder engagement is considered mandatory to achieving social, environmental and economically sustainable standards, and is often a legal requirement. This perspective is also true for the management of wild species, since science alone has not been able to address or reduce unsustainable use of biodiversity. For example, community-based management that involves various degrees of joint decision-making between communities and either governmental or non-governmental organizations (e.g., co-management see section 6.4.4.5) has taken off in fishing, particularly small-scale fisheries which accounts for up to 90% of the world's fishers, as discussed in section 6.5.1.1.

Indeed, governance arrangements work best when they involve consultation approaches, which seek to understand public attitudes towards the sustainable use of wild species, engage with local knowledge, and thus establish where there is political support for an activity. This approach can help inform the development of more effective policies. Management actions with little public support can be undermined and fail, especially when attitudes and beliefs of stakeholders and the wider public are contrary to the ones of wild species managers or wild species experts (Fulton *et al.*, 2014). Although consultation with stakeholders is an important way to gather information and to set priorities and objectives for policy, in most countries wild algae, fungi and plants harvesters and producers are drawn from the least powerful members of society and typically have little say in policymaking (Alexiades & Shanley, 2004; Hecht & Appelbaum, 1988; C. Shackleton & Shackleton, 2004; Shanley, 2002; R. Wynberg & Laird, 2007). Because such groups are rarely consulted during policy design, their needs seldom drive the policymaking process. Technical experts and even non-governmental organizations (which may not be representative of producers and harvesters, but can provide important assistance) often have more significant input into the design and drafting process than those directly involved in the harvest or trade of products. The consultations that do take place for gathering law and policy are often with larger and more powerful business interests.

One reason for the limited involvement of harvesters in the policy process is the dearth of producer organizations or institutional vehicles through which their views and concerns can be expressed, and a lack of organizational capacity to do so. Although peasant worker, grass roots worker, and civil society organizations and coalitions (e.g., *via* Campesina, International Collective in Support of Fish Workers, and the Civil Society Mechanism within the United Nations) have formed over the past 3 decades in an effort to redress this balance and gain a political voice to the least represented, but often most affected by sustainable use policies and biodiversity loss. Even in recent decades, Brazil nut measures were drafted and passed in Bolivia without public consultation. It was only in the late 1990s that small Brazil nut producers finally forced their views into the public arena, in part by being better organized (Cronkleton & Pacheco, 2010). In the United States of America, Canada and the United Kingdom of Great Britain and Northern Ireland, some effort has recently gone into including harvesters, buyers and processors in proposed regulatory reforms, either through the formation of industry-specific task forces or public hearings (Dyke & Emery, 2010; McLain & Lynch, 2010; D. A. Mitchell *et al.*, 2010).

6.4.4 Rights-based and customary instruments

Customary and rights-based approaches include formal and informal means of intervention that influence social and economic action through locally defined norms, customs, and tradition. Customary and rights-based approaches are often considered and conceived at local scales, however international agreements and guidelines (e.g., FAO small-scale fisheries Guidelines in Chapter 1, United Nations declaration of human rights), often developed through extensive consultation with rights holders, exist to guide new and support existing rights-based approaches. Rights-based and customary instruments at an international scale include treaties and guidelines, whereas at local and national scales they include customary laws, norms, and tenure, human rights-based approaches, and systems of traditional knowledge.

Customary and rights-based approaches, as policy instruments, are constantly developing and evolving in response to social, technological, environmental, and policy changes. However, many customary instruments predate more recent statutory policy options, which have often been introduced unaware that systems of governance were already present. Consequently, perhaps more evidently than the previous categories of instruments, rights-based and customary instruments co-exist with the other categories in ways that can erode, complement or enhance the sustainable use of wild species. In many countries, customary and statutory laws play complementary roles **(Box 6.2)**, but it occurs for new statutory laws to weaken effective customary systems.

Indigenous peoples' traditional ecological knowledge, traditional systems of control, use and management of lands and resources, and traditional institutions for self-governance are central components of customary and rights-based approaches and contribute substantially to sustainable use (Springer & Campese, 2011). Indigenous and place-based communities engaged in fishing, terrestrial animal harvesting, and gathering worldwide have self-organized to develop effective local-level institutions to conserve biocultural diversity. How communities maintain and adapt these institutions over time offers lessons for fostering more balanced human-environment relationships-an increasingly critical need as centralized governance systems struggle to manage declining biodiversity and ecosystem services (Montgomery & Vaughan, 2018).

An example of traditional ecological knowledge being applied in wild species management -through sustainable terrestrial animal harvesting- on common land, is presented by Rosales-Meda and Hermes-Calderón (2010), who worked with Maya-Q´eqchi´ communities that live in the surroundings of Laguna Lachuá national park, in Guatemala. The authors compiled the traditional ecological knowledge of hunters and local inhabitants and gathered information regarding problems with the hunting activity and the solutions proposed by the members of the communities. They proposed and communally validated a calendar of animal breeding seasons that includes temporary bans for the most pressured species, complete bans for some threatened species, hunting grounds, sacred hunting sites, grace periods and wild species refuges **(Figure 6.2)**. They formulated a community management system that allows local residents to make use of their hunting resource, to guarantee food security, according to their cultural practices and based on their own traditional ecological knowledge. Since the process of formulation and management of this proposal was carried out jointly with the people directly involved, it is more likely to succeed in its long-term implementation and sustainability (Rosales Meda & Hermes Calderón, 2010).

In conversations relating to biodiversity, gender is often discussed in terms of the roles, responsibilities and rights of men and women (Gutiérrez-Zamora, 2021; Lau, 2020; Nursey-Bray, 2009; Pfeiffer & Butz, 2005; Poor *et al.*, 2021; Villamor *et al.*, 2013). While this binary often has local relevance, it is important to acknowledge that cis gender identities (gender correlating to sex at birth) are not the only legitimate gender identities that need to be acknowledged through policy and practice (Tulloch, 2020).

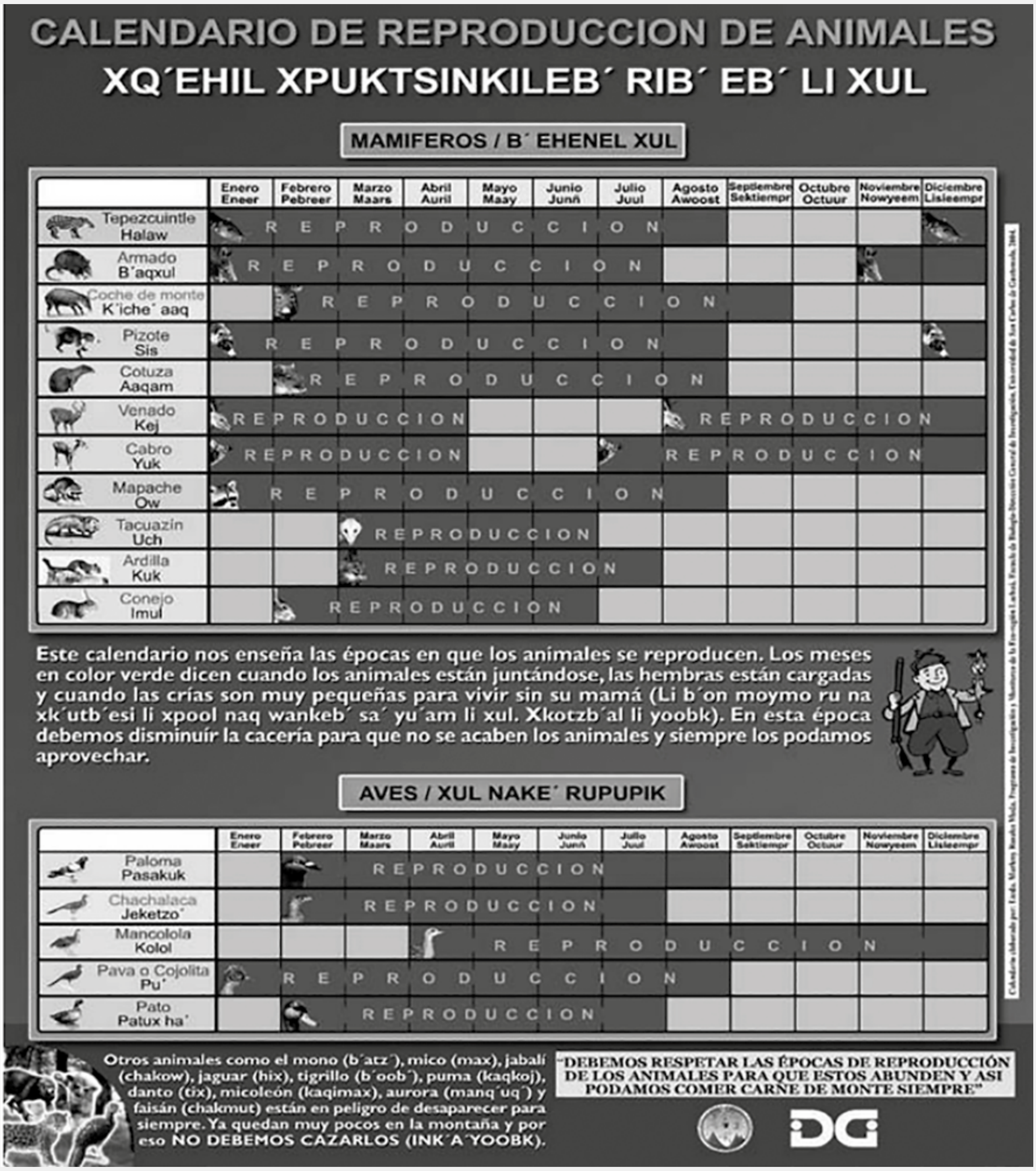


Figure 6 2 **The calendar of animal breeding seasons was elaborated in Q´eqchi´ and Spanish with drawings and in colloquial language for easier understanding.**

Copies were delivered to local family and to the authorities so that they could be placed in visible and busy places in their communities. Source: *(Rosales Meda & Hermes Calderón, 2010)* © 2010 Secretaría de Educación de Veracruz CC-BY NC.

Transgendered people, whether formally acknowledged or not, are members of communities who often face discrimination and are marginalized in decision-making systems (Collins *et al.*, 2015; Hill *et al.*, 2017). It is important to also consider impacts of intersectionality (e.g., gender identity, race, indigeneity, socio-economic status) on participation in biological diversity conservation systems and how particular groups are often disenfranchised (Khalikova *et al.*, 2021; Lau, 2020). However, gender norms play a key role in influencing what activities are available to whom, with implications for the sustainable use of wild species.

Perceptions of the use of wild species is often dominated by the practices of able bodied men. Yet, women play an important, though often overlooked, role in for example, gathering such as in the Indian Himalayan region (Dhyani, 2018; Dhyani *et al.*, 2011), the use of medicinal plants by urban communities in Tanzania, and fishing all around the world where women account for about 50% of the workforce (Chuenpagdee *et al.*, 2006). However, men and women often use wild species in different ways, for different purposes, and have evolved different systems of governance. For example, in the Australian Martu community, women hunt primarily small, predictable game (lizards) to provide small kin networks, feed children, and maintain their cooperative relationships with other women. In contrast, men hunt as a political strategy, using a form of "competitive magnanimity" to rise in the ritual hierarchy and demonstrate their capacity to keep sacred knowledge (Bliege Bird & Bird, 2008). Similarly, in Morogoro, most men herbalists use roots while women prefer barks (Augustino & Gillah, 2005). In the Loreto region of the northeastern Peruvian Amazon, it is taboo for any woman to hunt (Espinosa, 2010) but medicine women go deep into the forests to harvest medicinal plants. They have the spiritual knowledge and power to negotiate nature and its spirits in ways others cannot, thanks to their knowledge of rituals (Espinosa, 2010). Finally, although terrestrial animal harvesting and fishing are perceived to be dominated by men in indigenous communities in Canada, women play an essential role in food harvesting and gathering (IPBES, 2019a).

These gender differences mean although men and women may agree in principle on the need for conservation approaches, the strategies they will embrace will likely differ. In the Australian Martu community men trade off reliable consumption benefits to the hunter's family for more unpredictable benefits in social standing for the individual hunter (Bliege Bird & Bird, 2008). Systems of sustainable use thus often fall along gendered lines, for example in Thailand, the Karen people have a very strong a matriarchal social system (IPBES, 2019a), and in India, *Mahila mangal dals* (women self-help groups) regulate gathering of wild plants and enforcement of penalties (Dhyani *et al.*, 2011, 2013; Misra *et al.*, 2008). Formal and voluntary policies are beginning to recognize the importance of gender norms and look to rectify the historical oversight. For example, Kenya has committed to introduce laws that will allow girls to inherit land and to get their own title deeds. Whereas, the FAO's small-scale fisheries guidelines contain acknowledgement of the roles of women in the small-scale fisheries value chain, the need for gender equity and equality in access to human well-being resources, and the need for equal gender participation in fisheries governance (Kleiber *et al.*, 2017).

6.4.4.1 Tenure, access, and property rights

Communal ownership of land and wild species is widespread among indigenous peoples and local communities who have traditional ecological knowledge, associated with fishing, hunting, and gathering practices, and for whom wild species are imbedded in their cultural identity and social norms (Delisle *et al.*, 2018; Guerrero-Ortiz, 2013; Tauli-Corpuz *et al.*, 2020). However, in many parts of the world, governments (often colonial governments) claimed as state land, areas that were traditionally owned and governed by indigenous peoples and local communities, undermining customary systems of tenure, overlaying new rules onto traditional practices (Domínguez & Luoma, 2020). Consequently, where people have maintained continuous attachments to their lands, there are likely to be situations of "legal pluralism" – i.e., overlapping systems of statutory tenure (codified in state law) and customary tenure (derived from ancestral ties and regulated through traditional institutions) (Vanderlinden & Gilissen, 1972).

More recently, there has been growing recognition that weak tenure is a prominent political driver of unsustainable use (see Chapter 4), exacerbating the gap between statutory and customary rights to lands and resources (Tseng *et al.*, 2021). Through increasing recognition that tenure derives from statutory and customary laws and institutions, many national constitutions now recognize some customary rights, though often in limited ways. Elsewhere, statutory devolution of natural resource ownership and management rights and responsibilities, especially of forests and waterbodies, is underway (Magessa *et al.*, 2020).

In some cases, land tenure may be secure, but resource rights are not. In Mexico, most forests are collectively owned, and while local communities have some autonomy in the management of their natural resources, and how they organize their gathering practices, the state sporadically exert control over their use. For example, agave extraction has been regulated for hundreds of years through local institutions within the ejido and indigenous community structure. They have been responsible for regulating access, management practices and the distribution of benefits based on history and traditional knowledge of the species. Norms and agreements are established by general assembly and are continually modified or replaced in a dynamic process that responds to new situations and to tensions of environmental, socioeconomic, cultural or technological origin. Even with such a dynamic and sophisticated system, however, local harvesters are required to present a legal harvesting permit (Granich *et al.*, 2010).

Resource rights are undergoing change alongside broader views of property rights in many countries. For example, in Sweden and Finland, the centuries-old principle of 'everyman's right' to harvest wild berries and mushrooms through gathering is being tested by the seasonal in-migration of large numbers of non-nordic pickers, raising public concerns about immigration and tax policies, labor practices and benefit sharing (Richards & Saastamoinen, 2010). Similarly, in England, Scotland, and elsewhere tension exists for non-extractive use practices, between customary rights to roam, the codified versions of those rights (Dyke

& Emery, 2010), and potential rising environmental impacts (Beery, 2018; Sandell & Fredman, 2010). In Canada, in a reversal of trends in many other countries, as part of asserting aboriginal fishing and gathering rights and title, First Nations are demanding the return of their right to regulate access to wild algae, plants and fungi (D. A. Mitchell *et al.*, 2010).

6.4.4.2 Customary laws: rules norms, and rights

Local communities and traditional societies have a wealth of approaches to support the sustainable use of wild species that apply to gathering, small scale fishing, terrestrial animal harvesting, logging, as well as some forms of non-extractive uses. Customary laws, which include communal property rights, customary use rights, as well as many unwritten rules, and norms, have often developed for social or cultural purposes, such as feasting (Foale *et al.*, 2010; Foale & Manele, 2004), or to support processes considered locally as fair, but also serve to ensure over-use is prevented and enough will be left for future generations. Furthermore, article 10(c) of the Convention on Biological Diversity states that "Parties shall: […] protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements" (CBD, 2010a). Highlighting nations' obligations to recognize customary laws and ensure legitimate representation of indigenous peoples and local communities in the development of policy.

Many of the customary use rights, communal management systems, and customs indigenous peoples and local communities have provided incentives for efficient use and management of natural resources, but many remain undocumented. These range from water rights in India which influence logging, customary marine tenure in Melanesia that regulates fishing (Cinner, 2007), communal forests and land rights in Papua New Guinea that shape gathering, and hunting practices, to customary fishing rights in Brazil, Sri Lanka, and Côte d'Ivoire (Cinner, 2007; Foale *et al.*, 2010; Zwarteveen & Meinzen-Dick, 2001). These systems, far from being outdated, contain valuable lessons and essential elements for the design of effective systems of managing natural resources. While many customary systems did not withstand historical processes and others

Box 6 2 **National and regional recognition of customary law.**

Customary law is widely recognized at both the national and international level as having a role to play in the regulation of the rights and interests of indigenous peoples and local communities over their natural resources and traditional knowledge. A number of regions, including in Latin America, Australia, and North America, have historically adopted policies, which promote the integration and assimilation of indigenous peoples, but eliminate their legal systems, languages and cultures. While, these systems dominate in urban centers, traditional systems of law, land rights and cultural relations continue unchanged in the rural areas occupied by indigenous peoples, and where the majority of indigenous peoples continue to maintain their own systems of community life. Attitudes towards indigenous peoples shifted in the 1990's when all Latin American countries, then part of the Andean Community, adopted new constitutions. These reflected a shift from a policy of assimilation towards one of recognition of the pluri-cultural and multi-ethnic nature of the state. Some constitutions such as that of Peru and Colombia go further recognizing special rights of indigenous peoples to apply their own laws to regulation of their internal affairs (Oviedo & Noejovich, 2007), and recognized indigenous knowledge on living with nature (e.g., Buen Vivir) (Gudynas, 2011).

The Andean Community of Nations has, since the entry into force of the Convention on Biological Diversity in 1993, been one of the leaders in the development and implementation of law and policy on access and benefit sharing (Nagoya Protocol) and traditional knowledge issues (Tobin, 2008). The Andean Community of Nations is a regional economic group whose decisions are legally binding on member states. In 1996 it established a regional regime on access and benefit sharing, which recognized the rights of indigenous, Afro-American and local communities to control access to their traditional knowledge. Decision 391 requires that, as a pre-condition for approval of bioprospecting agreements, a side agreement be signed with communities for the collection of resources on their land or for use of their traditional knowledge. Countries of the region have championed the debate on disclosure of origin at the World Trade Organization and have been amongst the promoters of the concept of certificates of origin in the international Access and Benefit-Sharing negotiations at the Convention on Biological Diversity (Tobin, 2008). Andean legislation requires prior informed consent of indigenous, Afro-American and local communities for access to and use of traditional knowledge creating an opportunity for communities to apply their customary law to regulate procedures on prior, informed consent. Customary law may also be used to guide decisions on issues of benefit sharing, confidentiality of information, and resolution of conflicts (Tobin, 2008).

Bolivia's 35 indigenous peoples number approximately 8 million people, or 70% of the national population (De La Cruz Modino, 2007). The Constitution of 1994 recognized Bolivia to be multiethnic and pluricultural. It commits to recognizing, respecting and protecting the social, economic and cultural rights of indigenous peoples, in particular with regard to their traditional lands, the sustainable use of natural resources, their identity, values, languages, customs and institutions (150 Article 171).

are undergoing intense pressure including from population growth, new markets, and modern technologies (indigenous and local knowledge dialogues), they nevertheless act as prototypes of management systems that are attuned with the local cultures and provide insights into the design of modern systems of natural resource management.

Customary law is often unwritten, but flexible, relational, and negotiable in character. Customary norms are seldom used to determine directly who wins and who loses, but are rather used as a starting point for discussions towards mediated outcomes (Lau *et al.*, 2020; Ubink, 2018). Thus, customary norms are inherently participatory, formulated, renegotiated and flexibly applied in administrative structures and dispute settlement institutions. This involves paying attention to issues of representation and participation of marginalized community members in policy and decision-making processes (N. Fraser, 2010), and their ability to make use of these systems to uphold their rights and obtain outcomes that are fair and equitable (Ubink, 2018). The unwritten, negotiable and relational nature of customary law and the variety in normative beliefs and practices within customary communities is characteristic of customary norms, often making them place specific and can result in them being overlooked despite increasing recognized in international conventions, guidelines, national state legislation (e.g., United Nations declaration on the rights of indigenous peoples).

Intact customary law has a significant role in ensuring sustainable and equitable practices. For example, in Fiji, 83 per cent of the total land area, and the sea bed, available for gathering and fishing is under customary tenure ('native lands'). But, even with secure land tenure and resource rights, dramatic social, cultural, technological, economic, and other changes have strained customary and local laws. Similarly, landownership in the Philippines is vested in communities, each with its own rattan territory, and many with strong customary laws that promote sustainable rattan gathering practices (Arquiza *et al.*, 2010).

6.4.4.3 Indigenous peoples and local communities and taboos

Social taboos exist in most cultures, both Western and non-Western. They are good examples of informal institutions, where norms, rather than governmental juridical laws and rules, determine human behavior (Colding & Folke, 2001; C. Negi, 2010). In many traditional societies throughout the world, taboos frequently guide human conduct toward the natural environment (Colding & Folke, 2001). Local habitat taboos provide effective protection of smaller ecosystems in, for example, different parts of Africa (Byers *et al.*, 2001; Golden & Comaroff, 2015; Lebbie & Guries, 1995), India (Sinha *et al.*, 2003), Polynesia (Foale *et al.*, 2010), and China (Hongmao *et al.*, 2002). Colding and Folke (2001) suggest that social taboos can constitute systems of local resource governance that can lower transaction costs for monitoring and enforcement compared with formal governance systems. Areas protected through informal institutions, such as taboos, have seldom been incorporated into biological conservation schemes, partly because of the narrow definitions of what constitutes conservation (Folke *et al.*, 2002). There is a growing need to identify and analyze resource practices and social mechanisms of traditional societies, such as taboos, and to investigate their possible ecological significance not only of species, but also of ecosystem processes and functions, such information is being lost rapidly (Colding & Folke, 1997).

Some taboos associated with *Hariyali Devi* and *Tungnath* sacred groves in Himalayas, India are to be followed by all (Singh *et al.*, 2017). These include the following:

- Fetching/gathering of fodder and fuelwood and the movement of women (as women are main harvesters of fuelwood, fodder, and other wild species) and *Shudras* (scheduled castes) have been strictly prohibited in this grove since the Mahabharata period (9th and 8th centuries BCE).

- Use of tools in any form (knife, sickle, etc.) on the wild plants and animals will be a step to hurt the sentiments of *Devi* (goddess). The forest fairies in turn are angered and their wrath can make person mad or deformed and also can lead to disaster in the family of offender.

- Killing/hunting of wild animals and plucking/uprooting of wild plants are strictly forbidden in the sacred groves.

"In communities along the Loretoyacu river in the Ticoya reserve or resguardo, a territory shared by Ticuna, Cocama and Yagua indigenous peoples, hunters have stories of encounters with forest spirits that help them find game or keep them from hunting in a certain place. Those encounters, combined with practices related to preparing the meat for meals, are traditional ways of controlling hunting in the territory" (B. Fraser, 2016).

Hunters offer various accounts of places where hunting is permitted, but hunters can only take what they need, or as places that keep hunters at bay, with thunder, lightning and rain if a hunter gets too close. When certain plants are flowering or bearing fruit, the meat of animals that feed on them has an unpleasant flavor and can cause nausea, diarrhea or rashes, so hunters avoid hunting those animals in places where they see those plants. More than two-thirds of the beliefs that limited the hunting or use of wild game were related to consumption. Eating the meat of a tapir, for example, could cause a pregnant woman to miscarry. Women also should not look at or touch the turtle known as a matamata (B. Fraser, 2016).

The largest number of "taboos" about meat consumption in Colombia involved the jaguar, a top predator that also has spiritual significance to many Amazonian people. Other animals regulated by traditional beliefs included tapirs and snakes. The largest number of beliefs related to the way meat is handled involved turtles for example, touching the blood of a turtle while preparing the meat is said to produce warts. Failure to respect taboos is considered to cause illness, and could result in a decrease in the number of animals or make hunters unlucky in their search for wild game. Fishermen respect similar practices. One lake in the reserve is known to fishermen as a dangerous place, home to huge river otters, jaguars and giant caimans (B. Fraser, 2016).

The radiated tortoise, *Geochelone radiata*, is endemic to the semi-arid region of southern Madagascar. Despite formal protection by law since 1960 and listing in the Convention on International Trade in Endangered Species of Wild Fauna and Flora since 1975, tortoise populations have been reported to be in rapid decline, mainly due to illegal harvesting for food and commercial trade. The Tandroy people, inhabitants of the Androy region, which covers approximately half the tortoise distribution range, do not, however, exploit the species. The Tandroy prohibition against tortoise consumption is expressed as a taboo or fady (Lingard *et al.*, 2003).

Sacred sites are protected by indigenous national laws or codes of conduct by indigenous peoples many times associated to believes, and have not been assessed in the literature. However, some authors argue that due to those believes sacred sites and consequently the species associated are conserved. In the Ikoma culture, killing a totemic species leads to a community penalty (Kideghesho, 2009). The literature highlights the potential of spiritual sites for conservation however, beliefs can also be detrimental for some species. In Thathe Vondo in Limpopo province, South Africa, the harvest of fuelwood and to extract any products (roots, bark or leaves) from the sacred forests for medicinal purposes (Sinthumule & Mashau, 2020) is a taboo. To get firewood from both the Chirozva and Daramombe hills was considered taboo by the Nharira community in Chikomba district, Zimbabwe. Tree species such as muzhanje/mushuku *(Uapaca kirklania)*, mushuma *(Diosphyros mespiliformis)* and mutohwe *(Azanza garckeana)* were not used as firewood on the pretext that they produce a lot of smoke that causes total blindness. Other forms of mishaps that are associated with the use of fuelwood from such trees included drought episodes, reduction in crop yields and losing field crops to baboons. Yet from a nutrition perspective, the three trees are a source of wild fruits to the community. Hence, the need to protect them from rampant destruction. Muzhanje/mushuku *(Uapaca kirklania)* bears nutritious fruits during December and January when other wild fruits are in short supply. In drought periods such wild fruits become an alternative source of food as the trees survive long periods of dry spells (Mavhura & Mushure, 2019).

The following illustrates sustainable use and management of indigenous plant resources by the mantheding community in Llimpopo province, South Africa: "Dependency on indigenous plant species necessitated the development of cultural practices to preserve the species. The harvesting of useful indigenous plant species from communal lands is regulated through observance of strict harvesting methods by all community members who harvest the species to satisfy particular needs. The management methods include specific harvesting methods, seed propagation and control of the use of plant species by the local chief. Preservation of sources of vegetables is accomplished through harvesting the tender leaves. Species are left to grow to maturity and bear seeds and fruits, which help in the propagation of the species. Gathering fruits is regulated. The taboo restricting the stroking of fruits limits over-use of the fruit trees. Gathering plant material for construction is limited to straight-stem species. Crooked-stem species are sidelined" (Rankoana, 2016).

Contrasting with taboos, there are other traditional believes and practices, such as traditional medicine, which -if not carried out sustainably- can lead to overexploitation of the natural resources they are based on. According to the World Health Organization (WHO), as much as 80% of the world's population could depend on traditional medicine (based on the therapeutic use of animals, fungi, plants and microorganisms), for primary health care (Alves & Rosa, 2005; World Health Organization *et al.*, 1993). Traditional medicine is protected internationally by many legally binding instruments such Convention 169 of the International Labour Organization (ILO), Article 8(j) of the Convention on Biological Diversity, and, most recently, the United Nations declaration on the rights of indigenous peoples, specifically article 31 which states that: "Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs, sports and traditional games and visual and performing arts".

Some traditional medical practices have been gaining popularity, expanding to new locations and users, highly increasing product demand (Lee *et al.*, 2014). Some widely known examples of animal parts used in medicine include tiger bones, rhino horns, antlers of various deer species, bear bile, salamanders, parts of reptiles such as geckos and turtles, among others (Byard, 2016; Feng *et al.*, 2009; Still, 2003).

An introduction of certification systems for traditional medicine products (e.g., Fairwild, although it is exclusively for wild plants (Antosch & Morgan, 2017), therapeutic alternatives (e.g., chemical remedies, synthetic substitutes) and demand reduction strategies when demand is greater than supply, can be part of the solution (Still, 2003). Also, increasing public awareness through education campaigns and advocating sustainable wild species consumption could have a higher impact (Lee *et al.*, 2014).

6.4.4.4 Human rights-based approaches

Human rights, are evidently, and frequently recognized in international documents and commitments as relevant to the conservation and sustainable use of natural resources. Indeed, millions of people around the world are dependent on natural resources for their food and wellbeing (UNDHR Art 25). In 2004, the Third International Union for Conservation of Nature World Conservation Congress adopted resolution 3.015 of the International Union for Conservation of Nature: "Conserving nature and reducing poverty by linking human rights and the environment". This resolution affirmed that […] social equity cannot be achieved without the promotion, protection and guarantee of all human rights…" (Greiber *et al.*, 2010) **(Box 6.3)**. More recently, on the back of decades of campaigning most notably by indigenous groups and environmental defenders, a land mark resolution was passed (UNDHR Res 48/13) by the United Nations Human Rights Council, recognizing a healthy and sustainable environment to be a human right (UN News, 2021).

The centrality of indigenous peoples and local communities' rights and customary law and international recognition of the rights of indigenous peoples to regulate their affairs in accordance with their customs, customary laws and institutions has been clearly set out in national and international legal instruments. Since the adoption in 1966 of the United Nations international covenants on civil and political rights and on economic social and cultural rights, recognition of indigenous peoples' rights to self-determination has progressed steadily in the global policy arena. Other instruments that advance recognition of the rights of indigenous peoples and the role of customary law as both a source of law and as self-standing legal systems governing the affairs of large sectors of the global populace include the Convention on the Prevention of all Forms of Racial Discrimination; the Convention on the Rights of the Child; European, African, and American regional human rights instruments; and the United Nations declaration on the rights of indigenous peoples (Tobin, 2008).

United Nations declaration on the rights of indigenous peoples Articles 18 and 41 affirm, respectively, that indigenous people "have the right to participate in decision making in matters which would affect their rights" and that "ways and means of ensuring participation of indigenous peoples on issues affecting them shall be established" (CITES, 2016). Whereas Article 19 of the United Nations declaration on the rights of indigenous peoples, and Article 10(c) of the Convention on Biological Diversity link biodiversity, customary sustainable use, and traditional knowledge stating "Each Contracting Party shall, as far as possible and as appropriate: (c) Protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements" highlighting the obligation to work with indigenous peoples, through their representative institutions, to uphold customary use of wild species, and cultural value". The International Labour

Box 6 3 **The International Union for Conservation of Nature environmental law centre principles for assuring human rights in conservation.**

Source: (Greiber *et al.*, 2010). © 2009 International Union for Conservation of Nature and Natural Resources

- Promote the obligation of all state and non-state actors planning or engaged in policies, projects, programs or activities with implications for nature conservation, to secure for all potentially affected persons and peoples, the substantive and procedural rights that are guaranteed by national and international law.
- Ensure prior evaluation of the scope of conservation policies, projects, programs or activities, so that all links between human rights and the environment are identified, and all potentially affected persons are informed and consulted.
- Ensure that planning and implementation of conservation policies and actions reflect such prior evaluation, are based on reasoned decisions and therefore do not harm the vulnerable, but support as much as possible the fulfilment of their rights in the context of nature and natural resource use.
- Incorporate guidelines and tools in project and program planning to ensure monitoring and evaluation of all interventions and their implications for human rights of the people involved or potentially affected which will support better accountability and start a feedback loop.
- Support improvement of governance frameworks on matters regarding the legal and policy frameworks, institutions and procedures that can secure the rights of local people in the context of conservation and sustainable resource use.

Organization, Convention 169, and the United Nations declaration on the dights of indigenous peoples recognize the collective rights of indigenous peoples to their traditional lands and resources, and the requirement to give due regard to customary law.

Recognition of the specific situation of indigenous peoples as maintaining customary institutions and ties to their traditional lands, often in combination with conditions of vulnerability, have resulted in provisions on indigenous peoples in core human rights treaties, as well as international rights instruments specifically addressed to indigenous peoples (particularly International Labour Organization 169 and United Nations declaration on the rights of indigenous people). "Rights of indigenous peoples include collective or group rights, which are linked to their individual rights, as collective rights (such as to territory) often need to be realized in order to fulfil individual rights (such as to food and health)" (Springer & Campese, 2011).

The term "rights-based approach" has been used in various contexts and has been defined in different ways. For example, in fishing, Allison *et al.* (2012) advocate for a move away from governance based on economic incentives to embedding governance challenges in a broader perspective of human-rights. A rights-based approach recognizes that activities and projects related to sustainable use of wild species can have a positive or negative impact on human rights, while the exercise of certain human rights can reinforce and act in synergy with the goals for sustainable use of wild species (Greiber *et al.*, 2010). The concept of developing and applying a human rights-based approach to the sustainable use of wild species could be perceived as such an instrument (Greiber *et al.*, 2010).

While linking environment and human rights issues is not a revolutionary suggestion, the rights-based approach is a relatively new and evolving way of thinking about how to adjust legal and policy instruments in order to acknowledge and strengthen this interrelationship so that sustainable use can be achieved. The harmonization of the two dimensions – sustainable use of wild species and people's rights – and their integration through a rights-based approach in all relevant policies, legislation, and project activities could even be perceived as concretizing or "simplifying" the concept of sustainable use (see Chapter 1 and Chapter 2).

Implementation of such a rights-based approach to conservation remains slow to date, with the possible exception of voluntary guidelines for securing sustainable small-scale fisheries, endorsed by the FAO committee on fisheries in June 2014. As the Millennium Ecosystem Assessment indicated, continuous environmental degradation still adversely affects individual and community rights, such as the rights to life, health, water, food, and non-discrimination (Millenium Ecosystem Assessment, 2005). Countermeasures that aim at halting such degradation are often criticized for their negative impacts on people's livelihoods. Furthermore, the vulnerable communities of the world are both the ones that are suffering the greatest burden of environmental degradation and those least able to mobilize against rights abuses (Millenium Ecosystem Assessment, 2005). The Tamshiyacu Tahuayo communal reserve offers an example of community-based conservation in the spirit of a rights-based approach. An area of 322,500 hectares located in the northeast Peruvian Amazon, this reserve was created through a coalition of local communities, researchers, non-governmental organizations and government agencies, which aimed to diminish terrestrial animal harvesting, fishing and logging by outsiders (see Section 6.5 for more).

Sustainable use activities can also generate negative impacts where their links to issues of human rights and well-being are not sufficiently understood or addressed, and weak fulfilment of rights can also undermine conservation outcomes (Kittinger *et al.*, 2017; Springer & Campese, 2011). Integration of human rights introduces new elements into conservation practice, particularly efforts to ground them in defined standards based on international human rights frameworks, as well as relationships of accountability between "rights-holders" and "duty bearers". The 1972 Stockholm declaration on the human environment was an early trigger for discussions on adopting a human rights approach to environmental protection.

6.4.4.5 Community-based or co-management

The growing recognition of the importance of participation and legitimate involvement of indigenous peoples and local communities has resulted in the growth of support for community based or co-management approaches for the sustainable use of wild species. Co-management systems are a way of use and management of natural resources. They are often formulated in terms of some arrangement of power sharing between the State and a community of resource users (Carlsson & Berkes, 2005). Definitions of co-management can vary across a gradient from centralized management to self-managed **(Figure 6.3)**. Similar to co-management, though closer to categories of self-management, community-based management is a way of natural resource management that involves the community in its management.

Support for such approaches, as highlighted above, can be seen in the United Nations declaration on the rights of indigenous people (2007) Article 8, 18, 19 and 26 that support rights of indigenous peoples on their lands and rights of participation in decision making (United Nations, 2007) as well as, the Convention on Biological Diversity plan of action on customary use of biodiversity (2010) that

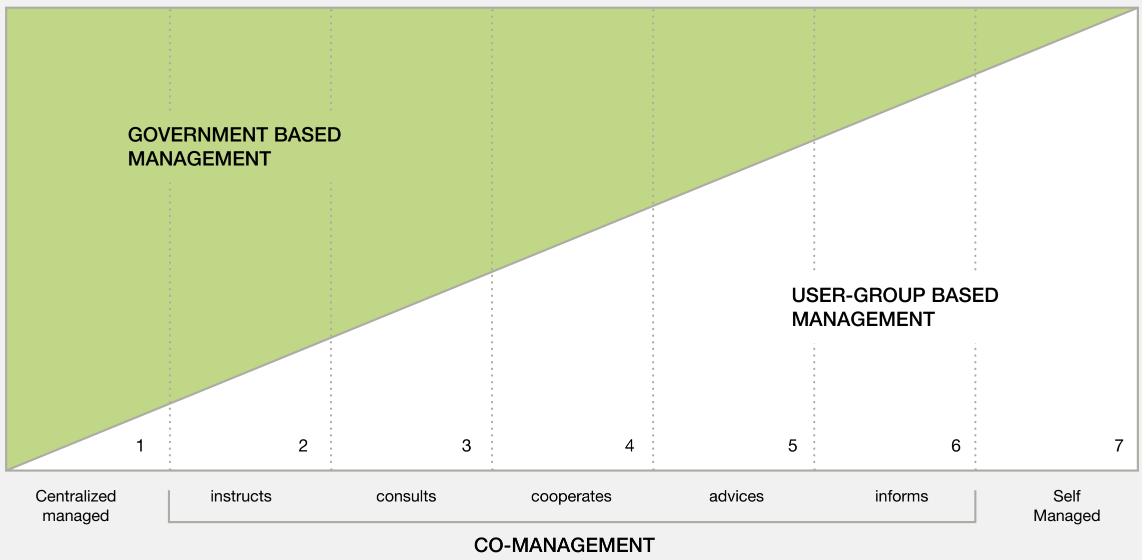


Figure 6 3 **The spectrum of co-management arrangements.**

Adapted from (Sen & Raakjaer Nielsen, 1996) under license number 5166360520661 CC-BY NC.

ensures just implementation of Article 10(c) at local, national, regional and international levels and to ensure the full and effective participation of indigenous and local communities at all stages and levels of implementation (CBD, 2010). Motivated by concerns about the recent upsurge in the illegal trade in wild species, against a background of widespread unsustainable use of wild species (covering fauna and flora, and including timber and fisheries) (Cooney *et al.*, 2018). Resolution 2/14 passed at the second meeting of the United Nations Environment Assembly in May 2016 (Hub, 2016), called for "…an analysis of international best practices with regard to involving local communities in wild species management as an approach to addressing the unsustainable use of and illegal trade in wild species and wild species products […]". Whereas, the Convention on International Trade in Endangered Species of Wild Fauna and Flora explicitly recognizes the benefits of community based natural resource management for the sustainable use of wild species: "Community-based natural resource management promotes sustainable use of wild species, and reduces illegal use and trade in wild species. It fosters the support of local people for conservation, by generating income and stimulating local economies. The Preamble of the Convention recognizes that peoples and States are and should be the best protectors of their own wild fauna and flora, which is being achieved through community-based natural resource management" (CITES, 2016).

Community-based natural resource management programs have been employed for the sustainable use of wild species and reduction of poverty, for example through the legal trade in wild species and devolved wild species proprietorship as a crucial solution to fight poaching and consequent illegal wild species trade and achieve the goals and targets of the 2030 agenda for sustainable development (CITES, 2016). The long history of experience in community wild species management remains crucially relevant for current efforts to combat the illegal trade in wild species crisis, but has been largely overlooked in the race for solutions emphasizing a top-down and increasingly militarized approach (Cooney *et al.*, 2018). "Community-based approaches are frequently written off as ineffective, even before the necessary effort has been made to put in place the conditions that will make them effective" (Cooney *et al.*, 2018).

Community-based tourism is a form of community-based natural resource management, applied to non-extractive use practices, and a popular enterprise-based strategy for biodiversity conservation, and a common element in integrated conservation and development projects. Community-based tourism illustrates the compromises involved in trying to meet multiple objectives. For biodiversity conservation, nature-based tourism is a fairly good land use, but not as good as (effective) pure protection. It can generate some income and contribute to community development, but only within limits and with considerable investment of support and time. It can also reduce the need for long term external financing for conservation under some circumstances, but will rarely eliminate it entirely (Kiss, 2004). The sustainability of community-based tourism is expected to come from three sources: (i) an ongoing conservation incentive in the form of income dependent on biodiversity; (ii) reinvestment of some of the income to maintain the business and protect the biodiversity asset base, thereby eliminating or at least reducing the need for external funding; and (iii) once a basis has been established (community awareness and organization, basic infrastructure, etc.), the entry of the private sector to provide the capital for further development and expansion (Kiss, 2004).

The involvement, participation and empowerment of traditional populations and local communities has grown similarly in the governance of fishing. Here, a wide variety of collaborative arrangements between governments and users exist, in a spectrum ranging from instructive to informative (Sen & Raakjaer Nielsen, 1996) **(Figure 6.3)** (see section 6.5 for more details on effectiveness). However, the rapid growth of these approaches has meant many co-management arrangements are still more inclined towards government based, than to fully empowered and self-managed. Furthermore, the focus of these arrangements has generally been on small scale fisheries; highlighting the context dependent nature of how governance and management emerges.

Within fishing, the differences in governance and management approaches exist in part because of the lack of resources to monitor fishing and enforce regulations by the central government in these contexts (Begossi, 2008, 2014). For example, in intensively-managed industrial fishing, total allowable catches, established by applying some target exploitation rate or harvest control rule to an estimate of resource abundance, are a preferred instrument for controlling total harvest (Hilborn *et al.*, 2020; Melnychuk *et al.*, 2021). Such approaches require good-quality stock assessments which are usually done using data-rich and complex analytical methods. Regulatory instruments and sources of information used in support of management tend to be very different in small-scale fisheries, where data and capacity are often limited, diversity of species and gears makes single-species norms impractical, and dispersed landing sites makes it difficult to collect data and enforce regulations **(Table 6.5)**.

Local knowledge, participatory surveys and much simpler indicator-based systems are used to monitor resource status within small scale fisheries, and harvest controls tend to rely more on gear, effort and size regulations. Statutory norms used for granting access to fish resources and for allocating benefits are also in sharp contrast between industrial and small-scale fisheries. While quota shares and individual transferable quotas have been introduced in many industrial fisheries as a form of property right to increase economic efficiency and stop a race to fish (see section 6.5.2.1), statutory access rights in small-scale fisheries have more often taken the form of territorial use rights for fishing granted to local communities or fishing organizations (Christy, 2000; Orensanz *et al.*, 2013). A different form of statutory communal right that has been used in industrial fisheries has involved setting aside a portion of the total allowable catch to eligible communities usually to provide economic and social opportunities to disadvantaged groups and/or in recognition of customary or treaty rights of indigenous peoples. An example of such systems is the community development quota of Western Alaska (Carothers, 2011). In general, the inability to implement top-down command-and-control approaches in small-scale-fisheries has led to variable degrees of devolution of power and responsibilities to local communities in community-based or co-management system.

Table 6 5 **Contrasting approaches used commonly for the assessment and management of industrial and small-scale fisheries.**

		Industrial fishery	Small-scale fishery
Resource monitoring & fishing regulations	Stock assessments	• Centralized collection of data by fishery government agency • Data-rich quantitative, complex models used to evaluate stock status	• Participatory surveys • Local knowledge • Indicators of trends in resource abundance • Size-based methods
	Harvest controls	• Total Allowable Catch (TAC) • TACs calculated based on estimates of stock biomass and predetermined harvest control rules	• Effort limits and gear restrictions, size limits, closed areas, closed seasons • Simple empirical harvest rules that respond to indicators • Customary norms
Management Institutions	Governance	• Strong legal mandates to eliminate overfishing and rebuild stocks • Command-and-control approaches	• Devolution of power to local communities • Community-based • Co-management
	Access regimes	• Individual Transferable Quotas (ITQs) • Quota shares allocated by government agencies to individuals or companies	• Territorial Use Rights (TURFs) held by communal/fishers' organizations • Recognition of traditional forms of tenure

The move towards co-management or community-based management has been motivated by both recognition of the importance of human rights as well as of the "inextricable link" between biological and cultural diversity, whereby they are interdependent and geographically overlapping (Girot & Nietschmann, 1992; Maffi, 2007). This means that most biodiversity-rich areas coincide with the presence of indigenous cultures and traditional communities. This constitutes a key principle for an integrative and transdisciplinary approach to wild species conservation and management (Guerrero-Ortiz, 2013; Maffi, 2005). This context has lent way to the creation of biocultural protocols as useful community-led instruments that promote participatory advocacy for the recognition of, and support for, ways of life that are based on the customary sustainable use of biodiversity (Jonas *et al.*, 2010). Biocultural protocols enable communities to build relationships and bridge the gap between the customary management of their biocultural heritage and external stakeholders (researchers, companies, other communities) (Bavikatte & Bennett, 2015). These protocols have the potential to shift the dynamic of conservation initiatives to becoming more inclusive, locally appropriate processes driven by legally empowered communities (Jonas *et al.*, 2010). For example, a biocultural community protocol was developed based on the internal regulatory systems of the Comcáac People (Sonora, Mexico) (PNUD *et al.*, 2018), as a community instrument for sustainable development, that shows the exercise of community rights and internal participatory processes. It presents strategies for the protection of traditional knowledge, natural, biological and genetic resources found within their territory (common property). With regard to hunting, the community has shifted from subsistence hunting to managing trophy hunting of big-horn sheep *(Ovis canadensis)* (see **Box 6.10**). The protocol provides information on hunting grounds, on traditional authorities in charge of selling hunting permits, and on the community hunting committee, among others.

6.4.5 Prevalence of policy instruments

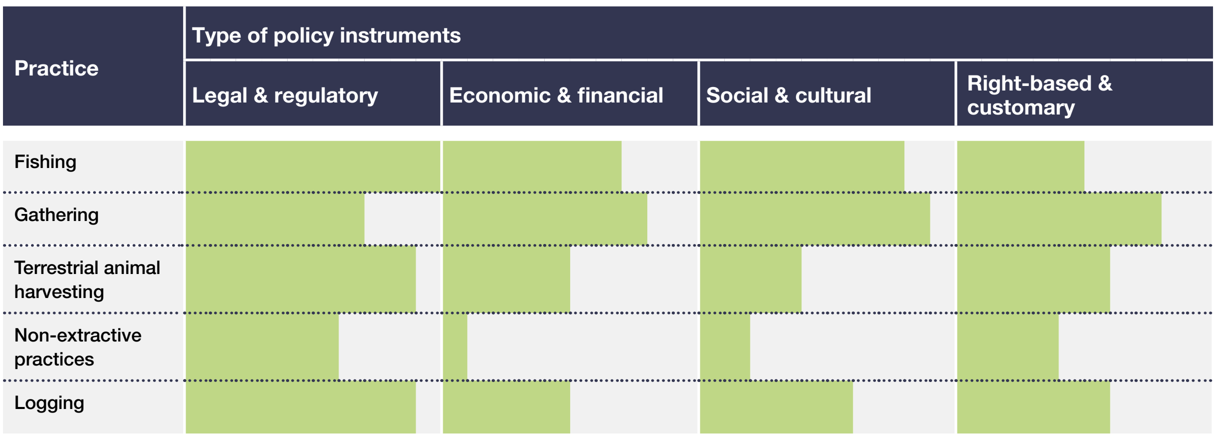
The prevalence of policy instruments covered in the systematic review of case studies is shown in **Table 6.6**. The bar indicates the proportion of the cases that cover each policy instrument. Across practices, and based on the selected cases, legal and regulatory instruments were the most commonly applied instruments overall. The exception is gathering, where although most instruments were applied in combination, social and information based were slightly more common. There was a paucity of instruments applied in the non-extractive use practice case studies, where policy instruments other than legal and regulatory instruments were seldom applied. Within non-extractive uses, regulations in the form of national parks were most common, allowing visitors to stay on the authorized trails during walking safaris in Tanzania (Brandt & Buckley, 2018; Mgonja *et al.*, 2015).

Most case studies (81%) reviewed reflect the application of a combination of policy instruments, and gathering practices were most likely to involve all four policy instruments. For example, case study examples from the gathering practice adopted ban on open grazing (Dhyani *et al.*, 2011), tax (Grivins, 2016), organic wild-crop harvesting standards (Brinckmann *et al.*, 2018), and traditional resource rights (Solis & Casas, 2019) **(Table 6.6)**. Overall, 8% of case studies involve all four policy instrument categories, whereas 18% only involve one.

The **legal and regulatory** instruments reviewed most often included international conventions, laws and specific rules.

Table 6 6 **Prevalence of policy instruments (N=84).**

Each bar indicates the proportion of cases, within each practice, that included each policy instrument. A full bar indicates the policy instrument was present in all cases (see see the data management report at https://doi.org/10.5281/zenodo.4663236).



International conventions and treaties influence national laws for regulating the use of wild species. For example, the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Migratory Species influence national laws on fauna and hunting in the case of Mongolia (Dixon & Batbayar, 2010), illustrating that international rules influence domestic policies with binding obligations on states (Bernstein & Cashore, 2012).

Permit and quota systems are common legal instruments in terrestrial animal harvesting, industrial fishing and gathering. With the exception of small-scale multi-species fishing, where quota management is practically impossible, quotas are the main practical basis for the regulation of wild species harvest and trade. Quotas may be established on a per-capita or per-permit basis, and a fee may be charged, or they may regulate the total extraction allowed over a given season. For example, in Mongolia, according to the law on hunting resource use and hunting and trapping, permit fees exist for scientific, cultural, artistic, and medicinal uses in terrestrial animal harvesting, for a Mongolian hunter, the permit fee is 20% to 40% of the animal's economic and ecological value (Article 5.1.2) and for foreigners, it is equal to the international market value, or 60% to 70% of the economic and ecological value (Article 5.1.5) (Janchivlamda *et al.*, 2014). For foreigners, it is equal to the international market value, or 60% to 70% of the economic and ecological value. In gathering, Greek legislation allows the extraction of two kilos of fresh plant material per plant species and person per day (Papageorgiou *et al.*, 2020).

Around half (53%) of the selected cases include **economic instruments** across all practices. Fishing and gathering, were most likely to use **economic and financial** instruments than other practices. Terrestrial animal harvesting and gathering cases tended to implement a fee or penalty in the form of a negative economic instruments. In contrast, logging cases tended to implement market incentives as positive economic instruments through certification systems as social and information-based instruments.

Around 61% of the selected cases include **rights-based instruments** across all practices. In many of the case studies, the communities have some degree of rights over the area or resource, some operate with catch shares, others not. However, there is no one combination model that appears more effective than others. While catch shares and strong ownership are often assumed to be beneficial, a case study on Madagascar for instance clearly shows that common property institutions can successfully implement management without property rights over the resource.

6.5 EFFECTIVENESS OF POLICY INSTRUMENTS

A variety of policy options have been introduced to control, or support, the sustainable use of wild species (see preceding section 6.4). Evaluating the effectiveness of these policy options is an important stage in the policy cycle (Giorgi, 2017; E. Young & Quinn, 2002). Effectiveness refers to whether a policy works as intended and meets the purpose for which it was designed (Sadler, 1996). Policy effectiveness can be assessed in terms of objectives, outcomes and impacts (Broc *et al.*, 2018). This section synthesizes the evidence on policy effectiveness for the sustainable use of wild species, evaluates the causal effects of specific policy combinations or programs as well as the conditions under which this effect arises. This chapter focuses on disentangling the impacts and effects resulting from different interventions in diverse contexts. Establishing when and why particular policy approaches are most likely to succeed is key to enabling the sustainable use of wild species. Because effectiveness is context specific, variables through time, practice, place, and culture, are considered. The concept of "enabling conditions" is used, which centers on conditions that facilitate approaches to address social and ecological challenges. They can be defined as factors that increase the likelihood of an intended change in the governance approach, strategy, or management regime. The presence of enabling conditions can facilitate the emergence of a particular environmental policy. In contrast constraining conditions are, factors that create barriers to effective management and policy implementation. These may comprise the absence of key enabling conditions or arise independently (Huber-Stearns *et al.*, 2017). Assessing policy effectiveness contributes to the experts' understanding of what worked as planned and provides input to the redesign or improvement of policies at the stage of policy evaluation. It contributes to narrowing the knowledge gap and supporting evidence-based decision making (Artelle *et al.*, 2018).

Taking advantage of the multi-sector approach Chapter 6's authors adopt in this chapter the analyses of effectiveness is based on a combination of: the general review; the mixed methods systematic review (based on selected case studies, see data management report at https://doi.org/10.5281/zenodo.4663236); and boxes selected to be illustrative of key points (see methodological approach section 6.2); that in combination draw on the best available evidence providing guidance to policymakers that can and should be updated over time.

Many studies made an explicit effort to identify and describe the enabling or constraining conditions for the effectiveness of policy instruments (one example being (McCay, 2014). However, in many cases, and as anecdotally described by

(Jentoft, 2004), sometimes it takes an outside perspective to understand the inside ongoing of a particular situation, or to identify key factors that seemed obvious before, because a culturally embedded institution seemed to be a given. For example, in countries where legal compliance is high, compliance is not usually highlighted as an enabling condition. Information access, technical infrastructure and capabilities may be other such factors that are not emphasized due to their prevalence. Therefore, in drawing information from across case studies on what conditions exist where policies are more effective, and conversely what conditions exist where policies are less effective, we are able identify patterns that enable or constrain policy effectiveness.

Most policies have the potential to be successful, however they also have the potential to fail and even exacerbate existing social and ecological conditions. The success of a given policy depends on the context and history in which it is applied. We identified a number of enabling and constraining conditions associated with the application of different policy instruments across practices. Enabling and constraining conditions were related to the values, norms, and principles (see section 6.5.1, 6.6.1, 6.6.2, 6.6.3), the rules and institutions (see section 6.5.2, 6.5.3), and the power asymmetries (See section 6.5.4) of the governing system and system to be governed (*sensu* the interactive governance framework **Figure 6.1**). These resulted in seven overarching constraining and seven associated enabling conditions **(Figure 6.4)**. When rights are not recognized, power relations are unbalanced, and policies ignore social dimensions whether of the local context social, or policy objectives the effectiveness of policies are constrained. However, in contrast governing systems that are inclusive and participatory, recognize and respect diverse forms of knowledge, and ensure benefits (and costs) are shared equally can result in more effective sustainable use policies. Similarly, when policy approaches overlook the historical context, focus on a limited number of commonly used instruments, rules inadvertently criminalize the most marginalized, and policies are not aligned across scale nor do they facilitate interactions the effectiveness of policies are constrained. In contrast, when governance institutions are robust, sustainable use policies are supported by broader policies, instruments are tailored to the local context, and rules and instruments are adaptive and processes democratic, sustainable use policies are more effective **(Figure 6.4)**.

6.5.1 Governance characteristics that enable sustainable use

6.5.1.1 Inclusive & participatory process

Policy tends to be more effective when developed through inclusive and participatory processes that involve representative leaders, transparent institutions, and community-based approaches. Legitimate participatory processes that involve a more equal balance of power,

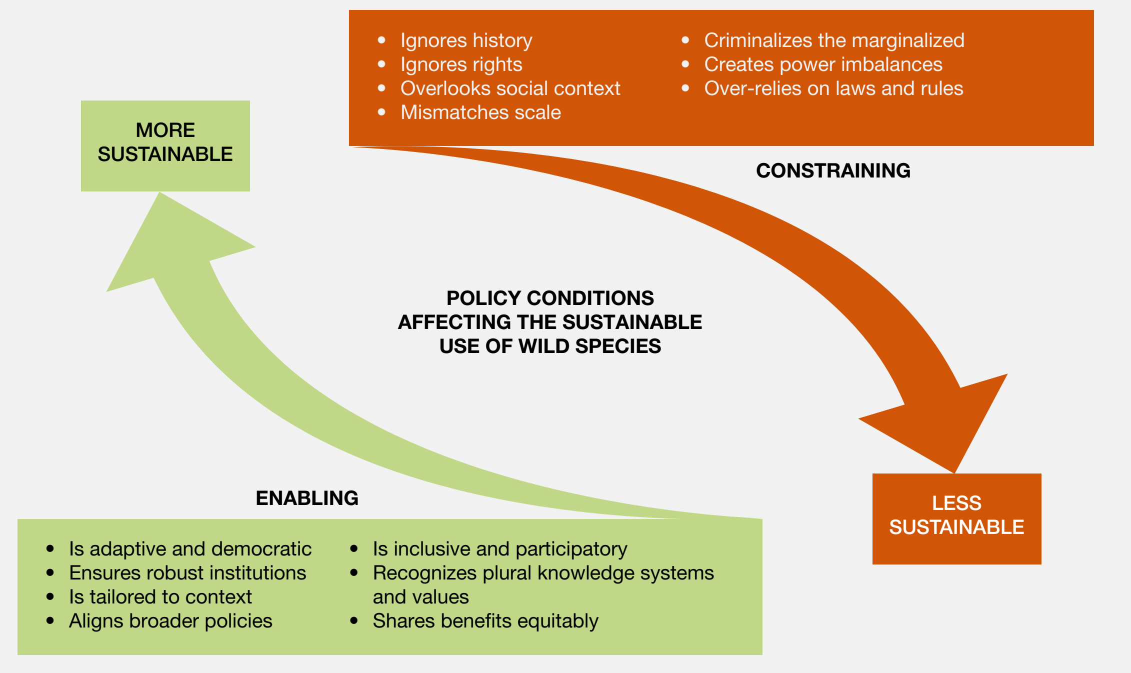


Figure 6 4 **Conditions that enable (green) or constrain (red) sustainable use policies.**

tend to support more effective policies because they draw on diverse perspectives and forms of knowledge, support collaboration, and increase buy-in. This in turn leads to better self-regulation, particularly for high value species.

The participatory model is built on the premise that local involvement is essential to achieve social justice and the long-term protection of the natural environment (Meola, 2013). Full and inclusive consultations encourage exchange and understanding, and provide awareness and opportunities for indigenous peoples and local communities to share local and scientific knowledge among relevant actors. Legitimate and effective engagement can also help build trust between actors, which is key for the long-term success of sustainable use initiatives. Multi-tiered systems of regulation that incorporate statutory and customary/local rules of use distribute responsibilities among the actors best able to meet them while participatory development of regulations motivates more effective enforcement at a local level. Evidence from the gathering case studies found that local communities are more flexible in adapting their management approaches for gathering wild species including high value species irrespective of the legal setting of the area, highlighting potential for adaptive management. Participation is achieved when all actors are included, and differences that exist across genders, identities, and abilities are taken into consideration.

Indeed, within terrestrial animal harvesting case studies, effective policy implementation was directly related to multi-actor involvement from the beginning of the policy process (e.g., **Box 6.4**). The successful terrestrial animal harvesting case studies established institutions including government structure, which monitored the regulation and application of norms and rules for conservation and sustainable use. These coincided with a mode of co-governing, through which all actors involved participated in the decision-making process and other activities. There was a similar emphasis in the fisheries case studies, on exchange, dialogue, and conflict resolution. Co-management was found to be more effective where transparency, fairness, leadership, and conflict resolution mechanisms were present.

Box 6 4 Inclusion of actors across multiple scales enables sustainability: Morelet's crocodile *(Crocodylus moreletii)* skins in Mexico.

The Morelet's crocodile *(Crocodylus moreletii)* is distributed in Mexico, Belize and Guatemala. In Mexico it is found on the slope of the Gulf of Mexico and the Yucatan Peninsula (Platt *et al.*, 2010). Morelet's crocodile have historically been overharvested. In the 1970s, because of overhunting and unregulated skin trade, Morelet's crocodile populations were threatened with extinction. This led Mexico to prohibit the commercial harvest of wild individuals (SEMARNAP, 1999).

Consequently, Mexico launched a pilot project to support the conservation of these crocodiles based on scientific evidence, monitoring, and regulated trade. In 2017, the "Cocodrilos Chacchoben" project was sustainably and legally harvesting wild *C. moreletii* eggs, that were later sold to grow in optimal conditions to reach commercial sizes (Mosig, Antaño, *et al.*, 2019). A key factor for the success of the pilot project was the involvement of and collaboration with multiple actors at various scales of governance, from international to local communities.

The Morelet's crocodile monitoring program Mexico-Belize-Guatemala (Sánchez-Herrera *et al.*, 2011), was implemented in Mexico for five breeding seasons (2011–2015). Over this period of time, an increase of the average estimated number of wild Morelet's crocodile was observed: from 44,890 in 2011, to 104,815 in 2015; with a general average for the 5 years of about 74,000 individuals, with an encounter rate of 3.2 ± 1.4 (ind/km), along a total of 22,833 km of potential habitat. In over 70% of the Morelet's crocodile monitoring program sites, a general upward population trend was observed (Rivera-Téllez *et al.*, 2017). The information gathered through the national implementation of the Morelet's crocodile monitoring program on status and trends, indicates that wild populations of Morelet's crocodile are in good condition and that there is a potential to develop sustainable productive projects for the benefit of indigenous people and local communities, of the species and its habitat.

In 2017, a pilot project was developed to establish an integrated production system of high-quality *C. moreletii* skins, based on the conservation of the species and its habitat, as well as on a sustainable, legal, and traceable scheme, with fair and equitable distribution of benefits throughout the productive chain, particularly for indigenous peoples and local communities (Mosig, Antaño, *et al.*, 2019). Activities carried out by the community members that are part of the pilot project, are guided by the ranching protocol for Morelet's crocodile (Barrios & Cremieux, 2018). The ranching scheme consists in harvesting eggs from the wild and taking them to incubators managed by the local communities, which rises the offspring survival rate from 1% in the wild, to up to 90% in captivity (Barrios & Cremieux, 2018). Through its implementation, standardized information on nests is obtained, which is the basis for defining sustainable egg harvest quotas and non-detriment findings on the Convention on International Trade in Endangered Species of Wild Fauna and Flora framework. It also provides detailed guidelines for nest extraction, egg transportation and the incubation processes.

After over 40 years of a national prohibition to harvest crocodiles, in 2017, "Cocodrilos Chacchoben", was the first Management Unit for Wildlife Conservation (UMA) to sustainably and legally harvest wild *C. moreletii* eggs. The hatchlings were later sold to the farm "Cocodrilia" where they grow in optimal conditions until they reach commercial sizes for the production of high-quality skins for the international leather market (Mosig, Antaño, *et al.*, 2019). A key factor for the success of the Pilot Project has been multistakeholder -multisectorial collaboration; involvement of federal and state governments of both environmental and agricultural sectors, Convention on International Trade in Endangered Species of Wild Fauna and Flora authorities, indigenous peoples and local communities, the private sector, the crocodile specialist group of the International Union for Conservation of Nature, national experts part of the group of crocodilians specialists in Mexico and civil society.

Through the implementation of the pilot project, the community of Chacchoben, has benefited from the sustainable ranching of Morelet's crocodile eggs. Knowledge about the species and population trends continues to be generated through the Morelet's crocodile monitoring pProgram. As a result, the crocodiles that used to be considered a threat, are now valued and they represent an additional income. This income incentivized the community to conserve 4,658 ha of habitat that is also home to about 560 other species of fauna and flora (Mosig, Antaño, *et al.*, 2019).

Photos: Morelet's crocodile *(Crocodylus moreletii)* © Iván Montes de oca Cacheux / CONABIO CC-BY and © Mariana del Carmen Gonzalez Ramón CC-BY.

Similarly, within gathering case studies reviewed, whenever legal and regulatory policies involved local communities along with local non-governmental organizations as facilitators in the process it resulted in an overall positive impact on ecological, economic and social development. Involvement of local communities in legal and regulatory policies along with intermediaries as facilitators emerged as an enabling condition to ensure sustainable gathering and overall positive impact on the socio-economic development of the community.

Empowering more women in local resource decision-making can lead to better resource governance and conservation outcomes. This is in part because women typically use natural resources differently than men, but are often left out of decision making on how local resources are managed, creating gaps in resource management decision making and policy. For example, there is strong and clear evidence from India and Nepal, of how including women in forest management groups results in better resource governance and conservation outcomes (Leisher *et al.*, 2016). In 2006, India had 106,482 registered as "joint forest management groups". Joint forest management guidelines, issued in 2000, recommended that village forest committees should consist of 50% women members, with at least 33% women on the executive committee-the principal decision-making body. Similarly, Nepal had 17,685 forest user groups in 2011, with approximately 800 women-only groups; government guidelines for community forestry recommended that women comprise 50% of a forest user group's executive committee. In both countries, groups with a higher proportion of women in their executive committee showed significantly greater improvements in forest condition than groups with a lower proportion of women (Leisher *et al.*, 2016). These benefits were likely in part due to greater degrees of cooperation among women, and women using their knowledge of plant species and methods of product extraction (Agarwal, 2009; Leisher *et al.*, 2016). Similarly, women had a significantly positive effect on cooperation in forest management in Paraguay. Women have also demonstrated the ability to mitigate elite capture of benefits during the process of decentralization, which could be particularly relevant during initial stages of the logging project. Therefore, a deliberate attempt to integrate women into project planning (and beyond) would likely benefit both the process and longer-term outcomes of extractive reserve logging (Cooper & Kainer, 2018).

In contrast, where women remain excluded from governance and decision-making processes, sustainable use can be hampered (Rohe *et al.*, 2018). For example, although women play an important role in small scale fishing communities in Solomons, such as contributing to food security, decisions on how the resource is managed are mostly taken by men. This has impacted social and ecological sustainability leaving women more inclined to break local management rules because: i) they were not involved in decision-making; ii) they had lost trust in the local male leadership, who they perceived had misused the money, and; iii) the management rules constrained the women's activities most as the marine closure was located where the women used to fish (Rohe *et al.*, 2018).

Similarly, some of the least successful gathering case studies did not specify the process followed to consult or include indigenous peoples and local communities or other actors in the development and/or implementation of projects, and as a result inclusive and transparent participation was not achieved. Full participation of all actors is crucial to guarantee that all points of view are taken into consideration and that the project is culturally appropriate and not imposed by an external actor.

Across practices, several successful cases studies involved co-governing or co-management through participation and collaboration by multiple actors. The interaction between different actors has been highlighted as a priority for transparency and participation to build governance. For example, in Costa Rica, three national institutions – the ministry of environment and energy, the institute of marine fisheries and the association for rural economic development – retain responsibilities for various aspects of the project (L. Campbell, 1998). The Ostional integrated development association (community institution), managed by an elected "junta directive" (board of directors), is responsible for the day-to-day activities.

In contrast, none of the five least successful terrestrial animal harvesting case studies applied community-based management which seems to be key for successful implementation of the policy instruments, although two of them considered traditional resource rights and traditional ecological knowledge. At the same time, the least successful terrestrial animal harvesting cases tended to exclude indigenous peoples and local communities in managing the resource and within the harvesting practices, either by the imposition of legislation that prohibited harvesting, or by an increase in resource management by the private sector.

The involvement, participation and empowerment of traditional populations and local communities is a particularly relevant governance approach to promote sustainability of small-scale fisheries worldwide, through a wide variety of collaborative arrangements between governments and users, in a spectrum ranging from instructive to informative (Sen & Raakjaer Nielsen, 1996) (see **Figure 6.3**). Such bottom-up management approaches that include indigenous and local knowledge have been promising, especially in a context of lack of resources to monitor fisheries and enforce regulations by the central government (Begossi, 2008, 2014). A brief overview of management and co-management systems directed to small-scale fisheries worldwide is provided here. Due to the spectrum of local arrangements (see **Figure 6.3**), which are rarely identified, the success and specific results are highly context dependent and not easy to generalize. However, most co-management arrangements are still more inclined towards government based, than to fully empowered and self-managed approaches.

Most of the more sustainable inland fisheries in South America include the involvement of local fishers in co-management schemes aiming to maintain the harvest of valuable fishing resources, such as the pirarucu *(Arapaima gigas)* **(Box 6.5)** and freshwater turtles, in spatially defined boundaries, such as floodplain lakes in the Brazilian Amazon (Campos-Silva *et al.*, 2020; Campos-Silva & Peres, 2016; Castello *et al.*, 2009; Petersen *et al.*, 2016). Some of these co-management systems have shown additional ecological benefits on top of increases in targeted species in the Brazilian Amazonian rivers, including increases in fish, aquatic mammals, birds and even invertebrate species not targeted by the fishery (Campos-Silva *et al.*, 2017; Silvano *et al.*, 2009) and in overall fish diversity in both managed and nearby unmanaged lakes after a period of 15 years (Medeiros-Leal *et al.*, 2021).

These co-management systems consist of formal agreements among local fishers' organizations, fishing companies, local and State governments, and non-government organizations. These agreements recognize the rights of local fishers to exclusive access to fishing grounds, and tenure rights over those fishing resources. A local participatory management board establishes local rules of access and use, recorded in annual management plans. The boards can also apply graduated sanctions when these rules are not met. Local fishers protect, monitor and assess fish stocks, and annual fishing quotas are granted by authorities based on these assessments (Castello *et al.*, 2009; Petersen *et al.*, 2016). These Amazonian co-management systems originated from demands of local communities to reduce conflicts and restrict access of large-scale commercial fishers to harvest large lakes in the Brazilian Amazon, especially in the Middle Solimões and Lower Amazon River regions (Castello *et al.*, 2009; de Castro & McGrath, 2003).

Although widespread throughout the major rivers in the Brazilian Amazon, there are only a few studies on the efficacy of these fishing accords (Almeida *et al.*, 2009). Moreover, the ability of these co-management systems to improve individual fish catches can be more related to informal local organization and capacity to enforce rules of each community, than to a formal recognition by the Brazilian government (Lopes *et al.*, 2019). Another co-management system in the Brazilian Amazonian rivers is that of the extractive reserves, which have shown promising evidences of increased abundance of fished resources, when compared to non-managed sites (Hallwass *et al.*, 2019, 2020; Keppeler *et al.*, 2017; Silvano *et al.*, 2014), although some high valued fish species may had decreased in abundance. This decrease, and lack of temporal data, make it difficult to confirm the ecological sustainability in these extractive reserves (Hallwass *et al.*, 2020).

Box 6 5 **Participatory co-management enables sustainable use: Pirarucu in the Amazon.**

The Pirarucu fishery is an example of a successful participatory, and adaptive co-management initiative, where indigenous and local, and scientific knowledge are used together to guide management and monitoring. The initial alliance formed between fishers and government agencies, established a clearly articulated division of powers, benefits were equitably distributed across the community, and capacity building was a clear feature, together ensuring successful social and ecological benefits.

Pirarucu *(Arapaima gigas)* is among the largest freshwater fishes in the Amazon, reaching 3 meters in length and almost 200 kilograms (H. L. de Queiroz, 2000), playing an important part in the Amazonian economy and culture since the 16th century (de MENEZES, 1951; H. L. Queiroz & Sardinha, 1999; Verissimo, 1895; Viana *et al.*, 2007). As one of the main impacts of the introduction of modern technologies in the second half of the 20th Century, the increase of the fishing pressure and offtake led to the overfishing of pirarucu stocks in most parts of the Amazon (Isaac & Barthem, 1995; H. L. Queiroz & Sardinha, 1999). Official protective measures were first introduced in the 1980s by government agencies, but had little or no effect due to the lack of enforcement capacity of local authorities. Almost forty years after those attempts to protect the species, stocks are now recovered and increasing, due to a more effective protective measure, the community-based management of this fishery, introduced in the 1990s.

One of the main success cases of community-based initiatives of sustainable use of natural resources and biodiversity conservation in the Brazilian Amazon was first implemented by the small riverine communities of Mamirauá reserve, by the Japurá river, in the Amazonas state. The traditional ecological knowledge of the local populations was adopted in the management system, especially in the annual stock assessment technique in place (Arantes *et al.*, 2007; Castello, 2004; Lopes & Queiroz, 2009). To provide technical support to this fisheries management, scientific research was conducted on the biology of the species (Arantes *et al.*, 2010, 2013; Araripe *et al.*, 2013; Castello, 2008a, 2008b; Castello, Stewart, *et al.*, 2011; Coutinho *et al.*, 2010; Queiroz, 2000), on the main aspects of its fishery (Andrade *et al.*, 2011; H. L. Queiroz & Sardinha, 1999) and also, on the social and economic aspects of the fisheries (Amaral, 2008; Lima & Peralta, 2017; Peralta, 2010). The first proposal for a formal management system of pirarucu was approved in an alliance with local fishermen of Mamirauá Reserve in 1998, and implemented since 1999 (Castello *et al.*, 2009; Figueiredo, 2013; Viana *et al.*, 2007). Members from the local communities agreed to negotiate, approve and adopt sustainability measures, adjust in fishing gear, establishing annual extraction quotas, monitoring and controlling the offtake, adopt a minimum size for the catch and the interruption of the activity during a banning period, at the reproductive period of the species. Management measures also included other participatory action, such as training courses and meetings to establish rules of access and use of fishing grounds.

Between 1999 and 2002 the experience at the Mamirauá Reserve was consolidated and underwent a first phase of expansion, replicated for a larger number of communities and their management associations (Viana *et al.*, 2007). This co-management was based on the division of powers and responsibilities among different institutions (Amaral, 2013; Peralta & Lima, 2012; Silva *et al.*, 2013). The governance system built was based on local management committees that are able to set and enforce rules, conduct and oversee the activity and equitably distribute the benefits generated, ensuring resilience and growth. Several stakeholders are involved in the participatory governance of the pirarucu fisheries. Fishermen provided their traditional knowledge and are responsible not only for protecting of the fishing grounds, the local lakes. Fishermen are also responsible for the organization and distribution of fishing groups in the managed lakes, they perform the annual assessment of the stocks, the capture of pirarucus, they are responsible for marketing and trade, and of the local monitoring of all activities (Viana *et al.*, 2007). After the fishing season, they are responsible for the equitable sharing of benefits. The technicians from the supporting institutions are responsible for building capacity among local fisher's associations (Castello *et al.*, 2009). They also provide guidance to the fishing groups and supervise their actions regarding the compliance to the guidelines established in the annual management plan. Technicians are also responsible for monitoring the sustainability of the management system based on a group of environmental, social and economic indicators. The representatives of the government are responsible for licensing, for the oversight and for the annual evaluation the management. Local institutions maintain research programs that also act as monitoring programs, providing the follow up, assessing the sustainability of pirarucu fisheries, and a continuous evaluation of the ecological, socioeconomic and

Box 6 5

socio-political impacts of the community-based management and the participatory governance system in place. The results of these on-going surveys and evaluations allow the enhancement of the technical guidelines supporting the activity, in a truly adaptive management approach (Gonçalves *et al.*, 2018).

After more than two decades, pirarucu fisheries management proved that conservation of the species can be reconciled with its sustainable use, generating social, ecological and economic results. Management projects conducted in the Amazon are largely successful. In those places where all criteria are met, the stocks of the species increased annually by almost 25%. Income generation by fishermen and women involved more than doubled, and an additional 4 million United States dollars were generated and distributed to local fisher's associations. These very positive results attracted fishermen from urban areas around the protected areas, and also from other small communities. Federal Brazilian government formally recognized all those participatory fisheries management initiatives (Figueiredo, 2013), and during these processes, local fisher's associations had visibility and social recognition, increased their participation in public policy discussions, and had some access to their social rights. There was an important increase in gender equity. In 2017, 38% of members of pirarucu community-based fishery management were women, but in first years, 1998–2002, they were less than 5% (Gonçalves *et al.*, 2018). As a consequence of all these positive outcomes, a second expansion and replication took place after 2010 (Campos-Silva *et al.*, 2017; Campos-Silva & Peres, 2016; Castello, McGrath, *et al.*, 2011; Figueiredo, 2013). Nowadays the community-based management of pirarucu is performed at hundreds of small local communities spread the Brazilian Amazon, and in some other Amazonian countries, both inside and outside protected areas (Gonçalves *et al.*, 2018).

Coastal fisheries have also been improved by co-management or commons-based management systems, through established territorial rights to local fishers, who exploit highly valuable and resident resources. For example, commons-based tenure systems that recognize rights to fishers to exclusively exploit coastal areas by following well defined management rules have contributed to recover or maintain catches of valuable marine invertebrates, such as shellfish or lobsters, in Mexico (Álvarez *et al.*, 2018; De la Cruz-González *et al.*, 2018; B. Salas *et al.*, 2014), Chile (Defeo *et al.*, 2016; Gelcich *et al.*, 2010, 2017), Uruguay (Defeo *et al.*, 2016), Australia (Mayfield *et al.*, 2012) and in Pacific Island countries (Thaman *et al.*, 2017). Territorial use rights for fishing (TURFs), which are usually suitable for sedentary or low-mobility resources, can vary enormously in area, origin, objectives of the management measure and intensity of resource management within territorial use rights for fishing boundaries (Orensanz *et al.*, 2013). Collaboration with fishers and inclusion of their knowledge had contributed to improve catches of lobster *(Panulirus argus)* through a management program involving artificial habitats in the coast of Mexico (B. Salas *et al.*, 2014). Nevertheless, in some regions the territorial use rights for fishing boundaries coastal co-management in Chile may had caused depletion of shellfish (Aburto & Stotz, 2013), in addition to displacing effort and thus resulting in depleting resources in nearby open access areas (Garmendia *et al.*, 2021). Sustainable coastal fisheries for reef fish have been observed in regions or communities involved in community-based, sea tenure systems, or in bottom-up co-management, especially in some Pacific Island countries (Busilacchi *et al.*, 2013; Cohen & Alexander, 2013; Léopold *et al.*, 2017; Webster *et al.*, 2017) and in Hawaii (Friedlander *et al.*, 2013). These traditionally managed systems incorporate community rules and beliefs, usually showing positive social outcomes (Cinner *et al.*, 2012; Tilley *et al.*, 2019; F. J. Webster *et al.*, 2017; Yang & Pomeroy, 2017). However, their ability to sustain fish catches will depend on the species being exploited and on the specific management regime, for example the duration and frequency of opening areas periodically closed to fishing (Cohen & Foale, 2013; Goetze *et al.*, 2016; Hamilton *et al.*, 2019; Yang & Pomeroy, 2017).

In Europe, the crisis in the small-scale fisheries demanded urgent reforms that were only put in place very recently. Only a decade ago, more than 60% of all fish stocks exploited in European waters did not include analytical assessment, due to a lack of the necessary information (Macdonald *et al.*, 2014). Moreover, until very recently it was believed that about 90% of all fishing stocks were either depleted or overexploited (Rivera *et al.*, 2017). Since 2013, when the European Union reformed the Common Fisheries Policy (CFP, Regulation N°. 1380/2013), according to which all European fish stocks should be exploited at Maximum Sustainable Yield (MSY), or less, by 2020. This should be achieved through multiannual plans developed with the involvement of all stakeholders (Quetglas *et al.*, 2017) and implementing an "ecosystem approach to fisheries management (EAFM)". Specific management regulations were introduced to mitigate problems of small-scale fisheries, including "collective actions" for the development of Local Management Plans (LMPs) (Battaglia *et al.*, 2017) and co-management practices. Nevertheless, some of these management regulations and measures, including the establishment of marine protected areas, were not always completely effective, and important problems were identified, such as the inadequate levels of social involvement and participation, and the use of ineffective communication tools (Baeta *et al.*, 2018; Morales-Nin *et al.*, 2017). However, there are examples of very successful management measures adopted by small-scale fishing systems in Europe, including better fishing practices in many places, and the recovery of many of the exploited fishing stocks, the re-adaptation of old technologies and gears, and even the recovery of lost jobs and of economic viability (Cillari *et al.*, 2012). If co-management practices are potentially very effective in the adoption and promotion of good fishing practices, there are also examples of unsuccessful cases (Morales-Nin *et al.*, 2017; Rivera *et al.*, 2017; Silva *et al.*, 2019), due to the inappropriate governance systems adopted (Braga *et al.*, 2017; Carvalho *et al.*, 2017). In some instances, the reduction or the control of fishing effort, and the enforcement of the rules of protection to vulnerable aquatic habitats are not always related with the governance system in place (Lloret *et al.*, 2018).

6.5.1.2 Policies aligned across scale and interactions supported

Policy instruments that are aligned across modes of governance, spatial scale, activities, and incentives, such that policies complement or reinforce one another, result in more positive outcomes. However, policy alignment is dependent on the effective inclusion and participation (section 6.5.1.1) of all actors which requires the investment of time, resources, and thought into developing governance frameworks and approaches that can successfully coordinate interactions.

Within non-extractive use case studies, international conventions that form part of the international context were not intensively assessed. When national laws were found to link to specific local rules that guide activities, such as with whale watching regulations and permits, this resulted in more successful social and ecological sustainability outcomes for most countries. However, most of the case studies across practice reported a lack of this multilevel interaction among the diverse set of actors involved or affected by sustainable use policy, which resulted in illegal trade, lack of mutual trust, common goal conflicts, gaps in ecological data and conservation status of species due to taxonomic complexity, institutional barriers etc. (*Terminalia chebula*, India; Jucara Palm). Governance processes that pay attention to coordinating interactions thus supported more effective policies. For example, the most effective gathering case studies (Biggs & Messerschmidt, 2005; Brinckmann *et al.*, 2018; He *et al.*, 2011) highlighted the importance of healthy interactions on a common platform for diverse actors from different levels and sectors in gathering, that included the national government, indigenous peoples and local communities, women, local authorities' non-governmental organizations, middlemen, micro/small scale industry representatives, research organizations and if possible international agencies (He *et al.*, 2011; Hopping *et al.*, 2018; Misra *et al.*, 2008; Negi *et al.*, 2015; Poudyal, 2004; Stryamets *et al.*, 2012). Joint stakeholder consultations encouraged exchange and understanding, awareness and provided the opportunity to local communities and indigenous peoples to share local and scientific knowledge among relevant actors. This helped in closing the gap between the communal and governmental efforts for adaptation and encouraged transformation towards sustainable resource management.

Interactions between actors in the fishing case studies were not always described in detail, but generally were supported by informal or formalized processes, e.g., *via* some kind of exchange forum. For example, in the case study from Baja California (Mexico) fishing cooperatives banded together into a federation providing a crucial link to the government agencies (McCay, 2014). Whereas, in the Amazonian pirarucu fishing case study **(Box 6.5)** (Campos-Silva & Peres, 2016), there was an explicit partnership formed between local communities, local associations, and government agencies. In contrast, where interactions are not supported on an equal footing, and management objectives between fishers and government agencies radically differ, as was the case for Lake Victoria inland small-scale fishing, then partnerships deteriorate rapidly to the point of severe conflicts and sometimes power abuse by the government (See section 6.5.4.3, **Box 6.15**) (Nunan, 2020; Nunan *et al.*, 2015). Dialogue and partnership are thus highlighted as important in ensuring management works.

Examples from Tanzania provide evidence that positive effects on wild species populations were made possible when support to grassroots law enforcement was provided (Lee, 2018; Mgumia & Oba, 2003). Similarly, when customary systems of governance are recognized and legitimized within statutory processes, policies are more likely to align. For example, in Ghana, sufficient local governance capacity was crucial to success. Chieftaincy remains integral to Ghana's electoral system and, as ultimate landowners, the chiefs are a respected authority that external agencies can engage directly. Consequently, the designation of the protected core zone, the establishment of conservation-related by-laws, and the negotiated resettlement of communities were made at the local level. As opposed to decrees passed down by remote government agencies, local representation in the decision process can yield support from even the most disadvantaged individuals. Furthermore, since chiefs challenge one another, a balance of power is established that facilitates accountability, transparency and equitable benefit distribution (D. J. Sheppard *et al.*, 2010). Therefore, a community's governance system should be understood and, if aligned with community based natural resource management approaches, co-management systems should be developed to fully empower community control over revenues and natural resources. In parallel, sufficient time is required for the planning phase to learn about the community's spiritual, cultural and economic connections to nature (D. J. Sheppard *et al.*, 2010).

However, supporting actor interactions and aligning laws and policies acting at different levels requires a considerable investment of time, research, and resources. This level of investment in gathering law and policy is extremely rare. The result is legal frameworks that are inconsistent and confusing, and a lack of clarity about which laws and government departments have jurisdiction over these products and activities. For example, the gathering policy environment in South Africa is characterized by a plethora of inefficient and sometimes contradictory national and provincial laws. These laws are only sporadically implemented, are often incompatible with each other, and are largely unknown by local communities. The laws then interface with customary systems that have eroded to varying degrees as a result of colonial and apartheid administration, but often offer the most effective regulation for wild algae, plants and fungi (Shackleton *et al.*, 2010; Wynberg & Laird, 2007). However, this is not limited to South Africa and legal frameworks were found to similarly lack clarity in hunting cases from other parts of the world.

Sometimes a lack of implementation results when government departments compete with each other, or their mandates conflict or overlap. As a result, no institution delegates the resources or staff needed to implement gathering regulations (Antypas *et al.*, 2002). In Cameroon, the 1994 Forestry Law (Republic of Cameroon, 1994) set up a gathering sub-directorate within the then ministry of environment and forests. This new body was provided with a civil servant to oversee activities, but had no budget and extremely limited power compared to the timber interests residing in the same ministry. Financial returns from taxes and fees on wild algae, plants and fungi went to other departments and ministries (Laird *et al.*, 2010). It is often the case that revenue streams, which could strengthen and build capacity within government to effectively regulate and manage wild algae, plants and fungi, are diverted to other, more powerful, entities in government. In the Western Ghats in India, for example, royalties collected on uppage *(Garcinia gummi-gutta)* went to the state treasury, with no allocation for conservation of the resource, and state efforts focused on policing the movement of material in order to collect royalties, rather than monitoring harvest and trade to ensure sustainability (Lele *et al.*, 2010).

6.5.1.3 Robust institutions

Considerable attention has been directed towards the understanding and evaluating the importance of governance quality as a short hand to understanding the extent to which structures, resources, capacity, and trust exist in sufficient quantities to ensure rules are adhered to and outcomes are monitored and fed back into an adaptive process. Chapter6's experts draw on the notion of 'robust governance' to capture quality, a concept more often applicable to corporate governance, understood to be an accountable and adaptive governance system with transparent distribution of roles and command, reporting and communication lines, inbuilt feedback mechanisms and understanding of operated realities (Baret *et al.*, 2013). Robust governance also broadly applies to the concept of policy robustness, which is defined as "the ability of governance arrangements in a policy to maintain performance in the presence of external/internal disturbances" (Capano & Woo, 2017).

Although the focus on governance quality has tended to be on centralized modes of government, this concept is applied across all modes of governance from statutory to customary, and make no judgement on what modes of governance are preferred. A functionally close concept to robust governance is "good governance" which results in a similar outcome (i.e., a policy implemented) (UNESCO, n.d.). However, while robust governance systems, can be considered 'good', they can also deliver outcomes without being considered 'good', e.g., with no orientation towards the consensus-seeking or transparency. This may be the case in top-down or even authoritarian governance regimes that manage to build a functional line of command through discipline.

Legal and regulatory approaches are far more ubiquitous than any other category of policy instrument **(Table 6.6)**. Consequently, there is clear evidence of both failure and success, although government rules and institutions remain a backbone of governing wild species. Some of the best evidence of successful legal and regulatory approaches comes from industrial fisheries in regions with strong, and robust, management institutions, where resources and capacity exist. Consequently, governance is often highlighted in studies on fisheries management, be it through aspects on strong institutions, enforcement, participation, legitimacy or other aspects as a critical enabling condition **(Figure 6.5)** (Ye & Gutierrez, 2017). Despite recognition of the importance of robust institutions for legal and regulatory approaches, governance is weak in many contexts. Yet, legal and regulatory approaches remain the most commonly applied category of instrument in fisheries management across much of the world, and weak statutory governance remains a significant limiting factor.

In contrast, where robust governance institutions exist, a suite of management regulations have been adjusted and applied in response to changes in the status of exploited populations resulting in improved stock status of assessed fisheries (Hilborn *et al.*, 2020; Hilborn & Ovando, 2014; Melnychuk *et al.*, 2021; Worm *et al.*, 2009). The latter studies highlight, for instance, that where fish stocks are assessed and centralized institutions are strong, stocks are increasing or at target levels, and many are in good condition and suggests the overfishing problem and the need to identify alternative appropriate strategies mainly lies

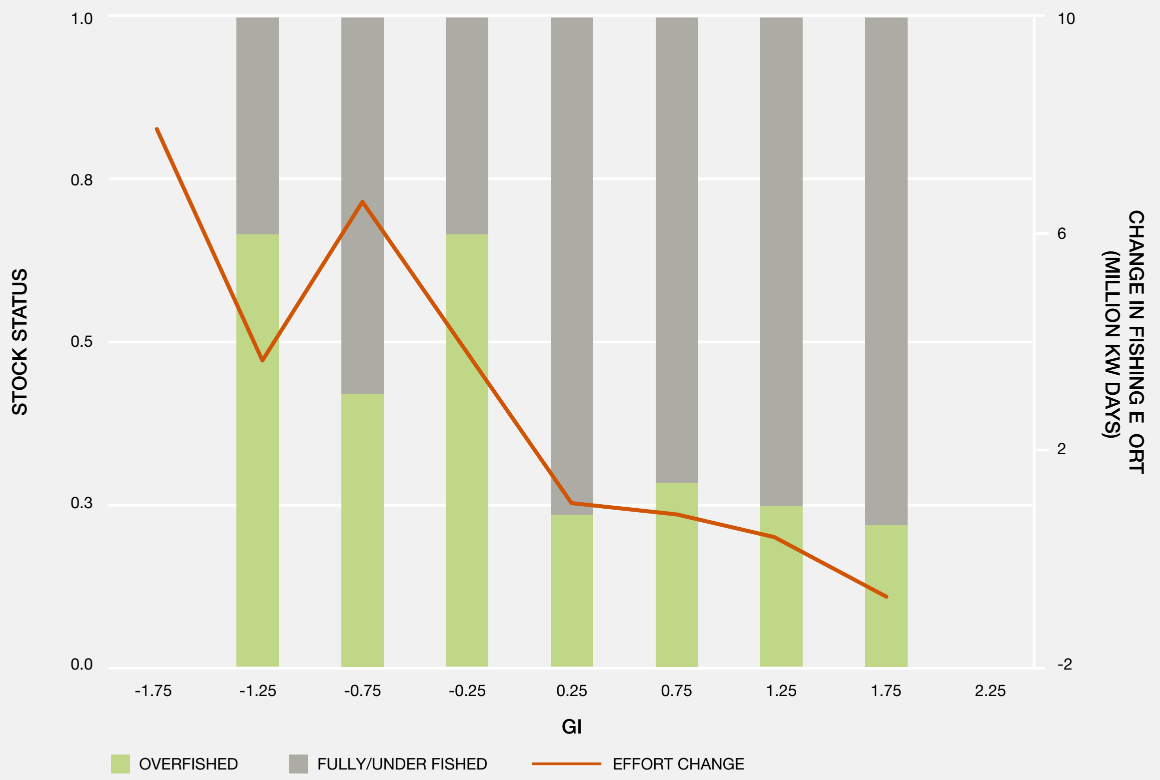


Figure 6 5 **Linking fishing patterns to governance.**

Relationship between governance index (GI) scores of countries and their capacity to restrict fishing effort (as change in efforts from 1970 to 2013; blue line) and to manage their fish stocks sustainably (as percentage of stock not overexploited; bars). Given that some stocks are targeted by several countries with different governance index scores, the proportion of overexploited stocks for the most extreme governance index median interval (-1,75) is missing. ANOVA: F (6.275) = 2.44, P=0.026. Source: (Ye & Gutierrez, 2017) under license number 5165931340256 CC-BY NC.

with the unassessed stocks (Hilborn *et al.*, 2020). However, it should be noted though, that if a stock is unassessed, it is also impossible to judge if the level of fishing is appropriate and thereby determine whether it is overexploited or not.

According to one model-based metanalysis that included assessed and unassessed stocks, median fisheries were estimated to be in poor health and business as usual would likely lead to more collapses (Costello *et al.*, 2016), but according to estimates in the same study, it would take less than 10 years to recovery with simple management. A recent evaluation of the effect of historical management interventions on the status of 288 assessed marine populations found that explicit harvest control rules used to set quotas and formal rebuilding plans were most effective and that the benefits of co-occurring management measures at the local, national and international levels were cumulative (Melnychuk *et al.*, 2021). However, more successful outcomes associated with legal and regulatory fisheries management tend to be found in countries with stronger central governance, and large industrial fisheries where enforcement and monitoring is possible. A higher redundancy in management tactics were also present in such countries with stronger central governance and having a high Human Development Index, thereby contributing to success (Gutiérrez *et al.*, 2011).

Robust formal or informal institutions, including clear mechanisms to monitor, detect, and enforce rules, are relevant across various forms of governance. In the dry forest of southern Madagascar, southern Androy, 188 forest patches were mapped and characterized, revealing 174 “taboo forests”, ranging in size from, 1 to 142 hectares. All of them were protected by taboos and referred to as ala kibory, forests that are burial grounds for the ancestors and thus highly respected and protected. Human interaction with and resource extraction from the taboo forests are highly restricted by the taboos, with heavy sanctions enforced by the local community as well as through beliefs in spiritual powers. Enforcement of the taboos is responsibility of the clan that owns the patch. If forest damage is found, a clan meeting is called to establish guilt and sanctions. Regulated hunting, grazing, honey harvesting and gathering of wild species are permitted. Taboos were applied to a variety of forest types, including areas with a weak association to spiritual beliefs, such as honey groves and private forest, which illustrates the generality of taboos as a rule mechanism in the society. Thus, they can be seen as a component of a local governance system for forest resources that receives additional legitimacy through the respect for the ancestors, shared by non-Christians as well as Christians in the community. In addition to belief systems, the study also shows how other mechanisms play a key role in maintaining the protection of the taboo forest, such as the well-established and recognized physical sanctions decided on by the clan elders and functioning enforcement including mechanisms for monitoring, detection, and conviction. The local faly, meaning forbidden or "you shall not," is a component of the laws inherited from the ancestors. These rules are thus more restrictive than the state rules and sanctioning is much stronger and more efficient (Tengö *et al.*, 2007).

Thus, secure forest resource tenure and management rights; systems for monitoring and regulation; systems for adaptation and control; and greater access to markets repeatedly emerge as enabling sustainable use across gathering case studies. *De facto* community tenure systems for wild species enable an important opportunity for initiating community-based resource management that can be complementary to state policy efforts.

Although democratic decentralization has improved levels of public participation and, in some cases, government accountability, its ability to address rural inequality and poverty has been relatively modest (Johnson, 2001). Effective decentralization requires the construction of accountable institutions at all levels of government and a secure domain of autonomous decision making at the local level. The political dynamics in policy reforms usually play a crucial debilitating role. It creates a divergence between the rhetorical claims for decentralization and the institutional changes that take place (Ribot *et al.*, 2006).

While top-down robust governance systems can quickly achieve setting objectives, they are usually less effective on post-project sustainability and strategic oversight. Bottom-up robust governance approaches in contrast, are often slower (Niedziałkowski & Shkaruba, 2018). For example, the Solability 2020 governance efficiency ranking (Solability, 2021) based on good governance indicators places Belarus on the 90th position, while Ukraine is on the 81st and Romania is on the impressive 18th. Both Ukraine and Romania have sustainability concerns with devastating impacts on biodiversity, including large scale illegal logging in the Carpathian Mountains (including logging in protected forests) (Schlingemann, 2017). Yet, this is not a problem in Belarus (which also boast a large forest stock), arguably due to the stern discipline in the chain of command in this autocracy. In contrast, governance systems for both democracies, Romania and Ukraine, is weak and highly susceptible to corruption. The scale of the problem can be illustrated by the non-governmental organization Earthsight's investigation 'flatpacked forest' (Earthsight, 2020). This investigation highlighted a clear connection between illegally harvested beech timber from protected forests in Ukrainian Carpathians, and Forest Stewardship Council (FSC) certified beech timber sold to IKEA. Despite the presence in Ukraine of national forest and biodiversity conservation monitoring and oversight agencies, the globally most relied upon mechanism of private governance in the trade of sustainable timber (FSC), a business globally renowned for its respect for the environment (IKEA), and the European Union global mechanism for preventing illegal timber imports (European Union Forest Law enforcement, Governance and Trade action plan), sustainability policy is failing because of the absence of a 'robust' governance framework.

6.5.2 Institutional arrangements that enable sustainable use

6.5.2.1 Tailored to the context

For sustainable use of wild species, specialized policy instruments focusing on the use of wild species, that are tailored to the local social and ecological context are necessary. However, in many cases, strategic policies for managing use of wild species are not well established or implemented. Oftentimes, policies effective in one timescale and context are applied uncritically elsewhere with mixed outcomes. More effective policies: i) are targeted to the species or group of species context; ii) ensure the costs of management do not exceed the benefits; and iii) direct resources to where needed.

Different management schemes work better -and are more effective- depending on the different groups of species hunted (vertebrate classes). For example, for reptiles, ranching has proven to be a very effective sustainable use scheme, which increases the survival rate of the harvested eggs, while increasing the production of crocodile skins and providing incentives for indigenous peoples and local communities to conserve the whole ecosystem under management **(Box 6.4)**. However, for big mammals, mixed-use management that involve hunting or harvesting individuals in the wild, while also reproducing or raising them in captivity to reinforce wild populations when needed, has proven to be effective, as this scheme enables a bigger offer and a higher benefit for indigenous peoples and local communities and the involved stakeholders, while maintaining healthy populations and habitats.

'Sticks', such as permits, quotas, taxes and restrictions on trade are often employed to regulate wild product use, particularly in a perceived overharvesting crisis. However, 'carrots' in the form of incentives and supportive legal frameworks, such as government support for producer, trade and processing groups; market access and premium prices *via* certification; tax breaks; and outreach and education on new policies and laws usually work best for this category of products. In some cases, particularly when there is sudden and high commercial demand, both approaches are necessary.

The effects of installing private property rights will vary depending on the ecological and country context. The introduction of individual quotas within fisheries inevitably means a change in the structure of fishing and who can access the resource. This has implications for equity and social cohesion of the communities that are affected. Individual transferable quotas or catch shares assign private property rights on a fraction of the total allowable catch or effort to individuals or firms who can use them, lease them or trade them. They have been advocated as a way to eliminate the "race for fish", increasing economic efficiency by rationalizing access to a common-pool resource, improving safety at sea, and promoting a long-term view on the sustainability of the fishing. As a relatively new but increasingly used tool in management of industrial, data-rich fisheries, they have been highly controversial, with divisive arguments raised from both philosophical and empirical grounds. Opponents have questioned on ethical principles the *de facto* privatization of an otherwise public resource; whereby initial quota recipients are granted shared ownership at no charge while future entrants have to purchase or lease quota to access the resource. Individual transferable quotas are used in industrial, data-rich fishing that manage with total allowable quotas based on biomass estimates and harvest control rules. Small-scale fisheries most often lack the data required to implement conventional fisheries management. This hinders or precludes the use of some management approaches that rely on data, such as individual transferable quotas – which are generally considered inappropriate for small scale fisheries.

In terms of performance, the implementation of individual transferable quotas entails clear trade-offs between different sustainability dimensions, and outcomes vary depending on program design and fishing characteristics. On the one hand, increased economic efficiency associated with consolidation of the fishing power into a reduced number of more efficient vessels has been supported by several studies (Arnason R., 2002; Fox *et al.*, 2003; Grafton *et al.*, 2000; NRC (National Research Council)., 1999) although others have found that quota leasing may introduce inefficiencies (Pinkerton & Edwards, 2009). On the other hand, concentration of quota ownership has raised equity issues (Donkersloot & Carothers, 2017), as deck hands and fleet sectors have been displaced, as illustrated by the Pacific halibut case study **(Box 6.6)**. They may lead to skewed power relationships, which may increase conflicts and result in 'poaching' instead of controlled extraction. While there is abundant anecdotal evidence that secure catch shares promote increased fishers' participation and stewardship (Grafton *et al.*, 2006), it has been argued that the theory that quota ownership may promote stewardship remains unproved (van Putten *et al.*, 2014) and may break down when quotas are increasingly leased and quota owners are separated from fishing operations (Edwards & Pinkerton, 2019b).

The extent to which individual transferable quotas contribute to ecological sustainability is hard to evaluate because of confounding effects of other regulatory measures, mainly a total allowable quota or an effort quota, that are a prerequisite for the introduction of individual transferable quotas. In other words, the ecological effects of the individual allocation of transferable quota shares are hard to separate from the effects of the total allowable quotas *per se* (i.e., the benefits from setting and enforcing an adequate total allowable quota) (van Putten *et al.*, 2014). While Costello *et al.* (2008) concluded that well-designed catch shares may prevent fishery collapse, other empirical studies have failed to find clear evidence that the implementation of individual transferable quotas has led to improved resource status (Essington *et al.*, 2012; Thébaud *et al.*, 2012). A more recent global empirical analysis of 800 stocks conducted using a different methodology to attribute causality (Isaksen & Richter, 2019) found that property rights may have a positive ecological effect, reducing the probability of a stock collapsing, but the effects depend on attributes of the quota system, the resource and the institutional context. Individual quotas were found to be more effective when they are transferable, when there is high ownership protection and trade openness, and when the species have high value and high growth rate. The positive effects of quotas materialize around 10 years after implementation, as it takes time to rebuild stocks, species with high turnover responding faster to policy. An interesting result of the analysis was that many fisheries have either favorable ecological condition to introduce private property rights, or institutional conditions, but rarely both. Therefore, due to feedbacks and interactions between different forces a clear prediction of effectiveness cannot be generalized.

The focus in gathering, fishing, and logging certification schemes on large scale enterprises is due to the high cost of the certification process. However, successful policies ensure the costs of management do not exceed the benefits. Candidates for certification must pay for certification and have well developed infrastructure and finance to support marketing needs and reporting requirements. As a result, certification is less likely to be pursued, awarded, or sustained for small-scale fishing, small-scale logging, gathering, or terrestrial animal harvesting (especially community-managed ones). For example, within terrestrial animal harvesting and gathering, a limited number of species

Box 6 6 Pacific halibut case study.

The Pacific halibut fishery has been considered a poster child for how the introduction of individual transferable quotas led to increased economic efficiency and safety at sea, together with improved product quality and availability. However, clear trade-offs exist with social impacts of individual transferable quotas implementation.

Pacific halibut is distributed on the west coast of the United States of America and Canada, from California to the Bering Sea. The directed fishery is intensely monitored and regulated by the International Pacific Halibut Commission, established by convention in 1923. Total allowable quotas are set for each of several regulatory areas based on annual assessments of stock size, supported by a rich data base including coast-wide setline surveys of abundance and intense monitoring of fishing operations. While the stock has been declining and the global total allowable quotas is at its lowest level since the 1980s, a responsive management system is in place and the latest stock assessment report (IPHC, 2021) concluded that the resource is not overfished nor subject to overfishing. The fishery from Alaska and Washington has been certified by the Marine Stewardship Council since 2006.

Individual quotas were introduced in Canada starting in 1991 and in the United States of America in 1995. In the United States of America, prior to the introduction of individual transferable quotas, there was no limit in the number of fishing licenses that could be issued, which led to an increase in fleet size and a concomitant reduction in the duration of the fishing season as the fishery was closed when the total allowable quotas were caught. In the end, some regulatory areas in Alaska had openings that lasted less than two-days a year, which resulted in difficulties to control the total allowable quotas, lost gear and unsafe fishing conditions, and glutted markets and reduced prices. With the implementation of individual transferable quotas, the fishing season was extended to 9 months, fresh fish became available to consumers, prices increased and there was a 50% fleet consolidation (Donkersloot & Carothers, 2017). The situation was less extreme in Canada, where a limited-entry program existed prior to individual transferable quotas.

While the concentration of quota ownership into fewer hands following individual transferable quotas implementation increased economic efficiency, it redistributed benefits and resulted in equity issues, displacing labor and smaller-scale fleet sectors and disproportionally affecting small, mostly indigenous communities in Alaska and Canada. Restrictions on quota trade between sectors have been introduced to address community goals at the cost of decreased economic efficiency (Kroetz *et al.*, 2015). The community purchase program established by the North Pacific fisheries management council to allow small communities to purchase quota collectively has failed to redistribute quotas due to high quota price and lack of quotas for sale (Donkersloot & Carothers, 2017). While traditionally the halibut fishery was operated by owners, the majority of the catch in Canada is now leased out by processors and larger fishing companies (owner-operators own only 16% of the quota in 2016) (Edwards & Pinkerton, 2019b), and it is hard for new entrants to purchase quota. The increase in lease prices and the disconnection of quota owners from fishing operations conflict with the rational for individual transferable quotas as an efficient market-based management instrument and erode the effectiveness of ownership to incentivize resource stewardship (Edwards & Pinkerton, 2019b; Pinkerton & Edwards, 2009). The Canadian government has been buying licenses since 1997 for repatriation of fishery access to indigenous peoples. In 2018, there were 76 such licenses making up 16% of the total allowable quotas (Edwards & Pinkerton, 2019a). As a whole, these authors have argued that the program has failed to meet stated objectives for distribution of benefits.

are legally tradeable (hunting), or have sufficient tradeable value (gathering) to sustain market-based mechanisms. For example, some of the wild species' products on the market that can be successfully and legally commercialized, that come from hunting, ranching and farming, and in which the costs of certification are considered justified, are crocodile and alligator skin, meat, and eggs.

Consequently, certification programs that account for the reality that many collectors' livelihoods (and conservation) strategies are based on the absence of a market mechanism for harvesting activities are more likely to succeed, this has been found to be particularly relevant for the gathering of wild plants for trade. Certification programs that can support the overall livelihood strategies of wild plant collectors are more likely to be effective at supporting sustainable use **(Box 6.7)**. Local adaptability of wild plant certification is grounded in an understanding of what ecological and economic sustainability mean to the target community and individual collectors (Makita, 2018). For example, certifications and labeling schemes have been developed that recognize the value of indigenous and local knowledge which have been used to support local economies and community well-being, associated with gathering wild edible plants, seaweeds, and mushrooms which have a tradable value.

Around 30% of the total selected cases, across all five practices, include community-based management. Community-based management is particularly prevalent in the gathering and non-extractive use practice cases. (D. E. Lee, 2018). For conservationists, the real question is whether community-based tourism provides an effective incentive for communities to take conservation action. This incentive can take several forms. The ideal is a direct linkage, in which nature-based tourism earnings are so

Box 6 7 **Gathering – FairWild (India).**

The FairWild certification system was implemented to enable tribal community members to sustain Haritaki trees *(Terminalia chebula)* scattered in their private plots and the forestland's vegetation by benefiting from the commercial value of the tree species in Bhimashankar wildlife sanctuary, India. By providing economic incentives through certification, FairWild aimed to induce a shift from the harvest of immature berries to mature berries. Due to an increase in demand over the last decade for immature berries in local markets, the majority of collectors increased their harvests of mature berries for the FairWild project while continuing to harvest the same quantities of immature berries for local traders. This unanticipated project outcome was attributed to the unique nature of wild plants as an uncertain income source without any financial, physical, or human investments. Collectors developed their own concepts of ecological and economic sustainability derived from this unique income source endowed by nature, and incorporated the new economic opportunity into their own natural resource management strategies that evidently differed from those designed for the FairWild project.

FairWild certifications are applied in many ways but, collectors have their own objectives for introducing certification within a specific setting. FairWild primarily benefited the most vulnerable members of the community but also ironically increased the net amount of Haritaki berries harvested. It was difficult to dislodge the collectors' belief of sales of immature berries being more lucrative, despite the introduction of the FairWild project for mature berries. Although, increase in value added to mature berries secured recognition of the importance of Haritaki trees within the community, the certification does not relate with the community concept of ecological sustainability. Confirmation of the higher value of immature berries could have resulted in increasing ecological sustainability but, collectors believed that their gathering practices were already sustainable with the belief that they cannot increase the harvests of immature berries with the aim to sell the available quantity of immature berries at a higher price. FairWild strategies contributed to economic sustainability but the income was insufficient and required introduction of another stable income source complementary to FairWild certification and an alternative or a direct intervention in the harvest of immature berries (Makita, 2018).

high that people deliberately protect biodiversity to protect that income. Nature-based tourism can also draw local labor and capital away from biodiversity unfriendly activities (Wunder, 2000).

A ban is a stringent legal instrument, and although wild species trade bans may be necessary and are valuable tools in specific cases, their effectiveness depends on many context-specific factors that should be considered including: demand for wild species, capacity to enforce regulations in exporting and importing countries, governance, the species conservation status, local customs, traditional use, and alternatives for indigenous peoples and local communities' livelihoods, among others. In the short term, hunting bans can be effective by giving threatened species time to recover, while drivers of population decrease are identified and remedial actions are implemented. In the long-term, a hunting ban is a costly conservation measure that requires large enforcement efforts and heavy budgets, while providing disincentives to conserving ecosystems, often resulting in land use change to promote other activities that provide revenues to local communities (see **Table 6.7** for the list of cases studies on terrestrial animal harvesting).

Rowcliffe *et al.* (2004) investigated the effectiveness of species protection law in the Democratic Republic of Congo, where limited hunting was allowed, with the exception of some mammal species. The authors tested if species legal protection was in any degree effective, by comparing a prey choice model to collected data. Data was collected in a protected area (Garamba National Park), where hunting was prohibited, and in a hunting reserve (Azande Hunting Reserve), where some species could not be hunted. Use of automatic rifles was illegal in both areas. In the study, the authors conclude that legal protection has had no effect on hunters' prey choice decisions in the analyzed system. This means, protected species were equally or more hunted than unprotected species. The authors indicate as a main reason the minimal enforcement of species protection laws registered in the area during the duration of their study and indicate that selective protection is likely to be extremely difficult to achieve in the absence of robust institutions. They also indicate that the effectiveness of species protection laws could be improved most dramatically by increasing the probability that violations will be detected, rather than by increasing penalties.

The idea of directing investments more towards active fisheries management worldwide has been proposed, however depending on definitions, this may lack realism due to the amount of money and logistics required to carry out the major elements of conventional fisheries management such as fisheries surveys, stock assessments, etc. in areas that are not equipped to invest into such processes, without clarity on who would pay for such processes and their effectiveness. It is also a recurring question whether the conventional management approach developed for large-scale single species industrial fisheries, is suitable and applicable in small-scale multi-species fisheries (see **Table 6.5** for a contrast in assessment and management approaches used in industrial *versus* small-scale fisheries). The conventional tools such as effort regulations and

Table 6 7 **Example list of cases from terrestrial animal harvesting regulations.**

Other case studies to be in the data management report at https://doi.org/10.5281/zenodo.4663236.

Case study	References
Bighorn Sheep	Félix, 2006; Flores, 2015; Gobierno del Estado de Sonora, 2012; R. Lee, 2008; Luque Agraz & Doode Matsumoto, 2009; Luque & Doode, 2007; Mosig, Muñoz-Lacy, *et al.*, 2019
Polar bear	Tyrrell & Clark, 2014
Saltwater crocodile harvest & ranching	Fukuda *et al.*, 2019
Lions (countries A: Namibia & Mozambique)	P. Lindsey, Alexander, *et al.*, 2012; P. Lindsey, Balme, *et al.*, 2012
Lions (countries B: Zambia, Zimbawe & Tanzania)	P. Lindsey, Alexander, *et al.*, 2012; P. Lindsey, Balme, *et al.*, 2012
Subsistence Hunting (Mayas)	Rosales Meda & Hermes Calderón, 2010
Kangaroos	Chee & Wintle, 2010; Descovich *et al.*, 2015; Gilroy, 2004; Lunney, 2010; Olsen & Low, 2006; Williams & Price, 2010; G. R. Wilson & Edwards, 2019
Turtle eggs harvest (Ostional)	Ballestero *et al.*, 2000; brenes Chavez & Cedeño Solis, 2017; L. Campbell, 1998; L. M. Campbell *et al.*, 2007, 2012; Cedeño Solis, n.d.; García & McHugh, 2005; Klopfer, 2014; López, 2012; Sardeshpande & MacMillan, 2019; SINAC, 2012; Valverde *et al.*, 2012
Ritual maya	Santos-Fita, 2015
Falco trapping (artificial nests)	Dixon, 2011, 2016; Dixon & Batbayar, 2010; Janchivlamdan, 2014; Naranjo *et al.*, 2015; Rahman *et al.*, 2014
Subsistence hunting Brazil	Antunes *et al.*, 2019; Bragagnolo *et al.*, 2019; Tomas *et al.*, 2018; Vieira de Mattos *et al.*, 2019
Spectacled and black caiman	Botero-Arias & Regatieri, 2013; Franco *et al.*, 2019; Marioni *et al.*, 2013; Mendonça *et al.*, 2016; Pimenta *et al.*, 2018
Hunting in a region of China	Jia *et al.*, 2017; Lundberg & Zhou, 2010; Yin, 2006; Y. Zhou & Lundberg, 2009
Hunting in Congo	Mavah, 2011; Smith *et al.*, 2019a
Bear hunt in Croatia	Knott *et al.*, 2014; Majić *et al.*, 2011

in particular catch quotas and size limits are difficult to implement due to lack of data and general resistance among fishers, and more community-based approaches are more likely to succeed. This, however, requires acceptance among policymakers that the industrial-scale framework is inappropriate, which is rarely the case (Kolding & van Zwieten, 2012).

Available money can be spent in various ways, including on subsidies capacity enhancement (with negative ecological effects) or limiting fishing pressure (positive ecological effects) – and monetary investment can support reaching management objectives if focused on the latter rather than the former (Melnychuk *et al.*, 2017). Money could also be invested into active management of world's unmanaged fisheries (capacity development towards conventional fisheries management in more places). Rather than focusing on creating conventional data-driven conventional fisheries management situations (which seems highly unrealistic from a financial point of view, and have severe ecological side effects such as fisheries induced evolution and disturbed ecosystems from selective harvest patterns), other options may include: (i) invest in creating leaders, social 'capital' (Gutiérrez *et al.*, 2011); (ii) support low-income countries' efforts to transition away from capacity enhancing subsidies (Gill *et al.*, 2017; Sumaila *et al.*, 2021).

Additional measures could include area-based measures. There is something to be said about establishing marine protected areas all over the world as currently happening also due to the push within the Aichi targets framework (note the % in Exclusive Economic Zones (EEZs) has been achieved but not the networking of marine protected areas, which is also part of the target) without providing sufficient capacity to enforce them (Gill *et al.*, 2017). Moreover, the term "marine protected area" can have a broad variety of meanings and affect many dimensions of marine uses (fisheries, mining, shipping etc.) so the type of marine protected area (as well as the process by which it is put in place of course) would have a strong influence on whether it can be viewed as adding to sustainability of fishing. In addition, marine protected areas are systematically set up in areas with low political opposition (Stevenson *et al.*, 2020), sometimes reducing their capacity to fulfil the biodiversity goals they were initially intended for.

Of the 33 analyzed gathering case studies, 22 cases (67%) involve legal or regulatory instruments, however in all cases these were applied in combination with economic, social, and/or rights-based instruments. Laws specifically tailored towards the different types of wild plant and fungi use (e.g., subsistence, local trade, commercial trade, recreational) are most effective. This would mean, for example, that subsistence use is only regulated in cases where there are clear risks of overharvesting, but that attention is paid to internationally traded industrial-scale products. Linked to this is greater attention towards understanding the relationship between wild product use and agriculture, the importance of harvest timing for subsistence and cash income, and other critical features. In general, regulatory instruments have the potential to generate positive ecologically sustainable outcomes and are reinforced when accompanied by codes of conduct and community-based instruments with social and economic aspects. Within gathering case studies, flexibility in measures was found to enable adaptation to accommodate shifts in market demand, safety concerns, climate change, other land-use activities and other common disruptions to wild product trade.

A few governments have developed gathering law and policy in a more strategic manner. This includes undertaking research and building ecological, economic, social and cultural understanding of species, incorporating comprehensive consultations with stakeholders, and developing a strategy for the resulting legal framework. In the past decade, for example, Namibia has taken a proactive and progressive approach towards gathering policy and regulation, recognizing that these products provide vital income and livelihoods for communities in an environment characterized by extreme aridity and few economic opportunities (Bennett, 2006; Cole & Nakamhela, 2008; Nott & Wynberg, 2008; R. P. Wynberg, 2010).

Finland is also a notable exception to the rule of government neglect for wild algae, plants and fungi. The Finnish government has supported scientific research on wild berries for decades, including studies of their cultural and economic importance, as well as biological and ecological research (Kangas, 1999). At the same time, it has actively promoted berry and mushroom harvesting as an economic activity and cultural practice. Indeed, rather than discouraging harvesting as many countries have done, the government has developed programms to promote harvesting and related industries. These include a berry crop forecasting system and income-tax relief favorable to harvesters, providing them with the information and incentives they need to participate more effectively in gathering industries (Richards & Saastamoinen, 2010).

Successful social and information-based approaches within gathering case studies include a strong focus on ecological, economic, social and cultural understanding of species, incorporating comprehensive consultations with stakeholders and developing an overall strategy for implementation. Within non-extractive use case studies, local codes of conduct in addition to normative rules are very useful and result in more positive outcomes of social and economic sustainability. The effectiveness of community-based nature tourism is context dependent since there is often a lack of skills and education limiting the economic potential of this activity and sometimes social conflicts can emerge, but in general they are successful in economic and social aspects.

One example where (ecological) effectiveness may be improved by social and information-based tools come from catch and release recreational fishing. This has gained increasing attention during the last decades both due to its potential impacts on fish populations (Cooke & Cowx, 2004) and the environment (Lewin *et al.*, 2019), but also because of its high socioeconomic importance engendering substantial social and economic benefits (Hyder *et al.*, 2018; Lynch *et al.*, 2016). Recreational fishing takes place in freshwater, saltwater and brackish water environments, and recreational fishers use a range of fishing gear including traps, nets, longlines, and spears, but most commonly rod and line. Harvest of the catch for consumption is an important component of recreational fishing (Cooke *et al.*, 2018), however, a large proportion (in many cases more than 50%) of the catch is released both in freshwater and marine environments (Cooke & Cowx, 2004; Ferter *et al.*, 2013). Releasing a fish alive to the water where it was caught with rod and line is termed “catch-and-release”, a practice performed both due to management regulations (i.e., regulatory catch-and-release) and personal motivations (i.e., voluntary catch-and-release) (Arlinghaus *et al.*, 2007).

While the underlying assumption of catch-and-release is that the released fish survive without major impacts, catch-and-release practice can lead to unintended sublethal impacts or post-release mortality. Post-release mortality varies substantially by fish species and fishery, and depends on many factors including, but not limited to, anatomical hooking location, capture depth, fighting time, air exposure duration, and water temperature (Bartholomew & Bohnsack, 2005). Anatomical hooking location is one of the most important factors influencing post-release mortality. When fishes are hooked in the lips, hooking injury and associated bleeding is often limited, but deep- and gill-hooking can cause severe injuries and bleeding which often causes mortality of the released fish. Capture depth plays an important role for some fish species with a closed swim bladder. When these fish are pulled to the surface, the air in the swim bladder expands due to decompression causing so-called barotrauma which results in swim bladder rupture, gas bubbles in the blood, and “pop-eyes” (Ferter *et al.*, 2015).

While some fish species recover from barotrauma, others experience high post-release mortality rates. When practicing catch-and-release, minimizing negative Catch-and-Release impacts is essential if the aim is to reduce fishing mortality while maintaining recreational fishing opportunities. This can be achieved by developing species-specific best-practice guidelines based on scientific knowledge (Cooke & Suski, 2005). These guidelines can inform recreational fishers about the survival capability of their target species, environmental conditions when catch-and-release should be avoided, and specific fishing and handling practices which can be adopted to minimize post-release mortality. While catch-and-release practice is not appropriate for all fish species, for some species, its practice can come close to a "non-lethal" extractive use when best practice is followed.

6.5.2.2 Clear and aligned ownership rights, responsibilities, and goals

For successful policy formation and implementation, policy goals and instruments need to be clearly identified, aligned, and shared with stakeholders. Yet, often legal uncertainties, opaque policies, and a lack of resources inhibit the effectiveness of sustainable use policies **(Box 6.8)**. There is thus a need for access and ownership rights to be clear, for roles and responsibilities to be defined, and to articulate and align the purpose of both policy and instrument.

Evident across the gathering case studies the importance of clarifying access and ownership rights to resources and land when developing regulatory frameworks for the gathering of wild plants and fungi. Providing an enabling environment for traditional knowledge protection and local industries and producers helps to support sustainability outcomes. In this regard, customary laws can often provide a more nuanced approach to regulation, integrating unique local cultural, ecological and economic conditions in ways that better suit this category of products. Gathering case studies found where land tenure and resource rights are secure, customary laws are still strong, and local capacity exists to manage the resource base and deal with commercial pressures. Conversely, in cases where customary law has broken down to a significant degree, or outside commercial pressure has intensified well beyond the carrying capacity of traditional measures, governments can offer important and necessary complementary levels of regulation. Interventions should thus be crafted to

Box 6 8 **Legal uncertainties and lack of resources constrains hunting policies: Brazil.**

There is consensus among conservationists that wild species hunting is a major conservation issue in Brazil. Hunting is a widespread and culturally embedded activity throughout the Brazilian territory (Bragagnolo *et al.*, 2019; El Bizri *et al.*, 2015), but decisions on wild species management has historically disregarded the knowledge, interests, necessities and perceptions of those who practice hunting in the country (El Bizri *et al.*, 2015; Pezzuti *et al.*, 2018; Vieira de Mattos *et al.*, 2019). While new integrated landscape management policies were developed in Brazil to encourage sustainable production systems, i.e., agroforestry (Miccolis *et al.*, 2011), and to strengthen management strategies of value chains, i.e., wood and non-timber forestry production and fisheries (Campos-Silva *et al.*, 2017), hunting governance in the country remains weak, and formal hunting management systems are still virtually inexistent. In addition, the country faces a lack of land tenure regularization, especially in remote areas such as the Amazon, that affects the autonomy of rural, traditional and indigenous peoples in managing their territories according to their traditional practices (Constantino *et al.*, 2018; van Vliet *et al.*, 2019). The uncertainty in terms of land possession, along with the political invisibility of local cultural norms and management systems, weaken the decision power of local actors and allow illegal activities to flourish (Vieira de Mattos *et al.*, 2019).

One of the main drawbacks to hunting management in Brazil is the contradictory national legislation. The current legal framework on hunting is composed of a diffused set of policy instruments loaded with ambiguities and lacking crucial definitions of terms, concepts and rights, causing many people to live under legal uncertainty (Antunes *et al.*, 2019; Vieira de Mattos *et al.*, 2019). Indigenous peoples of Brazil (here, exclusively the people considered "Brazilian índios", around ¼ of all indigenous peoples in the country) are the only group unquestionably guaranteed by law (Law 6,001/73) of "the exclusive exercise of hunting and fishing in the areas they occupy". All other human groups, including traditional and rural people who often live in remote areas with poor access to urban goods and depend on wild meat for subsistence, are subject to the conflicting interpretation of the laws.

The main law regulating wild species hunting in Brazil is the wildlife protection law (Law 5197/67), which since 1967 prohibits the "use, persecution, destruction, hunting, or harvest" of wild species. The environmental crimes law (Law 9605/98), enacted in 1998, included an exception to hunting whenever it is carried out in a "state of necessity, to satiate the hunger of the agent or their family". One could state that this exception would be sufficient to permit subsistence hunting (hunting to obtain an essential source of food) to be carried out in Brazil. However, there is no clarity by these laws of what a "state of necessity" entails, meaning that environmental control agencies have the discretion to judge whether a person is hunting out of the need for food or not (Antunes *et al.*, 2019; Coad *et al.*, 2019). The lack of clarity of these laws drove Brazilian environmental control agencies to adopt criminalization and suppression of any type of hunting in the country as their main approach (Pezzuti *et al.*, 2018). Consequently, subsistence hunting is often regarded as a crime, which generates food insecurity to and imperil the culture and traditions of millions of local peoples (Pezzuti *et al.*, 2018).

On top of these legal uncertainties, surveillance and control of wild species crimes in Brazil is ineffective due to the country's extensive territory and lack of investment. For instance, in the Brazilian Amazon, only 1,229 officials are responsible for surveilling more than five million km^2 of forest, a rate much lower than that recommended by the International Union for Conservation of Nature (Oliveira *et al.*, 2020). Hunting is responsible for almost a quarter (18.2%) of all environmental infractions in protected areas of the Brazilian Amazon (Kauano *et al.*, 2017), but prosecutions and payments of fines related to these infractions are rare (Barreto *et al.*, 2009). Therefore, even if hunting were kept being considered as a crime, the Brazilian government would not be able to enforce the legislation and curb this activity in the long-term (El Bizri *et al.*, 2015). Meanwhile, there are very few formal plans or regulations for managing hunting implemented in the country, what means hunting is *de facto* open access.

Considering the challenges posed above, researchers advocate that to improve wild species management, strengthen local governance mechanisms, and reduce the impacts of hunting in Brazil, there is a critical need to amend national legislation and offer legal, political and technical support to community-based and co-management initiatives aimed at managing wild species (Campos-Silva *et al.*, 2017; Morcatty & Valsecchi, 2015). These steps, they claim, would increase democratization and decentralization of management decisions (Campos-Silva *et al.*, 2020), and consequently increase empowerment of local people, producing fair outcomes.

Photo: A lowland tapir *(Tapirus terrestris)* hunted for subsistence in a local community in the Brazilian Amazon. © Thais Morcatty CC-BY.

include local-level institutions and management systems where these are effective. Building on, aligning with, or complementing traditional resource rights is an important approach to minimize paperwork, avoid duplication of existing laws and enhance sustainable use. However, this requires real commitments of time, money, research, and extensive stakeholder consultation.

Clearly defined rights support more sustainable use policies; however, these rights may take many forms. In many of the successful fishing case studies, the communities have some degree of rights over the area or resource, some operate with catch shares, others not. However, there is no single combination model that appears more effective than others. While catch shares and strong ownership are often assumed to be beneficial, a case study of octopus fishing in Madagascar (Oliver *et al.*, 2015) for instance clearly states that common property institutions can successfully implement management without property rights over the resource. In other instances, indigenous peoples and local communities may have the rights to fish but government encroaches on this *via* creeping regulations or permit requirements (case studies on Sami fishing rights, Finland and Torres Strait islanders fishing). Court cases then reaffirmed the constitutional rights of indigenous peoples and local communities to e.g., maintain and develop their culture (Sami fishing rights, Finland). Clearly defined roles and boundaries, whether intentional or *de facto*- i.e., through isolation, can help with ease of enforcement. In the Baja California (Mexico) fishing case study, it was hypothesized (McCay, 2014) that the relative isolation of the fishing cooperatives on the Vizcaino peninsula contributed to the successful management of local benthic resources. Had they been closer to urban areas and with more people, enforcement costs and failures would likely have been higher and there may have been pressure to open the cooperatives to more members. However, there was not yet (in 2014) an actual comparison of the location with other locations at that time to really support this hypothesis. In the pirarucu fishing case study in the Amazon, a study showed direct impact of walking distance to nearest village on the ecological outcomes, as this related to the enforcement capacity of the protection of the lakes. Adjacency effects are also mentioned in the Baja California (Mexico) case study as leading to positive reinforcement of good practices when adjacent communities/cooperatives also care for their wild species (McCay, 2014). And in a coral reef fishing case study (East Africa), it is also suggested that there is a negative impact on own behavior if an adjacent community doesn't manage well.

The Convention on Biological Diversity addresses and highlights the role of protected areas for biodiversity conservation. However, protected areas are designated for conservation as well as sustainable use of wild species highlighting the need for clarity between goals and policies. At the national level protected areas clearly play a role as a key strategy for conserving biodiversity. Thus, the cases which adopted protected areas in terrestrial animal harvesting, non-extractive use, and gathering showed positive effects to ecological sustainability. However, there are few specific regulations which stipulate possible and prohibited activities for the use of wild species in the management of protected areas. Thus, specialized and sub-divided legal instruments are necessary to manage the use of wild species.

Designation of protected areas are effective for regulating wild species non-extractive use when a clear conservation objective and management program are applied that identify the number, zoning and appropriate activities for nature-based tourism. Natural protected areas in some cases have entrance fees but the number of visitors is estimated using different techniques such as visitor impact management between other techniques. The measurement of the number of visitors determines the success of the protected area in regulating nature-based tourism, especially in terms of environmental impact.

Total hunting bans have been proven to have limited effects when applied over the long-term. If applied, they should be evaluated on a case-by-case basis that takes into consideration the conservation status of the targeted species along with local traditions for species use. In most cases, it is preferable to apply temporary bans based on reproductive seasons of target species, or specific bans in key areas, for specific goals such as to promote species recovery and conservation. Restrictive hunting regulations, with no or insufficient options/alternatives for species use, are generally not effective in protecting species in the long-term, especially when areas or islands are very remote and more so when the state has week enforcement capacity **(Table 6.7)**. In these cases, hunting is often *de facto* open access, as evidenced by case studies from Brazil (Antunes *et al.*, 2019), Congo (Smith *et al.*, 2019a) and Tanzania (Haule *et al.*, 2002). Without regulation, overhunting and wild population declines have been the common outcome. There is strong evidence that total bans can negatively affect species conservation (Dickman *et al.*, 2019) and that in turn they tend to generate conflict in local communities, leading to reduced interests in species conservation, increasing resistance and undermining the voluntary participation of residents in conservation efforts (Strong *et al.* 2020). Restrictive regulations can however be an effective policy when they are used in the transition to a new arrangement for human livelihoods and the sustainability of wild species use, as shown in a case from Brazil (Freitas *et al.*, 2020).

Thus, restrictive hunting regulations can be effective at supporting sustainable use (i.e., through species recovery) when used in the transition to a new arrangement such as while conducting population studies for the establishment of limit harvesting (trade) quotas (e.g., in the case study of bighorn sheep in Mexico **(Box 6.9)**). Within the Convention on International Trade in Endangered Species and its significant trade review process, it is a very common practice that the parties subject to this review adopt voluntarily bans, while they have enough elements to establish a limit catch or take quota). In other cases, bans are established temporarily while populations recover, and later on, sustainable harvest limits are set.

6.5.2.3 Broader policies to support sustainable use

High level policies, such as in education and development, that align with targeted sustainable use policies such as those related to land tenure and resource access rights can create enabling conditions for the sustainable use of wild species. In contrast, when these policies do not attend to sustainable use, they can inadvertently exacerbate the drivers of unsustainable use (Chapter 4).

Fishing is inherently a complex system with many moving and interacting parts that rarely operate in isolation. Often, Box 6 9 **Transitional policies can pave the way for longer term policies: Bighorn sheep *(Ovis canadensis)* trophy hunting in Mexico.**

Sustainable trophy hunting of Bighorn sheep, mostly managed by indigenous peoples and local communities, is generating community well-being and leading the population's recovery and habitat protection in Mexico. During the 19th century and up to the mid-20th century, Bighorn sheep was extirpated from Northeast Mexico, and the population decreased significantly in the Northwest and the Baja peninsula (Sandoval *et al.*, 2014; Valdés Alarcón & Segundo Galán, 2007). In 1975, 45 Bighorn sheep were reintroduced in Isla Tiburon (Sonora, Mexico); which turned into 1,500 individuals by 2020 and served as nursery for repopulation purposes and hunting activities (Sonora, 2012; Valdés Alarcón & Segundo Galán, 2007). Bighorn sheep in Mexico can only be harvested in management units for the conservation of wildlife (UMA), which guarantee that habitat conditions continue to be favorable for the species and to ensure that hunting activities will be self-sustaining in the long term. More than half of the 60 management units for the conservation of wildlife of wild Bighorn sheep in Mexico are managed by rural dwellers (in "ejidos" – communal land), and some by indigenous peoples. Population monitoring and harvest rate estimations are based on aerial surveys funded by Government and stakeholders (communities). Once a Bighorn sheep is hunted, the meat is consumed in the site or left to the community, while the carcass (skull, horns and sometimes skin) is taken by the hunter (Félix, 2006). Only Mexico's populations are included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix II, and hunting trophies are offered in international auctions with prices up to 40,000 United States dollars per trophy, being the main drivers of international trade (CONABIO, 2021a). Each year legal harvest rates (10-20% of oldest males) of Bighorn sheep in Mexico are based on the best scientific information available, approved by the General Directorate for Wildlife (DGVS-SEMARNAT), which is also the Convention on International Trade in Endangered Species of Wild Fauna and Flora Management Authority, and reviewed by CONABIO, the "Comisión Nacional para el Conocimiento y Uso de la Biodiversidad" (CONABIO, 2021a). Hunting was suspended in the whole country (i.e., temporarily banned) in 1993 because of lack of reliable information on the population numbers, and re-opened in 1995 for some states once aerial surveys were conducted (Mosig, Muñoz-Lacy, *et al.*, 2019). There is a high revenue per trophy. Seri's communities traditionally have hunted Bighorn sheep populations, and a trust fund was constituted to compile earnings and share their benefits, which are distributed among stakeholders, with economic and social impacts; either directly (earnings) or indirectly (temporary jobs, scholarships, investment in infrastructure, etc.) (R. Lee, 2008; Luque & Doode, 2007). The Management Units for the Conservation of Wildlife framework maintains ecosystem benefits for the species and its habitat, and is key for the maintenance of corridors (Sanchez, 2006). There is some level of co-management in the system, as stakeholders are involved in monitoring the species (CONABIO, 2021a).

With a legal framework of National and International regulations, hunting in management units for the conservation of wildlife has helped maintain the species stability and its habitat connectivity for the last 20 years. This scheme of legal and sustainable use, with fair distribution of benefits throughout the trade chain and with investment in the conservation of Bighorn Sheep and its habitat, is already an example of best practice in terms of sustainable use and conservation of wild species in Mexico.

Photos: Bighorn sheep *(Ovis Canadensis)*.

multiple different stakeholder groups interact with each other, relying upon the exploitation of numerous species. These species are subsequently traded along supply chains of varying lengths, often to several final destinations. When evaluating the sustainability of fishing and mechanisms to improve it, it is important to look for answers both within and beyond fishing policy. The inter-connected nature of fishing systems means that they are influenced both by fishing-related policies but also by non-fishing-related policies. For example, the fishing activity of an isolated community who rely on the small local markets and lack of access to the larger and more populous markets may be impacted by a policy that changes national road infrastructure. While the intent of that policy may be to improve road transport and connectivity, there are likely secondary impacts for the fishing community that may subsequently gain access to better markets with better prices, or result in the exploitation of fish stocks (Cinner *et al.*, 2016). In theory this could lead to a reduction in fishing effort because the same pre-policy revenues can be maintained with less fishing effort overall. Conversely, better markets with better prices could lead to increased fishing effort. The exact outcome in such scenarios would likely depend on the size of the market, stewardship of the community towards the fishing resources upon which they rely, the status of those resources, and the ability of the resources to support increased levels of fishing pressure. This illustrative example is just one of many that highlight the potential of non-fishing related policy to impact the sustainability of fishing both positively and negatively.

The complexity of social-ecological systems and the interrelatedness of their components are increasingly recognized (Young *et al.*, 2006) particularly in terms of fishing sustainability (McClanahan *et al.*, 2009). The impacts of policies from one sector/part of society on other sectors/parts are, however, seldom recognized and/ or evaluated. Some progress has been made within the telecoupling literature in terms of highlighting the interconnectedness of systems across geographical scales (Lewison *et al.*, 2019; Liu *et al.*, 2013), including for fisheries (Carlson *et al.*, 2017, 2018); however, studies that link various policies specifically within and across distant systems are rare (though policy is identified as an important factor affecting telecoupling of systems: (Hull & Liu, 2018). The following illustrates some examples that specifically link non-fisheries policy to measurable impacts (positive or negative) on fisheries sustainability.

Freshwater fishing comprises 51% of the world's fish species, and approximately 30% of total landings. Freshwater ecosystems face a devastating combination of threats driven by human activities not related to fishing – including habitat destruction, such as drainage, river regulations, hydropower dams, over-abstraction of water for irrigation, various types of pollution, the introduction of invasive species and ongoing climate change. As such, one third of freshwater fish species are threatened with extinction and the multi-faceted drivers of change in freshwater systems highlight the ease with which these systems and their fisheries can be impacted by policies that do not directly relate to the fisheries that they support.

The institutional water framework of most national and international entities does not effectively address cross-sectoral issues relating to freshwater use and integrated management. The responsibilities for agriculture, water management, nature conservation, and inland fishing are often separated over multiple agencies (Cowx, 1998 as cited in (Cooke *et al.*, 2016). As a result, today a growing number of rivers run dry along part of their course for all or part of the year, including the Colorado (United States of America and Mexico) and the Huanghe River (China). While use of river water driven by non-fishing policy has brought enormous benefits to drinking water supplies, agriculture, and the hydro-electric industry, in many cases such policies have also brought costs. This is particularly so for freshwater fish populations. Over thirty-five years ago, Welcomme (1985) examined the relationship between river flow and fish production in Africa and illustrated it is possible to predict catches in river systems from regression analyses of the past performance of the fishing against discharge. Within decreased river flow comes decrease fish production, and the same is observed in natural lakes and reservoirs (Gownaris *et al.*, 2018; Kolding & van Zwieten, 2012). The positive correlation between river flow and fish production is also mirrored in coastal fisheries many of which benefit from high estuarine discharge, impacting both commercial and recreational fishing sectors (Loneragan, 1999). For this reason, Dugan *et al.* (2006) note the benefits of integrating water requirements for fish into water allocation decisions which very commonly do not account for impacts on freshwater fish stocks.

Governments aiming to meet broad economic objectives such as high employment, sustainable growth in industry and price stability often look towards economic development policy. This can encompass a suite of tools including fiscal policy, the regulation of trade, financial institutions, and taxes, and investment in infrastructure and services. The primary objective of these tools is largely economic growth. In many cases, this is often counter to the conservation of natural resources and biodiversity (Meng *et al.*, 2019). Economic growth generally constitutes a policy priority, whilst environmental protection often remains an ambitious goal and, in some cases, an unperceived need (Ferraro & Brans, 2012).

The commonly reported negative correlation between economic development and successful conservation, does not, however, always appear or need to be the case. Policy focused on the creation of jobs and/or alternative livelihoods can, in some cases, alleviate anthropogenic pressures on natural resource systems. In fisheries, the most linked alternative livelihood is that of aquaculture. Development policy that promotes growth in aquaculture sectors can, in some cases, reduce fishing pressures on wild fish stocks. For example, the trade of reef fish is known to be a significant threat in both marine and freshwater systems (Moreau & Coomes, 2007; Nañola *et al.*, 2011; Pomeroy, Parks, *et al.*, 2006) but the promotion of local aquaculture and aquarium practices to rear target species has been shown to lessen pressure on coral reef systems (Pomeroy, Parks, *et al.*, 2006; Pouil *et al.*, 2020). Similarly, policies that promote dive tourism, in many cases have shown significant positive impacts both in terms of reduced pressure on wild stocks and increased total revenues for fishing communities that have switched livelihoods either full or part-time (Lowe *et al.*, 2019). In Mexico the recreational diving industry generates between 455-725 million United States dollars per year, whilst the wild capture fisheries sector that generates 700 million United States dollars (Arcos-Aguilar *et al.*, 2021). Direct comparisons of such total revenues are, however, crude because they do not account for total livelihoods, employment numbers and individual full time equivalent values, and therefore require more in-depth case-specific understanding.

Development policy that is designed to promote growth in non-fishing-related sectors is advised to account for the profitability and feasibility of the transition to any alternative livelihoods available. Without the correct economic incentives, particularly in developing contexts, such policies are often unable to successfully complete the transition to alternative livelihoods rendering them unsustainable and, in some cases, practically futile (Pham, 2020; Pomeroy, Ratner, *et al.*, 2006). Now, with an increased drive from the blue economy, the so-called blue revolution, it is important that such issues are considered. Although aquaculture or tourism policy has the potential to alleviate pressure from wild capture fisheries, without holistic approaches that account for more than just the theoretical economic gains and transfer of worker effort, the success of such policies over the long-term will likely remain limited. It should also be remembered that both aquaculture and tourism are economic activities that are heavily dependent on, and therefore vulnerable to, changing demand drivers outside the control of the local initiatives.

Whilst it is commonplace to assume practical answers to fishing-related problems will come directly from the fishing sector in the form of fishing tools, management and policy, the analysis of how non-fishing-related policy can and does impact the sustainability of fishing requires more attention. More concerted cross-sectoral awareness should also help mitigate the risk of policy implementation that benefits policy outcomes unrelated to fishing to the detriment of sustainable fishing. Considering the United Nations' Sustainable Development Goals interrelated framework (Singh *et al.*, 2018), it is surprising that more work has not been undertaken to formally analyze links between non-fisheries policy and fisheries. Combining efforts across sectors with the above ideas in mind will likely facilitate meeting more of the Sustainable Development Goals' targets. Moving away from single stroke policy efforts focused only on single targets will require considerable collaboration between traditionally unrelated sectors both in industry and in policy.

6.5.3 Rules and institutions that can constrain sustainable use

6.5.3.1 Overlooking available breadth of policy options

Across case studies from all practices most successful sustainable use outcomes involved a mix of policy instruments, highlighting the need for complementary and synergistic strategies in order to regulate and incentivize good practices. Although, across all practices, the use of legal and regulatory approaches dominates (see section 6.4.5, **Table 6.6**). Most successful cases in gathering exercised a mix of legal and regulatory policies along with social and rights-based instruments.

The main constraining condition in terrestrial animal harvesting highlighted through the case studies, and also reflected in the fishing case studies, was the focus of policies on a limited number of high value species or commercialized products. This focus led to policies that overlooked the diversity of species harvested and products commercialized. Indeed, five out of the six most successful cases in terrestrial animal harvesting involved reptile and big mammal species with a high demand in the international market and with a high revenue per harvested specimen. In contrast, for the remaining cases, the resource was highly abundant and the main market was national, with less lucrative economic returns. This strong connection between the market and policy, whereby the market determines the success of the policy creates a vulnerability, as if there are any changes in the patterns of international/national demand (fashion industries, changes in wild species use or food consumption habits, etc.), the income received by the communities, and therefore their welfare, could be at risk. Similarly, if prices are to shift, the stability of the harvest could vary. For example, if prices drop, there could be an increase in the harvest volume in order to maintain the same level of income.

The focus of hunting policies on a limited number of high value species also plays out in fisheries to limit the approaches considered available, resulting in an overemphasis on legal and regulatory instruments **(Box 6.10)**. Fisheries management approaches are heavily influenced by the data selected and available to guide assessments and as well as what is considered the bounds of the system of interest. Conventional fisheries management, which has predominantly emerged from evaluations of industrial fisheries from temperate regions of the Global North (Kolding & van Zwieten, 2011), has tended to focus on single species stock status assessments. Such industrial fishing is often (intentionally) highly size selective, yet it is increasingly acknowledged that this can lead to changes in body size, reproductive size, (which both negatively impact recruitment) and evolutionary effects (S. M. Garcia *et al.*, 2012; Jørgensen *et al.*, 2007). Possible

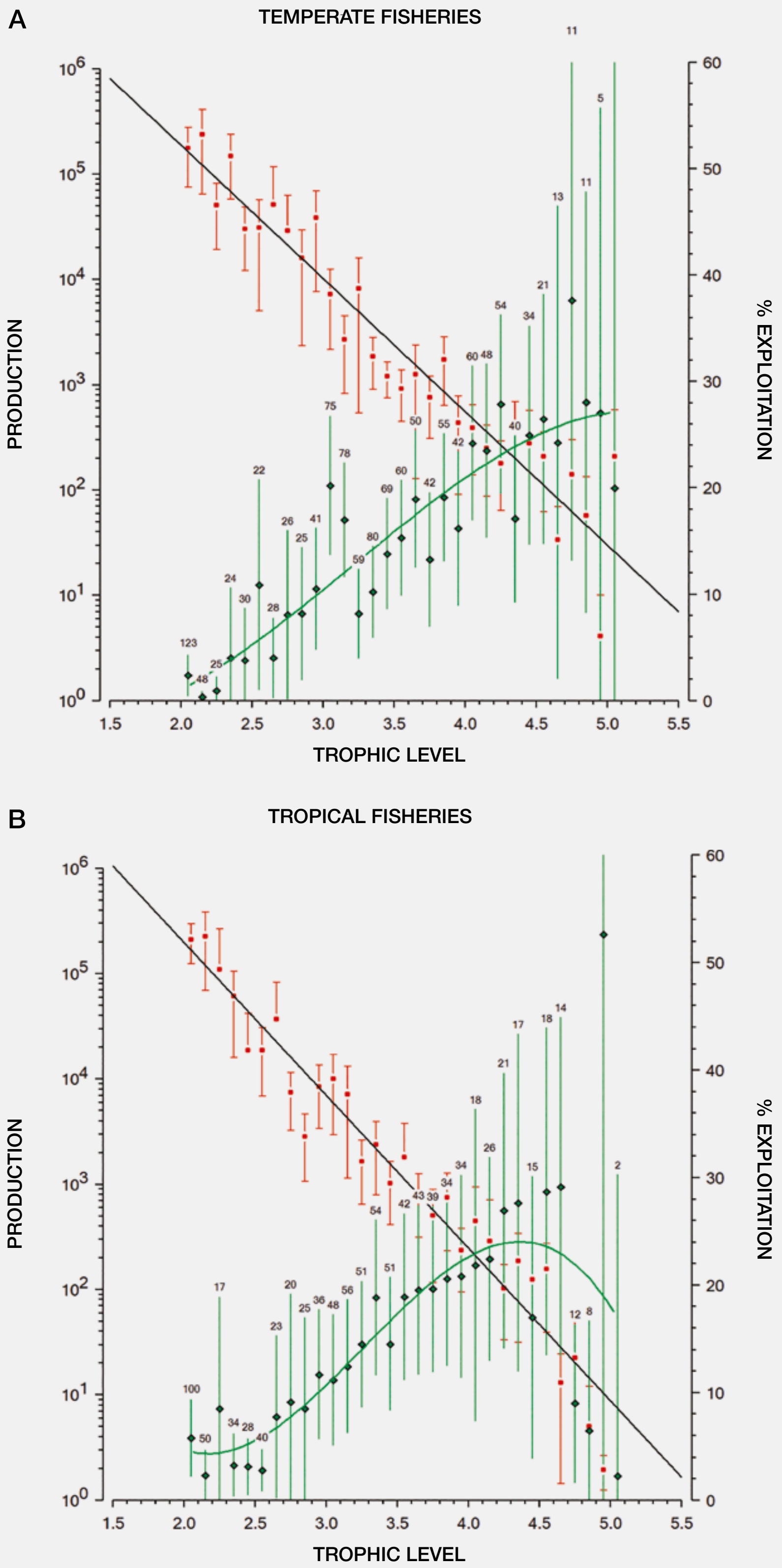


Figure 6 6 **Average global mass production (kg/km²) by trophic level with superimposed average percent exploitation ratio (catch/production).**

From (A) 47 Temperate and (B) 34 Tropical Ecopath models covering around 40% of the world's oceans (see data management report for the figure at https://doi.org/10.5281/zenodo.6453381).

management interventions include reducing harvest rates and selectivity (which only exacerbates the problem); refuges and protected areas; integrating trait-changes into management (Palkovacs *et al.*, 2018).

More recently, a number of alternative approaches and assessments have emerged, from a diversity of contexts, that emphasize broader changes in ecosystem structure. For example, balanced harvesting has been proposed as an alternative which would counteract both phenotypic and genetic consequences of fishing, as well as increasing overall yields **(Box 6.10)**. However, this approach has been mainly applied in theoretical studies or observed in small-scale inland fisheries, and no examples exist from large-scale fishing, except the overall findings that they are significantly unbalanced (Kolding, Bundy, *et al.*, 2016) **(Figure 6.6)**. One example seeking to illustrate the complexity of this endeavor in the industrialized Barents Sea fishery concluded the theory is great but in practice may be more challenging due to economic preferences and may require a pragmatic approach to implement only the most feasible aspects (Howell *et al.*, 2016; Zhou *et al.*, 2019). For less selective small-scale fisheries more aimed for maximizing food production, a balanced fishing pattern is feasible and can evolve organically **(Box 6.10)**.

A global assessment of fishing patterns and fishing pressure from 110 different Ecopath models, representing marine ecosystems throughout the world and covering the period 1970–2007, showed that human exploitation across trophic levels is highly unbalanced and skewed towards low productive species at high trophic levels, which are around two trophic levels higher than the animal protein received from terrestrial farming **(Figure 6.6)** (Kolding, Bundy et al, 2016). In contrast, exploitation levels from low trophic species represent <15% of total catches, while only 18% of the total number of exploited groups and species were technically overharvested (annual catches exceed >40% of the total annual production) (Pikitch *et al.*, 2012).

This work also compared temperate *versus* tropical fisheries, and found no difference in overall fishing pressure. However, while fishing pressure in temperate fisheries increased with trophic level, in tropical fisheries fishing pressure generally decreased at the highest trophic level, indicating a tendency to fish lower in the food web, where production, or species turnover, is also higher. These data further suggest that tropical fisheries, overall, are slightly more balanced (Garcia *et al.*, 2012) than temperate and that there is less evidence of general overfishing in the global South.

Another factor in the least successful terrestrial animal harvesting cases that has limited success in some cases is the lack of robust information (either traditional ecological knowledge or scientific knowledge) and of population and ecosystem monitoring. This is in part because terrestrial animal harvesting case studies tended to focus on harvested species, and as a result their effect on the habitat is not always taken into consideration, and much less their impact on broader nature's contributions to people, which is not considered in any of the evaluated case studies. The consideration of these three aspects could help gain a better and more integral understanding of ecological relationships and on how the policy instruments impact them.

Box 6 10 **Balanced harvest in Lake Kariba.**

Conventional fisheries management has been predominantly informed by fishing patterns in industrialized fisheries from the global north. These approaches, developed for single species fisheries that target high trophic level species that tend not to be very productive, focus on controlling inputs (e.g., effort) or outputs (e.g., total allowed catch or size of species) associated with the use of highly specialized and selective gears. The diversity of contexts in which fishing occurs has resulted in many instances in which conventional fisheries management has failed. As a result, alternate paradigms have emerged that question conventional logic and propose alternate approaches to fisheries management and governance. The contrast between conventional and alternate fisheries management paradigms have played out in Lake Kariba.

Lake Kariba, is a human-made lake on the Zambezi River in Southern Africa. The fisheries of Zambia and Zimbabwe, on opposite sides of the lake, have been subject to different types of management regimes. This situation creates a grand-scale ecological laboratory that can be used to study the impacts of exploitation. It offers a unique test of a well-managed system, in the conventional sense, against an open access "laissez faire" situation, which is conventionally believed to result in collapse and the tragedy of the commons (Kolding & van Zwieten, 2011).

Long-term data (1960–2000) collected from both sides of the lake have shown the unmanaged system in Zambia to evolve into one reflecting a 'balanced harvest' approach where all species and sizes are harvested in proportion to their productivity (S. M. Garcia *et al.*, 2012). The Zambian inshore fishery, with open access and no enforcement of regulations, has gradually experienced a much higher fishing intensity and a changed fishing pattern towards increasingly smaller mesh sizes resulting in a higher exploitation level and reduced stock sizes. However, the yields, per unit area, are 6 times higher, than in Zimbabwe while the ecological impacts in terms of demographic structure and relative species abundances are minimized (Kolding, Jacobsen, *et al.*, 2016).

Box 6 10

In contrast, the Zimbabwean side, where conventional tools of management regulations, controlling effort and enforcing minimum mesh limitations, have been implemented, have resulted in fishing pressures and fishing patterns, that while fluctuating due to environmental variation, have not changed much over time (Kolding & van Zwieten, 2012). The overall fishing effort, in terms of number of nets, is about seven times higher in Zambia than in Zimbabwe. However, the average artisanal catch rates are more similar (1.8 and 2.8 kilograms per net in Zambia and Zimbabwe respectively) and this is because the Zambian fishers are using small mesh sizes on average.

Thus, by ignoring mesh size regulations, the Zambian fishery appears to produce a high sustainable yield, in accordance with the United Nations Convention on the Law of the Sea (1982), while maintaining the relative fish community structure, in accordance with the Convention on Biological Diversity (1992). These positive counter-intuitive results of non-compliance evolve by a rational individual response to the open access regime. When effort grows in the open access Zambia fishery, and catches per unit effort decreases **(Figure 6.7 B)**, it is a logical and necessary reaction of individual fishers to gradually decrease some of their mesh sizes **(Figure 6.7 C)** to maintain an acceptable catch rate. The range of mesh sizes and their relative abundance will eventually be proportional to their individual catch rates, which becomes an ideal free distribution (Plank *et al.*, 2017) **(Figure 6.7 D)**, where all species and sizes are harvest in accordance to their productivity and thus maintains the overall size-structure of the fished fish community compared to an unfished situation **(Figure 6.7)**.

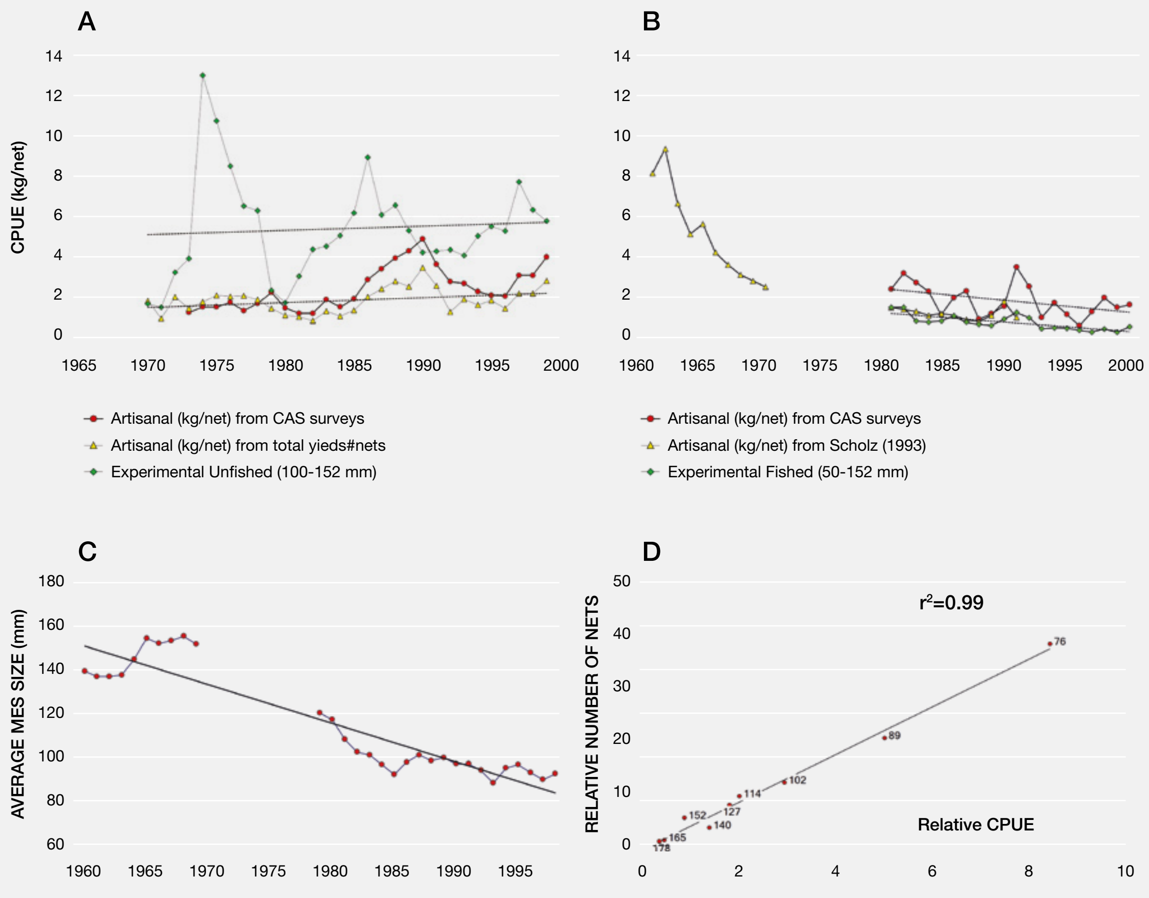


Figure 6 7 **The inshore fishery in Lake Kariba.**

(A) Catch rates in the regulated Zimbabwean fishery. (B) Catch rates in the open access Zambian fishery. (C) Average mesh sizes in the Zambian fishery between 1960 and 1999. As capture per unit of effort decreases with time, so does the mesh sizes. (D) Relationship between relative number of nets (mesh range 76-178 mm) and relative capture per unit of effort per mesh size in the Zambian fishery. The strong relationship indicates an ideal free distribution where the fishing pattern is proportional to productivity, which results in balanced harvest **(Figure 6.8)**. (A) and (B) from (Kolding, Jacobsen, *et al.*, 2016) under license CC BY 4.0, See data management report for the figure at https://doi.org/10.5281/zenodo.6453483

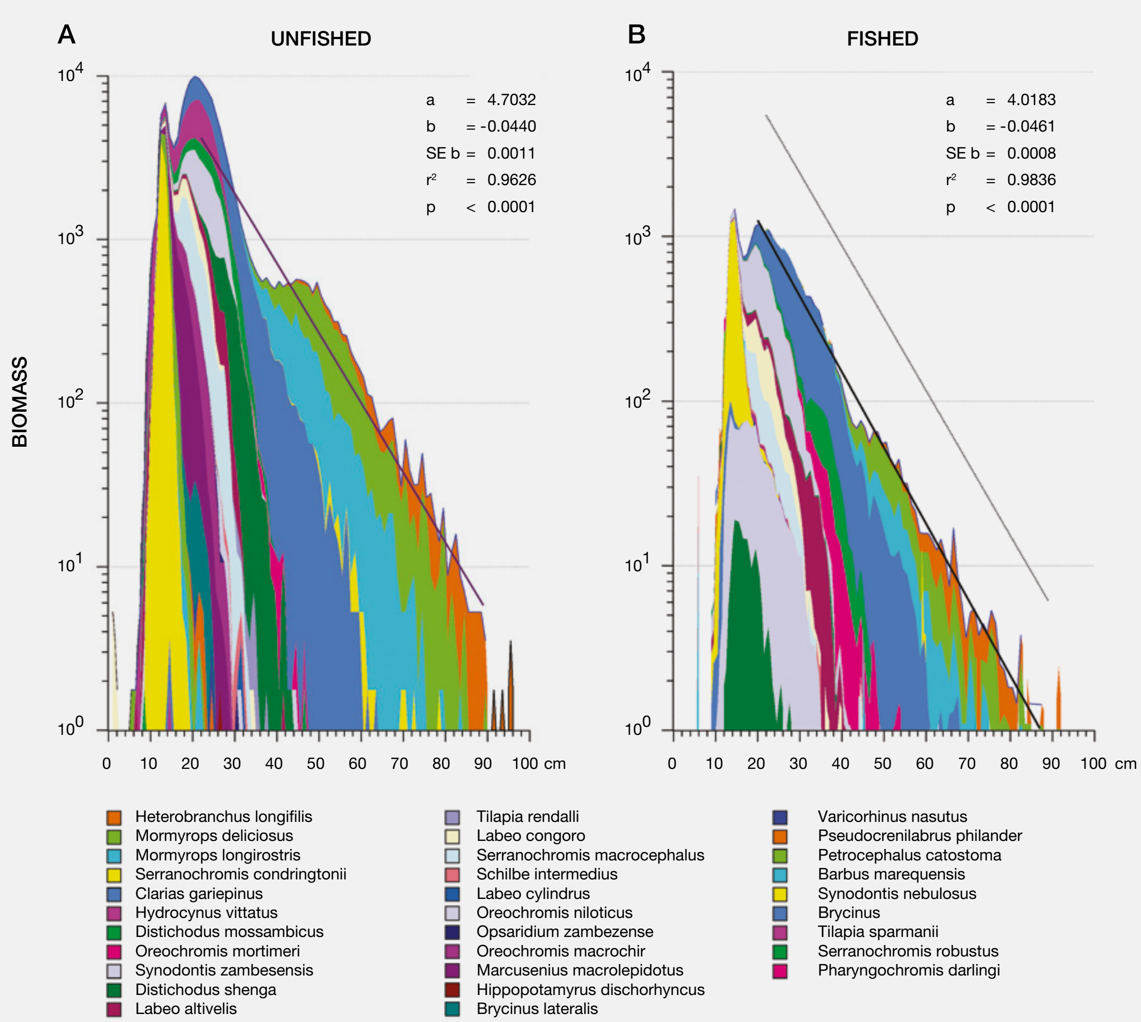


Figure 6 8 **Standardized biomass-size distributions in Lake Kariba from experimental fishing surveys 1980–1994.**

(A) unfished area, Zimbabwe; (B) heavily fished Zambian fishing grounds. No significant difference between the slopes (regression lines) of the unfished (dashed) and the fished (full) community indicates a significantly lower standing biomass but equal relative species and size compositions in the fished area evolving into a balanced harvest fishing pattern from the dynamics illustrated in **Figure 6.7**. Source: (Kolding, Jacobsen, *et al.*, 2016) under license CC BY 4.0.

6.5.3.2 Overlooking social context

The most successful cases are those that monitor and consider all sustainability domains (social, economic, and ecological) and that implement adaptive management based on these considerations. However, in many instances social dimensions of sustainable use are often overlooked. Of the five most successful terrestrial animal harvesting case studies, ecological outcomes have tended to be a focus; however, these cases have also managed to focus on social outcomes. In contrast, the least successful cases are characterized by a lack of balance between the three domains of sustainable use (economic, ecological and social). For these cases, one of the domains is typically favored over the others, which has proven to be inefficient. In such cases, public policies can even become counterproductive and lack proper implementation, which discourages sustainable use. A clear example of this situation is that the only case with good economic outcomes does not consider the social dimensions of the activities carried out.

Reflecting these patterns and drawing on the 84 case studies examples from the chapter's adapted systematic review, examples of effective sustainable use policy most often reflect economic or ecological success, and were most likely to reflect social losses **(Table 6.8)**. For example, total Allowable Catch (TAC) and Individual Transferal Quota's (ITQ) that limit overfishing, result in improvements to stock status and economic efficiency (Donkersloot & Carothers, 2017; Edwards & Pinkerton, 2019a, 2019b; Kroetz *et al.*, 2015; Pinkerton & Edwards, 2009). Reviews of fisheries status and performance of conventional fisheries management have a similar focus on ecological effects over economic and social effects, with economic factors often playing a stronger role (Hilborn *et al.*, 2020; Melnychuk *et al.*, 2021).

The most common negative outcomes were found in the gathering cases which appeared across all sustainability domains (social, economic, ecological) **(Table 6.8)**. This is in part, because legal and regulatory instruments were found to be most commonly applied to high value species within gathering, where these policies are vulnerable to market fluctuations and thus tend to be less effective than other options. In several cases of gathering, overharvesting was not controlled by national regulations, such as penalty and permit schemes, and resulted in a loss of species and habitat degradation (Chatterjee *et al.*, 2011; Wallrapp *et al.*, 2019). Excessive harvest of wild plants can lead to a decline of resources such as lichen (Chatterjee *et al.*, 2011; Gokhale & Negi, 2011). In contrast, the logging cases reflected a higher proportion of cases with both positive and negative outcomes than other practices, suggesting logging cases simultaneously exhibit successful and unsuccessful outcomes within a sustainability domain, associated with the adopted policy instruments, such as Forest Stewardship Council certifications.

The most commonly ineffective terrestrial animal harvesting policies (the majority of least successful case studies) involved prohibitions (e.g., bans) on the use of wild species imposed unilaterally by government authorities (hierarchical government context). These referred to specific prohibitions not related to those implied in some natural protected areas where harvesting is frequently prohibited, but which have proven to be successful conservation instruments. This is likely compounded by the fact monitoring seems to be stronger when there are government authorities involved. However, the ecological domain is usually the one more closely monitored (particularly the hunted species' population status); as opposed to the social and economic domains which are not always fully evaluated.

6.5.3.3 Overlooking customary practices, rights & indigenous and local knowledge

Even where there are clear statutory provisions, lack of knowledge or enforcement of tenure laws, or poor governance in general, can leave people vulnerable to violations of their rights (Springer & Campese, 2011). For example, in Bolivia, small-scale gathering producers maintained strong *de facto* control over the resource base for decades through a customary system of tree tenure. Access rights were based on rubber trails and later, when Brazil nuts became important, on access to Brazil nut

Table 6 8 **Policy effectiveness of economic, ecological and social sustainability (N=84).**

The darkness of color represents relative strength of positive or negative outcomes within each practice judges against. The color has three levels. Hatched cells mean that the practice has over 15% of the cases of both positive and negative effectiveness. The relative distribution of positive and negative effectiveness was divided into trisection with color darkness. The value of positive effectiveness has three ranges; over 75% (dark green), between 75% and 57% (green), under 57% (light green). The value of negative effectiveness has three ranges; over 25% (dark red), between 25% and 8% (red), under 8% (light red). See the data management report at https://doi.org/10.5281/zenodo.4663236).

Practice	Economic sustainability		Ecological sustainability		Social sustainability	
	Positive	Negative	Positive	Negative	Positive	Negative
Fishing						
Gathering						
Terrestrial animal harvesting						
Non-extractive practices						
Logging						

trees *(Bertholletia excelsa)* and related infrastructure. All these activities operated in the absence of statutory policy. However, in 1996 the Brazilian government introduced an Agrarian Reform Law that superimposed a new layer of rights over the region's forests by allocating logging concessions which led to conflict. Conflicts were further exacerbated when well-intentioned efforts to modify the 1996 Agrarian reform law to expand the size of land grants to more communities further undermined customary tree tenure arrangements. Land reform gave smallholders formal recognition of their tenure rights, but by basing it on control of contiguous territory (allocating each family 500 ha), it undermined the effective traditional tenure arrangements and access rights based on key resources (once rubber, and now Brazil nut trees) (Cronkleton & Pacheco, 2010; Stoian, 2005).

Traditional resource management systems can thus enable greater community participation. However, in many instances these customary systems have been bypassed resulting in sustained conflicts with communities (McClanahan *et al.*, 2005). For fishing in coastal Kenya is partly regulated by a largely successful network of marine protected areas, with the exception of one park that remains a paper park. This failure was largely due to a lack of communication and collaboration between resource users, managers, customary and statutory systems of governance. The failure to engage with local actors, recognize, and respect the local customary context became the cause of mistrust, leading to serious conflict, violence, and slow implementation of management (McClanahan *et al.*, 2005).

The challenge of developing environmental outcomes acceptable to stakeholders with different values is required as it affects decision making. A turtle and dugong hunting management plan was developed by the Hope Vale aboriginal community in the great barrier reef world heritage area, Australia. The discourses of the environmental managers and community members were very different. Hope Vale's primary discourse was based on the assertion of the superiority of "traditional" cultural knowledge over western science, while the management agency discourse was based on the presumed superiority of the scientific discourse. This imbalance reflects inequity within both the power and knowledge arenas. Hope Vale people prioritized cultural well-being; the staff of management agencies prioritized biodiversity outcomes. Hope Vale participants conceived traditional hunting as the apex of their contemporary expression of traditional culture because a hunt is the physical manifestation of a cultural right and an ancient tradition.

The importance of the practice was not diminished by the realities that: (i) hunters may not now need the meat to survive; (ii) green turtles and dugongs might not be found and caught; and (iii) some cultural methods and cultural weapons have changed or are no longer used. Thus, hunting culture is about relationships with country, place, clan estates, and the associated responsibilities that those relationships bring: a palimpsest of the indigenous knowledge domain as exemplified by the following quote: "Traditional Hunting? Well, it's us. It's our culture. It's who we are. Well, it is just in the blood I suppose. It is like, like it is carried on from the Elders and like we grew up, the Elders showed us and we know the skills now we show our nephews, our sons, and our daughters, show them those skills. We got to keep all them things alive, no matter what techniques we use, it's still our traditional culture today" (Nursey-Bray *et al.*, 2010).

These differences precluded effective outcomes despite considerable investment in hunting management over more than 20 years by both groups. Understanding the discursive terrain within environmental management domains can inform environmental decision making and the implementation of agreed management arrangements, enabling biodiversity objectives and indigenous cultural aspirations to be met in a socially just, economically viable, and environmentally sustainable way (Nursey-Bray *et al.*, 2010).

Unimplemented policy measures can be worse than no measures. In some cases, they weaken traditional structures that might better promote sustainable management or equity in trade; even cursory government regulation of wild algae, plants and fungi can undermine community institutions and control over resources (Arnold & Pérez, 2001; Michon, 2005). Confusion, conflict and corruption can also result when laws are unclear or unenforced, making the lives of producers, harvesters, and traders more difficult and encouraging unsustainable harvests of species (Arquiza *et al.*, 2010; Laird *et al.*, 2010; Ndoye & Awono, 2010).

Within the gathering cases reviewed, co-operation and sharing of rights and responsibilities emerged as key enabling conditions. Effectiveness was particularly noted among the community led organizations and government authorities that followed institutionally-mixed resource governance systems and where there was multi-level interaction as well as shared responsibilities and rights among different institutions and actors.

Successful examples of gathering case studies involved the integration of biodiversity conservation into livelihood development, recognized both indigenous knowledge and scientific knowledge, and brought together natural sciences with social sciences for better outputs. Integration of ecological and socioeconomic factors and different knowledge systems provided effective solutions. In one case study on wild mushrooms (Yunnan, China) the promise of economic and ecological benefits motivated the provincial government to scale up the adoption of appropriate technologies and catalyzed their willingness to further invest in participatory action research.

Awareness of the relationship between human rights, conservation, and the rights of indigenous peoples and local communities has grown. This growth has also brought increased scrutiny of the impacts that protected areas can have on rural communities – such as evictions and lost access to natural resources (Roe, 2010). Increasingly, it is understood that conservation and a quality environment are fundamental to realizing human rights – particularly where indigenous peoples' and local communities' livelihoods and wellbeing depend on ecosystem goods and services. It is generally recognized that conservation approaches are strengthened by adopting principles and standards related to human rights and mechanisms to monitor and enforce adherence to them (Järv *et al.*, 2021). The benefits of integrating human rights concern into conservation practice include improved security for local and indigenous communities, as well as more effective and sustainable conservation.

Building robust opportunities for indigenous peoples and local communities to be heard and to exercise their rights at all levels is critical in promoting more effective and equitable strategies of wild species conservation. Rights of indigenous peoples are often particularly relevant for conservation and sustainable use of natural resources, due to the frequent overlap of high-biodiversity areas and indigenous lands, and the vulnerability of natural resource-dependent customary livelihoods to changes in access or use. Indigenous peoples' traditional ecological knowledge, traditional systems of control, use and management of lands and resources, and traditional institutions for self-governance also contribute to conservation substantially **(Box 6.11)**.

In the successful terrestrial hunting cases, the main enabling condition was that resource use is implemented as part of the indigenous peoples and local communities' culture (i.e., respect to local culture) and is based on traditional ecological knowledge. In these cases, indigenous peoples and local communities are organized around the use of the resource, and national and international regulations have acted as levers to reinforce good practices of local management. The resource under use has a healthy population level and, based on traditional ecological knowledge and scientific information, use has not been detrimental. One factor that has boosted the continuation of the long-term use in the most successful cases is a multi- stakeholder approach around the process (indigenous peoples and local communities, non-governmental organizations, government, hunters, etc.).

Indeed, there is ample evidence of a link between taboos and sacrifices and resource scarcity of ritual plants. In Benin (West Africa), the use of 63 of the 414 ritual plant species was restricted; while in Gabon (Central Africa), 23 of the 256 ritual plants were associated with taboos and sacrifices. In Benin, restricted plants were significantly more often officially threatened, perceived as scarce, and actively protected than non-restricted plants. In the more forested and less densely populated Gabon, plants that were perceived as scarce were more often associated to local restrictions than officially threatened species (Quiroz & van Andel, 2015).

Colding and Folke (1997) analyzed the role of taboos for the protection of species listed as "threatened" by the International Union for Conservation of Nature, and also for keystone and endemic species. The study was limited to specific-species taboos that totally avoid or prohibit any use of particular species and their populations. It was found

Box 6 11 **Aspects of indigenous rights especially relevant in conservation contexts.**

Source: (Springer & Campese, 2011) under license CC-BY.

- Rights to traditional lands, territories and resources – including the "right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources."
- Rights to self-determination and to free, prior, and informed consent – Self-determination is a collective right reflecting indigenous peoples' status as distinct peoples. United Nations declaration on the rights of indigenous peoples establishes (Article 19) that "States shall consult and cooperate in good faith with the indigenous peoples concerned through their own representative institutions in order to obtain their free, prior and informed consent before adopting and implementing legislative or administrative measures that may affect them."
- Rights to control and management of lands and resources – through customary institutions and laws.
- Rights to development and equitable benefit-sharing – including to determine the development or use priorities and strategies on their lands, territories and resources and to benefit equitably from conservation and sustainable use of such areas and resources.
- Rights to traditional knowledge and indigenous heritage – redress United Nations declaration on the rights of indigenous peoples includes provision for redress for deprivation of indigenous peoples' means of subsistence and development, and for lands taken without free, prior, informed consent.

that around 30% of the identified taboos prohibit any use of species listed as threatened by the International Union for Conservation of Nature. Of the specific-species taboos, 60% are set on reptiles and mammals. In these two classes, around 50% of the species are threatened. Both endemic and keystone species that are important for ecosystem functions are avoided by specific-species taboos. Specific-species taboos have important ecological ramifications for the protection of threatened and ecologically important populations of species.

Similarly, in the dry forest of southern Madagascar, a region of global conservation priority, the continued existence of unique forest habitats in the Androy region is directly dependent on informal institutions, taboos, which regulate human behavior and ensure the continued existence of the forest patches and their associated biodiversity. For example, in southern Androy, 90% of the total remaining forest cover is protected through taboos; these informal institutions represent an important, and presently the only, mechanism for conservation of the highly endemic forest species. The social organization of rural Madagascar is a blend of the fanjakana, the formal institutions of Malagasy society, and the fokonolona, traditions and customs such as the clan leadership structure and taboos. The taboo or faly, meaning forbidden or "you shall not", is a component of the laws inherited from the ancestors. Respect and reverence for the ancestors and other spirits requires the Tandroy to follow the prohibitions of the faly. In southern Androy, analyses were made of taboo forests with strict restriction for human access and use, ala kibory; taboo forests with some restrictions on human use, salata; and public forests with few restrictions on human access and use (Tengö *et al.*, 2007).

The failure to recognize historical rights and practices of gathering wild species as an important livelihood in legal and regulatory policies widens the gap between community and government bodies within gathering case studies reviewed. Similarly, building on or complementing traditional resource rights in gathering wild species was an important approach to minimize paperwork, avoid duplication of existing laws and enhance sustainable use. This requires real commitments of time, money, research, and extensive stakeholder consultation.

The combination of scientific and customary knowledge can be particularly powerful. In rights-based instruments, community-based management is significant in all practices where diverse forms of knowledge are integrated. For example, in the gathering case study in China (J. He *et al.*, 2011), villagers used scientific data to formulate mushroom management practices to obtain the best production including sustainable harvesting. Tilling and debranching was conducted to reduce canopy density to 0.6 (canopy density is dense between 0.7 and 1.0). The litter depth was managed through adding or removing the litter to reach 2 to 4 cm. Farmers took information as critical criteria for targeting the areas where intensive management should be applied. In targeted areas, most of the households invested in installing a field guardhouse to stay overnight during the mushroom season to monitor the mushrooms. The improved harvesting technique has enabled better quality and higher quantity of mushroom gathering.

6.5.4 Power dynamics can impede sustainable use

6.5.4.1 Power imbalance

Bureaucratic hierarchy, power dynamics, conflicts and struggles between formal and informal governance arrangements are common in practices involving the use of wild species. Therefore, understanding the power dynamics and the alignment of objectives between stakeholders prior to policy formulation and implementation is likely to enhance the effectiveness of policies. However, understanding the influence of power requires comprehending a vast array of factors, from top-down state control, to the more dynamic and relational influences of economic value, ownership, and knowledge.

Power dynamics have a crucial influence for high value fish, plants, and fungi that have a significant international and national market demand. All actors (government, community, intermediaries and distant collectors) involved in using wild species have an interest in receiving benefits from high value wild species. An increase in market demand and price of wild species modifies access demands of all actors that in turn can trigger power struggles and conflicts. Gathering case studies found that policies that reduce monopolistic tendencies in wild plant and fungi markets are important but need to be implemented so that all stakeholders are supported along the value chain in a way that does not set them against each other. With shifts in corporate culture towards sustainability and equity there is increasing scope for reducing the length of value chains to alleviate state capacity constraints and improve producer income. Interventions that target gathering of wild species should thus not ignore malfunctioning market mechanisms and should implement other forms of assistance to complement certification, especially those that stabilize income sources to ensure sustainable use.

Policy action can result from both top-down processes, or through bottom-up processes made through customary systems of governance including contemporary cooperatives, such as is evident in the Baja California cooperatives (Mexico). In situations where the state has a strong say, even if along with a few other actors, acting to protect the State's interests or that of their allies, can result in other actors' interests being outweighed, ultimately undermining the sustainable use of wild species. This has been found to be particularly problematic where a clientelist network has formed, wherein goods and services are exchanged for political support, and the government is unable to respond in an unbiased and pragmatic way **(Box 6.12)**. The over dominance of the influence of the state can also be an issue for marginalized groups, such as indigenous communities and their rights. For example, indigenous communities including the Torres Strait islanders and the Sami were forced to take their governments to court to maintain their constitutional rights to fish (Lantto & Mörkenstam, 2008).

In instances where nations' national governance is weak, and the state has less power to start with – respective to other governance institutions, a power void may become filled in ways that undermine sustainable use. In general, effective and equitable co-management that empowers actors to participate on equal grounds can help equalize unequal power dynamics. For example, in the Amazonian case, local communities who successfully managed pirarucu acquired a greater sense of pride as their story became well known and spread **(Box 6.5)**. Similarly, where a legally pluralistic situation exists and customary rules are recognized, such as in the Madagascar fishing case (octopus fishing case study),

Box 6 12 Forest Stewardship Council (FSC) certification and state-dominated forestry – Belarus and Poland.

Belarus and Poland have the third and fourth largest areas of certified forest in Europe (FSC, 2021) but their experiences with implementing the Forest Stewardship Council process differ considerably. Belarus' implementation was smooth whereas Poland's mired in conflict, ultimately resulting in closing of the Forest Stewardship Council national office (Jabłoński, 2015). Both countries have strong, centralized governance structures, with forestry practices highly regulated and considerable capacity to sustainably manage the almost entirely state-owned forests. Both countries were interested in Forest Stewardship Council certification because of the improved access to international markets certification affords. Certification also made sense because of the scale of the operation and concentrated state forest management and ownership. Despite many structural similarities, the reaction of the governments differed due to different policy and historical contexts, resulting in vastly different outcomes.

In Belarus, the state was firmly in charge of forest policy and forest administration (Forest Europe, 2020), while non-governmental organizations were relatively weak and mostly ignored (Dawson *et al.*, 2021). The status quo was characteristic for bureaucratic policy networks with state domination, formal, hierarchical arrangements and mandated regulations. However, the government was also a sole owner of forests and had an economic stake in Forest Stewardship Council certification connected with large multi-national clients, potential increase in exports and price premiums. This motivated the government to organize conditions for a possibly frictionless implementation of the Forest Stewardship Council and left little room for power-play between foresters and conservationists. Public organizations did not appear to pressure non-states, and the actors involved (auditors, forest management units and non-governmental organizations) exhibited constructive interactions. Environmental non-governmental organizations were satisfied with the process and its outcomes, which strengthened their role as participants of decision-making processes and increased input legitimacy of the scheme. The facilitatory role of the state allowed for some adjustment of legal rules to the Forest Stewardship Council principles. Additionally, past conservation conflicts in forests were addressed in line with conservationists' suggestions. Nevertheless, the legitimacy of the Forest Stewardship Council rests solely on the pragmatic support of the state and could easily collapse if the support is withdrawn. A genuine (i.e., not moderated by the state) actor interest and consensus would be needed for making the Forest Stewardship Council arrangements sustainable in a long-run (Niedziałkowski & Shkaruba, 2018).

In Poland, the policy network in forestry practice was similarly top-down and bureaucratic but it also displayed characteristics of a clientelist network, wherein goods and services are exchanged for political support, (e.g., between the public forest agency and state forest holding) and had a quasi-corporate status with considerable financial and organizational autonomy (Blicharska *et al.*, 2020). The state's forest policy was shaped by state forest holding, which also benefited from it enjoying a monopolist position in the internal market (Forest Europe, 2020), which suggests a mechanism of "agency capture". Still, on several occasions, including nature conservation conflicts and financial relations between the government and state forest holding, the interests of the government and state forest holding clashed. Existing formal rules, securing the privileged position of state forest holding and limiting impact of non-state actors, were brought up by foresters to undermine unwanted stipulations of the Forest Stewardship Council. The Polish government, unlike Belarusian, did not attempt to adjust those formal rules or to press State Forest holding to comply. Foresters protected their management paradigm and perceived conservationists as competitors over forest resources (Blicharska *et al.*, 2020). Apart from treating the Forest Stewardship Council as a market instrument, foresters also perceived it strategically – first as a way to dismiss non-governmental organizations' criticism, and later mainly as non-governmental organizations' attempt to undermine forest practices of State Forest holding and to strengthen negatively perceived preservation. Consequently, foresters accepted new rules only to the extent they did not change established assumptions and practices (Niedziałkowski & Shkaruba, 2018).

regional management can be formalized by government at a later date, resulting in the bottom-up implementation of policies and more successful outcomes. In this case, the local Vezo community in Madagascar were also more empowered – economically, and perhaps also in being ahead of the government regulations.

In contrast, ill thought through policies, in certain contexts, have been shown to create or exacerbate unequal power dynamics between actors, such as the cases of halibut individual transferable quotas fishery (see **Box 6.6**) and the Lake Victoria Nile perch fishery (see **Box 6.15**). Individual transferable quotas were shown in the example of halibut fisheries **(Box 6.6)** to cause a more unequal distribution of benefits. These systems were found to remove power from the owner-operators who conducted fishing activities, but who were dwindling in numbers, in favor of patterns of investment that lease permits and contributes to the corporatization of the fishery and concentration of power in the hands of a few actors.

Box 6 13 Uncertainty or lack of knowledge can undermine sustainable use: Atlantic bluefin tuna case study.

Atlantic bluefin tuna has been sustainably exploited for two millennia by various traditional fisheries (Ravier & Fromentin, 2001). As for many other fish stocks worldwide, the development of modern and more industrial fisheries occurred after the Second World War in both the North Atlantic and the Mediterranean Sea and took the lead on the traditional fisheries (Mather *et al.*, 1995). The rise of the sashimi market during the 1980s generated a new and strong demand for fresh Atlantic bluefin tuna from Japan, resulting from an increasing domestic demand, but also from the overfishing of the southern bluefin tuna stock, which used to be the main source of fresh tuna for the Japanese market (Polacheck, 2002). Consequently, the value of Atlantic bluefin tuna increased and became, in the media, the fish that was worth its own weight in gold (as shown by the New Year auction of the Tsukiji fish market where a single bluefin tuna can be sold up to 3 million United States dollars).

The growing value of Atlantic bluefin tuna has led to a sharp increase in the fishing efficiency and capacity of various fleets as well as the entrance of new storage technologies and farming practices. This severe and uncontrolled overcapacity also due to deficient governance at both international and national levels generated a critical overexploitation of the resource and a severe problem of illegal catch (Fromentin & Powers, 2005). The management failure of Atlantic bluefin tuna at that time was partly due to the multilateral nature of the International Commission for the Conservation of Atlantic Tunas (which is the regional fisheries organization that has in charge to monitor and manage tuna and tuna-like species of the Atlantic Ocean) and to a decision-making process based on consensus. Indeed, conflicts of interests between the numerous countries that fished Atlantic bluefin tuna impeded strong decision-making, especially to limit catches. Furthermore, as Atlantic bluefin tuna market was highly profitable, economic interests took precedence over conservation-based ones, which is an unfortunate but quite common situation (Aps *et al.*, 2007).

The International Commission for the Conservation of Atlantic Tunas' scientific body had alerted the International Commission for the Conservation of Atlantic Tunas management body about critical Atlantic bluefin tuna stock status in the 1990s, but the scientific advice had little weight against fisheries lobbies, which were most influential at maintaining high catch levels. In particular, questioning the Atlantic bluefin tuna scientific advice through the issue of uncertainty has been commonly used by different lobbies that wished to push their own agendas. During the 2000s, the environmental non-governmental organizations became, however, more powerful and efficiently used communication tools to call the attention of the public to the poor stock status of Atlantic bluefin tuna (Fromentin *et al.*, 2014).

Following public interest, managers started to pay more attention to the scientific advice and implemented a first rebuilding plan in 2007, which was reinforced in the following years. The final Atlantic bluefin tuna rebuilding plan was ambitious, including the reduction of the fishing season for the main fleets, an increase in the minimum size, new tools to monitor and control fishing activities, a reduction of fishing capacity and of the annual quota (Fromentin *et al.*, 2014). It was also strictly enforced and rapidly led to the rebuilding of the Atlantic bluefin tuna population. Although the scientific advice is impaired by unquantified uncertainties, all of the latest scientific analyses clearly showed that Atlantic bluefin tuna is not overfished anymore and that the stock size is strongly increasing (ICCAT, 2017).

The Atlantic bluefin tuna case clearly shows that effective management of international fisheries that exploit highly valuable species that have been overexploited for decades is possible when there is strong political will. It also shows that uncertainty that is inherent to any scientific advice is also a source of misunderstanding (sometimes manipulation) between scientists and managers for whom uncertainty often means poor advice. Furthermore, these uncertainties can be weaponized by powerful political lobbies, whether intentionally or not, to advance a particular cause. Like in all scientific fields, fisheries scientists cannot provide certainties, but only probabilities and sometimes a consensual interpretation. More science is thus needed to deliver less uncertainty and better management recommendations (Mäntyniemi *et al.*, 2009), which is a pre-requisite to long-term sustainable use.

Indeed, when ownership changes so do power relations, altering system dynamics. For example, when The Nature Conservancy bought fishing licenses in the California United States of America case (Californian groundfish/trawling) (Gleason *et al.*, 2013), this conservation non-governmental organization had a very different seat at the table than before when it was 'only' an activism voice. In addition, the fishery had already been worn down (and declared a 'disaster') making space for change and this may also have given more power to this new actor bringing in innovative ideas.

In addition to state and ownership power, knowledge can be weaponized for influence. Ecological knowledge applied and generated from a management framework is a significant condition for designing policy instruments for sustainable use of wild species. When the species' ecology is well understood, and management scenarios are taken into account, these make for relatively high predictability of species population dynamics and also predictability and reliability of the anticipated impacts of management action (Scott & Seigel, 1992; Webb, 2015). The Baja California (Mexico) fishing case study with its fairly sedentary or habitat-attached benthic species (abalone, lobster) strongly highlighted this factor (McCay, 2014). When, on the other hand, there is high uncertainty in the understanding of a stock dynamic, this can make for lots of room for interpretation as well as doubt about the (necessity for and) anticipated effects of particular management action. This uncertainty and doubt can also be weaponized by actors from both sides of the spectrum between prioritizing use and conservation. This was the case in the Atlantic bluefin tuna case study (Fromentin *et al.*, 2014) (see **Box 6.13**) where first governments in the International Commission for the Conservation of Atlantic Tunas were using scientific uncertainty to delay action for protection, and later, when the tuna rebuilding plan had shown successful effects, some non-governmental organizations used the same tactic to try to prevent increase in fishing quota again.

Gender, or rather locally prevailing patriarchal power dynamics were highlighted in, e.g., Madagascar (octopus fishing case study) as playing a role in maintaining women fishers in a less influential position with regards to influencing fishery decision making and exercising their human rights overall. One of the positive aspects of the Pacific halibut case study's individual transferable quotas transition was the government repatriating fishing rights to First Nations, thereby also empowering these communities.

6.5.4.2 Neglecting history

Understanding the historical context, and learning from the past, is critical to supporting effective sustainable use policies and avoiding conflict. For example, although a range of factors contributed to the relative success of how Norway handled the 1989 Northeast Arctic cod fishery crisis in comparison to how the The Northern cod fishery crisis was handled in Canada around the same time (1992). The fact that the Norwegian government was able to learn from the historical collapse of the Norwegian herring fishery in the late 1960s and early 1970s placed it in a better position to rapidly respond, furthermore it had developed though this history better conflict resolution mechanisms, had learnt the limits of the oceans, and there was a greater trust in science **(Box 6.14)**.

Box 6 14 **Crises and (lack of) transformation towards sustainability – The case of Atlantic cod.**

Atlantic Cod, *Gadus Morhua*, is one of the most commercially important marine species on this planet, with 1.2 mil tons landed in 2018 (FAO, 2020). Atlantic cod comprises 27 different stocks, most of them having been fished for thousands of years. Only from the 1950s on, when offshore trawling was adopted widely, biomass levels declined and first signs of unsustainable use became visible (D. G. Webster, 2015). Even in light of growing awareness that persistent overexploitation may undermine the viability of the population and may trigger a fish stock collapse, transforming fisheries towards a regime of sustainability can be difficult in practice (Hilborn, 2007). Using the Northern cod fishery in Canada and Northeast Arctic cod in Norway as cases, we illustrate several key factors that play an important in facilitating or impeding sustainable use. First, even though fishing pressure is a key driver, it will always act in concert with various other drivers, such as climatic changes, which will determine the size of the fishing pressure that is sustainable (Hilborn & Litzinger, 2009; Winter *et al.*, 2020). Second, scientific evidence is usually incomplete and sometimes gives an incoherent picture of the state of the stock and which actions would be required to ensure sustainability (Finlayson, 1994). Building a solid knowledge base, rooted in fundamental science, and a clear separation of scientific advice from the policy process are important to facilitate sustainable utilization of fisheries resources (Winter & Hutchings, 2020). Third, notwithstanding how clear and complete the science advice may be, the policy process may be unresponsive, slow, or dysfunctional, each possibly making management responses avoided or delayed (C. J. Brown *et al.*, 2012; Scheffer *et al.*, 2003).

The Northern cod fishery in Canada is a widely cited example of a resource collapse due to unsustainable exploitation (Haedrich & Hamilton, 2000; R. A. Myers *et al.*, 1997; Rice, 2006). In 1992, when biomass levels where less that 1% of their historical peak, a moratorium was implemented. The end of the cod fishery caused also economic and social hardship in the local communities. Until today, the stock has not fully recovered. What caused this unprecedented resource collapse and could it have been prevented? Going back in time, Northern cod was fished extensively by foreign fleets – mostly Portugal and Spain – well back into 1400's or earlier. Exploitation intensified from the 1950s when offshore trawling became the predominant practice. When the United Nations Convention of the Law of the Sea (UNCLOS) was implemented and the national jurisdiction was extended from 12 to 200 miles in the late 1970s, the stock was already greatly depleted. Canada adopted a long-term recovery plan for the stock, which included an annual allowance of 90,000 tons for the inshore fishery taken off the top of each year's quota. Canada also built up an offshore fleet of trawlers, very much like the Europeans have used before. All went well for most of a decade. An increase in Catch per unit of effort (CPUE) even seemed to suggest a swifter recovery than was expected. However, in 1986 the catches of the inshore fishery failed dramatically, although the offshore fishery was doing fine – and also scientific surveys were continuing to show rebuilding of the stock. In the late 1980s, the inshore fishery generally deteriorated, and also surveys indicated that the rebuilding had ceased and decline was highly likely. In hindsight, climate change played a key role as a driver. Rising temperature, and particular melting of the Greenland glaciers and arctic ice led a strengthening of the cold intermediate layer of the Labrador current. As a result, the plateaus for most of the Grand Banks were covered in waters too cold for cod to enter more than briefly to feed on their key prey, capelin. Therefore, the cod did their spring migration inshore without being able to replenish their energy reserves. This led to higher natural mortality and lower weight at age, probably reinforced by fisheries-induced evolution, which may have led to higher predation by seals and also implied that more cod were taken per ton of quota. Individually, these different drivers may have been minor, but when added to the high fishing pressure, taken together the impact on the stock was no longer sustainable.

In hindsight, a much more drastic and early reduction in fishing pressure would have been required to prevent collapse. Why did this not happen? Back in the mid 1980s, fisheries science did not have tools to include oceanographic data directly in the population assessments and there was little consensus how to interpret the data at hand. There was high certainty the stock was declining, but high uncertainty about the speed and the causes of the decline, and if the decline might reverse as oceanographic conditions may change (Drinkwater, 2002; Hilborn & Litzinger, 2009; Hutchings & Myers, 1994; Hutchings & Rangeley, 2011; Myers *et al.*, 1996; Shelton *et al.*, 2006). In addition, the consultative advisory processes that involved all stakeholder groups was rather unconstructive, very much centered around blaming, rather than finding sustainable solutions. In the end, the combination of a scientific advisory body not fully understanding what was going on, and a dysfunctional political process under severe pressure, made the collapse inevitable. Quick and decisive action would have ameliorated the decline and made a rapid recovery more likely. But facing advice filled with uncertainties from science and an inclusive consultative process that could find consensus on almost nothing, no politician was going to made quick and draconian decisions (Alverson, 1997; Finlayson, 1994; Harris, 1990; Hilborn, 2007).

The Northeast Arctic cod fishery in Norway faced a major crisis almost at the same time. In 1989, an unexpected decline in the cod stock led to a reduction in quota to 340,000 tons from 630,000 tons in the year before (Hersoug, 2005). In that year, the cod was very close to shore and therefore fairly easy to catch. As a result, the quota was filled already very early in the season, when some fishers just had started. While some fishers had made good catches, others almost didn't catch anything. On 18th of April 1989 the fishery was closed. That day marked a regime shift in Norwegian fisheries policy (Holm & Finstad, 2020). Unlike in Canada, there was an immediate reaction by policy makers and the broader public to avoid a collapse and what was perceived as an outcome. There was a strong will to transform Norwegian fisheries, as described in Hersoug (2005, p11): "'Never again 18 April' was the slogan, all along the coast… from an administrative point of view this was a godsend. Now the time was ripe for a change…". Today, Northeast Arctic cod has recovered and supplies 57% of all global Atlantic cod catches in 2018. Also, Norway is seen as a role model for modern fisheries management (Gullestad *et al.*, 2014).

So, while the initial conditions in Norway and Canada seem similar when the crisis struck, the trajectories and outcomes could not be any more different. What caused those differences? First, very much like in Canada, in Norway, the coastal fishers received some preferential political treatment, particularly when it comes to weighing their interest over the interest of the offshore fleet of trawlers. However, in Norway, the fishing industry had already been through a process of rationalization, where the number of fishers declined between 1945 and 1990 from 118,000 to around 28,000, while they stayed the same in Canada throughout that same period (Hersoug, 2005). Holm and Finstad (2020) described the closure of the Norwegian coastal fishery as a shift of focus from social sustainability (employment) to environmental and economic sustainability. Tragically, the Canadian experience illustrates that the trade-off between social and ecological sustainability is illusive in the long run, as a collapse of the stock tends to go hand in hand with a collapse of the fishery.

Second, the Norwegian cod fishery has a very long history in conflict resolution, particular when it comes to distributional issues. Also, the collapse of the Norwegian herring fishery in the late 1960s and early 1970s has been an important lesson about the sustainability limits of the oceans. As a result, the destructive effects of overfishing, and the accompanied impacts on fishing communities, may have caused a greater awareness and alert when the cod was in crisis. Canadian Atlantic fisheries had also experienced serious declines, but foreign fleets were a ready target for blame, and the United Nations Convention of the Law of the Sea was viewed as a

Box 6 14

universal solution to safeguard sustainability, promising enough cod for everyone – inshore and offshore, and internal dispute resolution mechanisms weren't a priority.

Third, the role of science was very different in Norway and Canada. In Norway, the collapse of the herring fishery has played a big role in advancing the science of stock assessments and giving bigger weight to scientific assessments in the policy process. As phrased by Holm and Finstad (2020, p121), during the cod crises "there was no strong movement to attack the credibility of the scientific advice". This was a stark difference with the loss of trust and legitimacy in science observed in Canada, where two independent reviews of the science, one highly politicized, were called for between 1986 and 1990.

Fourth, in Canada distributional questions and sustainability question were highly convoluted and intertwined, with a stronger focus on who to blame than what to do. In Norway, distributional questions were discussed equally controversially and fiercely, but without trumpeting the sustainability discourse. To illustrate that point, Odd Nakken, director of the Institute for Marine Research during the cod crisis said "a dead cod is a dead cod regardless of the gear it was caught with" (Holm & Finstad, 2020).

Finally, and perhaps most importantly, environmental conditions in Norway were very different compared to Canada. While in Canada, temperature changes were unfavorable for recruitment of cod, the opposite happened in Norway, especially during the recovery year. In the end, in Norway a transformation towards sustainability was greatly facilitated by independent science, a constructive political process, but certainly also a good portion of luck in the form of favorable environmental conditions just at the right time (Diekert & Schweder, 2017).

Several further fishing case studies highlight how successful policy attends to the historical context and backdrop against which the finally considered-to-be-effective policy instrument (or combination thereof) are identified and described. For example, the Amazonian Pirarucu case study highlights the pre-existence of (sustainable use and sustainable development) reserves and the strong socio-political self-organization that had already been developed during the establishment of these reserves (Campos-Silva & Peres, 2016) (see **Box 6.7**). In the groundfish/trawling case study in California (United States of America), when a conservation non-governmental organization (The Natural Conservancy) bought-out fisheries licenses, it was critical to present the suggestions for protected area locations (developed together with fishers) at the right time with respect to the government/federal regulatory process for essential fish habitat identification and protection along the entire west coast of the United States of America (Gleason *et al.*, 2013).

Historical context should thus be considered and reflected in policy design for sustainable use of wild species. However, this is often not the case. In the case of terrestrial animal harvesting, it is highly recommended to take into account the historical context in which the policy instrument was designed and implemented. For example, in many regions of Africa, fishing and hunting was regulated by informal norms and rules from local and traditional communities (Haule *et al.*, 2002; Marks, 1984). When the European colonists settled, they introduced many factors which changed these pre-colonial systems of sustainable management, such as a strong market economy, firearms, and protected areas (DeGeorges & Reilly, 2009; Haule *et al.*, 2002). Even after independence, the new governments adopted the management systems already established, which resulted in the erosion of existing communal systems, and resource decline (Haule *et al.*, 2002). Colonial and state division of resources in different sectors also made it even more difficult to access common resources, especially in the case of wild species where local rights were typically appropriated by the states and hunters became poachers (Smith *et al.*, 2019b). This tendency to overlook the historical context has often led to conflict (e.g., **Box 6.10**).

6.5.4.3 Criminalizing local practices

The least effective terrestrial animal harvesting case studies, amongst other practices, have in common that they do not consider the practices, needs, traditional ecological knowledge and/or culture of the indigenous peoples and local communities involved. The result is existing prohibitions in these case studies involve all species in the area -even non-threatened species- and are usually not accompanied by alternatives for indigenous peoples and local communities' livelihoods and welfare. As a result, these policies tend not to work in many cases because they inadvertently criminalize local practices **(Box 6.9)** or when there is a weak law enforcement component- trigger illegal activities that are counterproductive. Furthermore, wild species populations subject to prohibitions are barely monitored, as there are no incentives to allocate resources and time to this. Local communities are more flexible in adapting their management approaches of high value species irrespective of the legal setting of the area. Despite legal and regulatory policies in place there is insufficient monitoring and management by government authorities unless it has high market value and demand associated (Yarshagumba, Nepal) (Gauli & Hauser, 2009).

Policy enforcement is challenging in many African countries, and to alleviate the problem, co-management has in principle been introduced in many places. However, as most of these are still of the more instructive type, which

Box 6 15 **Failed interactions constrain sustainable use: Lake Victoria.**

Lake Victoria in East Africa is the world's largest tropical lake and one of the largest freshwater fisheries, with annual fish landings of one million tons. The fishery is dominated by small pelagic fishes known locally as Dagaa/Mukene/Omena *(Rastrineobola argentea)* and Nile perch *(Lates niloticus)*, that together constitute more than 80% of the total catch and 80% of total biological production **(Figure 6.9)**.

For Nile perch, 97% of production and 70% of the catch consist of juveniles, which are currently illegal to catch. Fishing effort on the lake has increased almost exponentially since the 1970s, but neither the catch, nor the surveyed biomasses of the exploited stocks have shown signs of decrease (Kolding *et al.*, 2014). However, this observation is unsupported by all stock assessment models, which uniformly suggest that Nile perch, a 350 million United States dollars export industry, is overfished (Kolding *et al.*, 2008, 2014, 2019). The perceived overfishing is consistently blamed on illegal catch of juvenile fishes (< 50 cm total length), resulting in huge investment and support into management interventions and enforcement.

Co-management was initially introduced to address this perceived problem, but attempts failed to curb illegal fishing. Consequently, the co-management arrangement has deteriorated (Nunan, 2020) and in Uganda, in 2015, was replaced by severe military enforcement (Mpomwenda, Kristófersson, *et al.*, 2022; National Geographic, 2019). What all the assessment models failed to detect was that Lake Victoria was undergoing rapid eutrophication from agricultural run-off, and that productivity had followed suit (Kolding *et al.*, 2008). Despite concerns of overfishing, the three largest producing stocks, consisting of small indigenous species, including juvenile Nile perch, produce 11 million tons per year, but are only lightly exploited **(Figure 6.5)**. These stocks alone could sustainably yield 4 million tons per year to a riparian population suffering from chronic malnutrition (Kolding *et

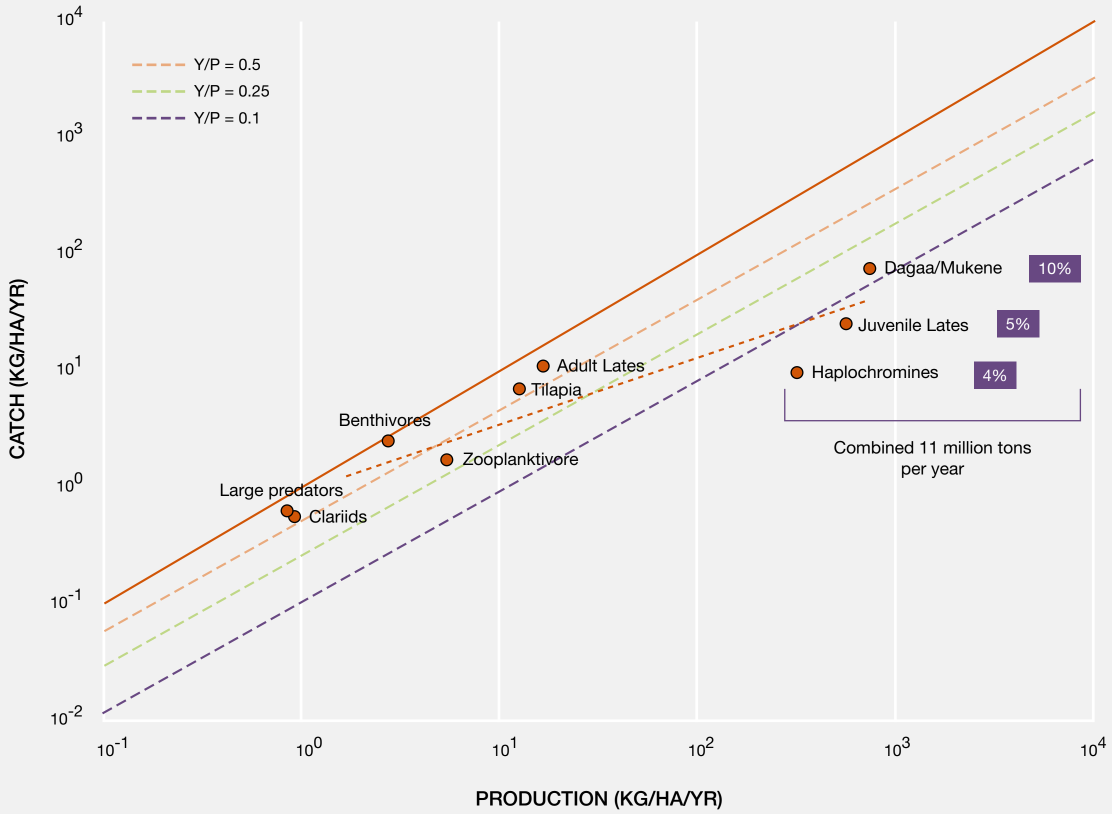


Figure 6 9 **Harvest relative to total biological production (on logarithm scales) for species harvested in Lake Victoria based on the Ecopath model of 2014 (Natugonza *et al.*, 2016).**

Exploitation rates equivalent to 10, 25, and 50% of production are given as dotted parallel lines. Blue boxes give the exploitation rates for the three most productive species groups. Dotted regression shows the unbalanced fishing pattern relative to production. Modified from (Kolding *et al.*, 2019) under license CC BY-NC-SA 3.0 IGO.

Box 6 15

al., 2019). The mismatch between observed data and the conventional models, based on steady state assumptions, that fisheries managers use to develop policies risks undermining local food security.

Power imbalances and fundamental mistrust between partners has led to the breakdown of co-management in Lake Victoria (Medard Ntara *et al.*, 2015; Nunan, 2020; Nunan *et al.*, 2015, 2018). The fishers do not see any evidence of the lake being overfished, as their catch rates are maintained (on average higher than other African lakes). They therefore do not understand why one of the most abundant resources cannot be fished (although officially they will agree if asked) (Kolding, personal knowledge). The policymakers, on the other hand, tend to focus solely on the value of the intensively exploited export industry of large Nile perch (1% of total production) and are doing everything they can to eradicate illegal fishing (Mpomwenda, Tómasson, *et al.*, 2022). Lake Victoria, probably the most productive lake in the world (1.6 ton/ha/year), has turned into a humanitarian tragedy with increasing conflicts and fatal hostilities, ignoring that a major driver of the observed changes, eutrophication, are coming from outside the fishery.

means that mechanisms exist for governments to consult with users but all decisions are taken by government (Nunan, 2020; Nunan *et al.*, 2015; Sen & Raakjaer Nielsen, 1996) **(Figure 6.3)**, there is a mixed degree of success. In most cases, it seems that co-management is a form of crisis management (Sen & Raakjaer Nielsen, 1996), where governments, witnessing the failure of their own management regime, decide to bring users into the management process. However, predominantly to simply assist in the enforcement of the already top-down decided regulations. In many cases, this approach has not succeeded in curbing the perceived illegal fishing (Kolding *et al.*, 2019) and has even resulted in the total abandonment of co-management and renewed calls for centralized enforcement (See **Box 6.15** on Lake Victoria Fisheries). Thus, there are many instances, especially in inland fisheries, when management measures, or governance models in place, may lead to a set of additional problems, instead of solving the current ones (Kolding *et al.*, 2014). Most of these are based on fundamental disagreement between fishers and managers on the appropriateness of the top-down gazetted regulations, and the lack of empowerment of stakeholders to influence these (Kolding *et al.*, 2019). In many African countries, inland and coastal participatory experiences in fishing management, such as the beach management units have been implemented and have shown some degrees of success and growing stakeholder engagements. During the last few decades, rights-based management strategies are becoming increasingly important, especially those strategies based on the indigenous local knowledge and performed by indigenous peoples and local communities (Gaspare *et al.*, 2015).

6.6 LEVERS OF CHANGE AND POLICY OPTIONS

Drawing on the seven enabling conditions **(Figure 6.4)** for the sustainable use of wild species identified through this chapter, we present seven key elements that can be used to leverage more effective policies to support the sustainable use of wild species **(Table 6.9)**. Local, national, and regional governments; local and customary institutions, the private sector, and civil society organizations can transition towards more sustainable use of wild species by: strengthening inclusive and participatory processes; recognizing and supporting multiple forms of knowledge and rights; ensuring equitable distributions of benefits; tailoring policies to the local context; monitoring practices and conditions; coordinating interactions and aligning policies; and building robust institutions **(Table 6.9)**.

These levers, represent the enabling conditions for effective sustainable use policies identified in this assessment, and align with a number of "key elements of sustainable use" compiled in Chapter 2 based on the Addis Ababa Principles and Guidelines for Sustainable Use of Wild Species (Chapter 2, section 2.2.6.2). Drawing on 25 international standards **(Figure 2.3)**, including six legally binding national agreements, six private sector certification schemes, and 12 voluntary agreements, Chapter 2, evaluated how sustainable use is conceptualized at the international level (see Chapter 2, section 2.2.6.2 for the full method). We draw on this analysis to determine progress across practices in engaging with the seven enabling conditions that emerge from our analysis and identify priority areas for action.

Based on the documents reviewed in Chapter 2, we find integration of these seven key elements into voluntary agreements, certification schemes and binding agreements differs among practices. Binding agreements that relate to fishing display good integration of these key elements, although inclusive and participatory processes and ensuring equitable distribution of benefits (the latter being key to greater support small-scale fisheries) are only reflected in certification schemes and voluntary agreements. Certification schemes for gathering and logging integrate most of these key elements, while these key elements are only reflected in voluntary agreements for terrestrial animal harvesting and observing **(Table 6.9)**. Integrating all seven key elements into future certification schemes for terrestrial animal harvesting and observing and into binding agreements for all practices is necessary for the future of sustainable use of wild species.

6.6.1 Strengthen inclusive and participatory decision-making

When procedures are adapted to support the inclusion of all actors, traditions, knowledges, and contexts, transformative change in sustainable use is possible. When approaches work to ensure the capacities of indigenous peoples and local communities, and all marginalized genders and identities are recognized, inclusion is possible. Full and effective participation in sustainable use of wild species can support effective learning and reduce redundancy (e.g., *via* knowledge brokers, mediators, facilitators), outcomes are likely to be better supported by communities, and damaging power dynamics can be illuminated and navigated. Stakeholder diversity promotes buy-in and collaboration, and expands the knowledge base for decision making (e.g., co-management), provided that power imbalances and conflicts are managed. Specific actions to promote inclusive and participatory processes include enacting policies with clear guidance on procedures for decision making and representation (e.g., specifying membership roles and responsibilities) and building capacity that enables all actors to participate fully.

6.6.2 Recognize and support multiple forms of knowledge and rights

Recognizing and supporting multiple forms of knowledge and human rights is crucial prerequisite for constructing foundation in forming and implement policy strategies for sustainable use of wild species. The knowledge of indigenous peoples and local communities, such as on wild species, is often undervalued and underrepresented in policy documents. Yet, this knowledge can provide extensive, additional information about the relationships between living beings and the environment, especially with regards to natural resources and nature's contributions to people that indigenous peoples and local communities depend on (also see Chapter 1). Ensuring the continuity and relevance of indigenous and local knowledge is necessarily linked to rights, access, recognition, survival (cultural, linguistic, spiritual, and material). The failure to include indigenous and local knowledge and indigenous languages in policy processes results in loss of language, community cohesion, and indigenous and local knowledge related to species and sustainable use. Sustainable use of wild species is integral to people living well and within their means and supporting human rights, including access to food, work, leisure, and a clean, healthy and sustainable environment. Thus, international laws, guidelines, and commitments exist to protect local food systems and livelihoods of indigenous peoples and local communities in recognition of both a moral obligation, and pragmatic reality that these can help support the sustainable use of wild species.

Table 6 9 **Seven key elements of effective policy for sustainable use of wild species, their presence in current international agreements and examples of policy options.**

Color coding based on the data drawn from analysis of the Chapter 2 (see Figure 2.3). Pictograms represent (from left to right): fishing, gathering, logging, terrestrial animal harvesting and non-extractive practices.

Key elements						Policy options
Inclusive and participatory decision-making	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements	Voluntary agreements	Enact policies with clear guidance on transparent processes for decision-making and representation Build the capacity of all actors Develop national, regional, and international contact points, platforms and community facilitators, mediators
Inclusion of multiple forms of knowledge and recognition of rights	Voluntary agreements, certification schemes and legally binding agreements	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements	Voluntary agreements	Ensure that decision-making processes are mandated to draw on diverse forms of social and ecological knowledge Develop measures to gain free, prior and informed consent for the use of knowledge and to ensure knowledge holders benefit Promote the obligation to secure the substantive and procedural rights that are guaranteed by law for all potentially affected persons
Equitable distribution of costs and benefits	Voluntary agreements	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements	Voluntary agreements	Incorporate the contents of voluntary guidelines on fair and equitable sharing of benefits into legally binding agreements Distribute costs of management through social safety nets while ensuring that costs of management do not exceed benefits Apply governance and institutional frameworks that promote equitable benefit-sharing Ensure that policies do not inadvertently remove access for indigenous peoples, local communities or marginalized individuals
Policies tailored to local social and ecological context	Voluntary agreements, certification schemes and legally binding agreements	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements	Voluntary agreements	Develop science- and evidence-based policies according to specific local ecological and social contexts, and follow the precautionary approach as appropriate Respect local communities' rights and access and customary rules Empower local communities
Monitoring of social and ecological conditions and practices	Voluntary agreements, certification schemes and legally binding agreements	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements	Voluntary agreements	Incorporate guidelines and tools in project and programme planning to ensure social and ecological monitoring and evaluation of all interventions and their implications for the rights of people involved Invest resources in coordinated social and ecological monitoring programmes Support scientific and community-based social and ecological monitoring programmes
Coordinated and aligned policies	Voluntary agreements, certification schemes and legally binding agreements	Voluntary agreements	Not present	Voluntary agreements	Voluntary agreements	Coordinate international, regional, national and subnational policies and governance Integrate policies across sectors Coordinate policies across practices
Robust institutions, from customary to statutory	Voluntary agreements, certification schemes and legally binding agreements	Voluntary agreements and certification schemes	Voluntary agreements and certification schemes	Voluntary agreements	Voluntary agreements	Design adaptive and dynamic institutions capable of adjusting to ecological and social changes Develop conflict resolution mechanisms and manage conflicts Integrate transparency measures into formal, legally mandated accountability policies Ensure all relevant customary and statutory policies, laws and institutions are respected in national and international agreements

VOLUNTARY AGREEMENTS · VOLUNTARY AGREEMENTS AND CERTIFICATION SCHEMES · NOT PRESENT · VOLUNTARY AGREEMENTS, CERTIFICATION SCHEMES AND LEGALLY BINDING AGREEMENTS

More sustainable use of wild species will benefit from policy processes that protect indigenous and local knowledge and draw on diverse forms of knowledge, bringing scientists and indigenous peoples and local communities together in a co-learning process. However, it is essential that such efforts include measures to ensure that indigenous and local knowledge holders have provided consent for, and receive benefits from, the use of their knowledge.

6.6.3 Ensure fair and equitable distribution of costs and benefits

Policies that overlook social equity increase the risk of unsustainable use of wild species. Specific actions include enacting guidelines on access and benefit sharing that are currently common in voluntary agreements, applying governance and institutional frameworks that promote equitable benefit sharing, and ensuring that policies do not inadvertently put local communities or marginalized individuals out of access.

In contrast, although successful non-extractive use policies are found to generate incomes for local communities, little attention is paid to benefit sharing, undermining long term success (G. He *et al.*, 2008; Kirkby *et al.*, 2010) (**Table 6.9**, Chapter 2). Similarly, the least successful terrestrial animal harvesting cases, it has been found that there are problems in terms of transparency in benefit distribution. Involvement in gathering practice policies of socially responsible companies, pro conservation, micro and small enterprise models, community consensus on boundaries and other rights, monitoring of sustainable gathering, conservation status, simple practical and enforceable rules, followed by penalties on breaking agreeable rules, equitable sharing of benefits, sound mechanisms for conflict resolution, and support from the local government concerned were important considerations discussed in most effective case studies.

6.6.4 Tailor policies to local social and ecological contexts

Context-specific policies are needed to ensure the sustainable use of wild species. Effective policies are purpose-built to local social and ecological conditions in which uses take place.

Tailored policies to the local and governance context include consideration of the ecological characteristics like species-specific conditions and the social pattern in using wild species. It is necessary to design a policy suitable for administrative capabilities. Actions to empower local communities and respect their rights, access and customary rules are fundamental to the development of context-specific policies. Context-specific policies including consideration for local communities are needed to ensure the sustainable use of wild species. Therefore, it is crucial to diagnose the ecological, economic and social conditions of use of wild species at the local level for designing tailored policies to the local contexts.

6.6.5 Monitor social and ecological conditions and practices

Monitoring wild species and practices will be crucial to prevent species decline and control unsustainable use of wild species. Regulatory instruments including international and national agreements and guidelines regulation and financial instruments including budget for technology and training can support monitoring of practices and conditions. In addition, monitoring can facilitate equitable participation of the different key actors. Monitoring requires both indigenous and scientific methods. In particular, community-based monitoring facilitates understanding of conditions of wild species and sustainable practices in use of wild species.

6.6.6 Coordinate and align policies

Policy instruments that are aligned at international, national, regional and local levels, and that maintain coherence and consistency with existing international obligations and take into account customary rules and norms, will be more effective. Policies outcomes will also be more effective and will lead to fewer negative and unintended consequences when attention is paid to coordinated interactions between approaches, actors, and scales. Following the same goal of sustainable use of wild species, national regulations can reflect international conventions and agreements agreed by many countries. Policies between different sectors are needed to coordinate. Relationship between wild product use and agriculture needs to be considered in designing and implementing policies of use of wild species. Fishing practice interlinks with non-fishing sectors such as agriculture, water management, and the hydro-electronic industry. In particular, logging, terrestrial animal harvesting and gathering are interconnected: forests are habitats of animals, and wild plants are food for animals. Thus, these three practices interact closely with each other. Therefore, inter-sectoral policy design will support sustainable use practice with consideration for multiple drivers to wild species conditions.

6.6.7 Build robust institutions, from customary to statutory

Robust institutions, including customary institutions, will be essential to future sustainable use of wild species. Institutions that are structured around collaborative and decentralized learning and shared interests in sustainable use are more effective than centralized systems aimed only at top-down governance. Adaptive and dynamic institutions capable of adjusting to changing circumstances will be needed to face current and future challenges of sustainable use of wild species. The integration of conflict resolution mechanisms will make institutions more effective, while transparency initiatives connected to legally mandated measures of accountability will enhance trust in institutions.

6.6.8 Enhance capacity building

Capacity-building emerges as an important enabling condition for the sustainable use of wild species in all practices. There is little evidence of value chains from concept to execution of sustainable practices reported in the successful practices from case studies. However, as these tend to include all stakeholders from the conception of the practices and throughout its different aspects/links, it is likely that some of these could be considered as such. Capacity-building of actors throughout the links of the production and commercial chains is also key for transforming these into value chains. Building the capacity of local and indigenous peoples helps producer communities to organize, navigate wild plant and fungi permitting procedures, and assert their rights against more powerful players.

6.7 KNOWLEDGE GAPS

(i) Policy effectiveness is under studied

Many studies described policies for regulating and supporting use of wild species. But only a few studies have evaluated directly the positive and negative effects of policies in using wild species. In particular, few studies measured effectiveness of economic instruments for regulating use activities in five practices. Within non-extractive use case studies, economic instruments such as nature-based tourism certification and fees effectiveness have not been studied extensively. Certification helps to reassure tourists about the responsibility and sustainability of the operator's activities but its effectiveness if not clear.

(ii) Evaluation of the influence of broader policies on sustainable use lacking

While direct and indirect drivers are clearly linked to practices, the effects of broader policies on the sustainability of the practice are lacking. It is necessary to design a comprehensive and integrated policy for controlling diverse drivers to unsustainable use of wild species in practices. The institutional framework of most national and international entities does not effectively address cross-sectoral issues such as those relating to sustainable use, health and sanitation, economic development, and education. The responsibilities of these sectors are separated over multiple agencies that seldom interact and may need to compete for finite resources.

(iii) Gaps in policy scope

Policies for supporting sustainable use of wild species are formed at the multiple levels; international, regional, national and local and interacted each other. In particular, at the global society new policy instruments for controlling use of wild species have been developed through collective intelligence. In practice, for following international conventions or agreements the national and local policies are required. Gaps between international agreements and national policy instruments emerge in implementing the agreed activities at the same time. Although countries agree the goals of international conventions and agreements, reflection of international agreements to domestic policies is limited. There is a time lag in regulatory enforcement between international agreements and national laws. As well, international agreements have limitation to include specific national conditions.

(v) Gaps between practices (cross-sectoral gap)

Multiple drivers exist in sustainable and unsustainable use of wild species. They influence five practices. At the same time, practices interact with each other. Logging influences the potential areas of gathering and terrestrial animal harvesting. Therefore, logging policies include policy instruments for gathering and terrestrial animal harvesting. For example, forest regulations include control of gathering and terrestrial animal harvesting. In fishing, whilst it is commonplace to assume practical answers to fishing-related problems come directly from the fishing sector in the form of fishing tools, management and policy, the analysis of how non-fishing-related policy can and does impact the sustainability of fishing requires more attention. More concerted cross-sectoral awareness should also help mitigate the risk of policy implementation that benefits policy outcomes unrelated to fishing to the detriment of sustainable fishing. Considering the interrelated framework of Sustainable Development Goals under the 2030 Agenda for Sustainable Development (G. G. Singh *et al.*, 2018), it is surprising that more work has not been undertaken to formally analyze links between non-fisheries policy and fisheries. Combining efforts across sectors with the above ideas in mind will likely facilitate meeting more of the Sustainable Development Goals' targets. Moving away from single stroke policy efforts focused only on single targets will require considerable collaboration between traditionally unrelated sectors both in industry and in policy.

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ANNEXES

Annex I - **Glossary**

Annex II - **List of authors and review editors**

Annex III - **List of expert reviewers**

ANNEX I
Glossary

A

Abundance (ecology)
The size of a population of a particular life form in a given area (IPBES core glossary, 2021).

Acidification
Ongoing decrease in pH away from neutral value of 7. Often used in reference to oceans, freshwater or soils, as a result of uptake of carbon dioxide from the atmosphere (IPBES core glossary, 2021). See 'Ocean acidification' for a specific definition.

Access and benefit sharing (ABS)
Access and benefit-sharing (ABS) refers to the way in which genetic resources may be accessed, and how the benefits that result from their use are shared between the people or countries using the resources (users) and the people or countries that provide them (providers). In some cases, this also includes valuable traditional knowledge associated with genetic resources that comes from Indigenous Peoples and Local Communities. The benefits to be shared can be monetary, such as sharing royalties when the resources are used to create a commercial product, or non-monetary, such as the development of research skills and knowledge (Convention on Biological Diversity, 2002, 2010b, 2010a).

Adaptation
Adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities (adapted from (IPCC, 2001) as cited in (Burton *et al.*, 2002).

Adaptive capacity
The resilience of an ecological, social or social-ecological system to unexpected or unpredictable shocks (Holling, 2001).

Adaptive management
Adaptive management is defined as a systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices and by taking in account the intrinsic changes in the system being managed over time. In active adaptive management, management is treated as a deliberate experiment for purposes of learning by doing.

Aerosol
A collection of solid or liquid particles suspended in a gas. They include dust, smoke, mist, fog, haze, clouds, and smog (Hinds, 1999).

Agricultural intensification
The process of increasing the use of capital, labor, and inputs (e.g., fertilizers, pesticides, machinery) relative to land area, to increase agriculture productivity (EUROSTAT, 2018).

Agrobiodiversity
Agricultural biodiversity includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes (Convention on Biological Diversity, 2000).

Agro-ecosystems
An ecosystem, dominated by agriculture, containing assets and functions such as biodiversity, ecological succession and food webs. An agroecosystem is not restricted to the immediate site of agricultural activity (e.g., the farm), but rather includes the region that is impacted by this activity, usually by changes to the complexity of species assemblages and energy flows, as well as to the net nutrient balance (IPBES core glossary, 2021).

Agroforestry
Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and animals, in some form of spatial arrangement or temporal sequence (Choudhury & Jansen, 1999).

Animism
A nature-culture ontology that is defined by the fact that humans acknowledge that non-humans have a different "physicality" or external appearance but that non-humans have an inner self that is similar to humans, which allows exchanges and relationships that may be conflictual or reciprocal (IPBES, 2019).

Aichi Targets
The 20 targets set by the Conference of the Parties to the Convention for Biological Diversity (CBD) at its tenth meeting, under the Strategic Plan for Biodiversity 2011–2020 (IPBES core glossary, 2021).

Anthropocene
A proposed term for the present time interval, which recognizes humanity's profound imprint on and role in the functioning of the Earth system. Since it was first proposed in 2000 (Crutzen, 2002; Crutzen & Stoermer, 2000), the term has evolved in breadth and diversity, now ranging from a proposed definition of a new geological epoch, a widely-used metaphor for global change, a novel analytical framework, a meme about the relationship of society to nature, and the framing for new and contested cultural narratives. Different starting periods have been proposed for the geological definition of the Anthropocene, including early agriculture and domestication, colonial species exchange, the onset of the industrial revolution, nuclear bomb deployment in 1945, and the post-WWII period characterized by the great acceleration of global changes and the spread of techno-fossils (Brondizio *et al.*, 2016). A proposal to formalize the 'Anthropocene' as a defined geological unit within the Geological Time Scale remains under discussion by the 'Anthropocene' Working Group for consideration by the International Commission on Stratigraphy (IUGS, 2018).

Anthropocentric
Anthropocentric qualifies an action or a perception of a given situation that is

interpreted by humans or consider humans as the main focus. Nature's contributions to people are fundamentally anthropocentric (IPBES, 2019).

Aquaculture
The farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants, in both inland and coastal areas, and involving some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated (FAO, 1997).

Archetypes
In the context of scenarios, an over-arching scenario that embodies common characteristics of a number of more specific scenarios (IPBES core glossary, 2021).

Assessment reports (in the context of IPBES)
Assessment reports are published outputs of scientific, technical and socioeconomic issues that take into account different approaches, visions and knowledge systems, including global assessments of biodiversity and ecosystem services with a defined geographical scope, and thematic or methodological assessments based on the standard or the fast-track approach. They are to be composed of two or more sections including a summary for policymakers, an optional technical summary and individual chapters and their executive summaries. Assessments are the major output of IPBES, and they contain syntheses of findings on topics that have been selected by the IPBES (IPBES core glossary, 2021).

B

Baseline
A minimum or starting point with which to compare other information (e.g., for comparisons between past and present or before and after an intervention) (IPBES core glossary, 2021).

Benefit sharing
Distribution of benefits between stakeholders (IPBES core glossary, 2021).

Benefits
Advantage that contributes to well-being from the fulfilment of needs and wants. In the context of Nature's contributions to people (see "Nature's contributions to people"), a benefit is a positive contribution to the material, relational and subjective aspects of people's life. There may also be negative contributions, dis-benefits, or costs, from Nature, such as diseases (adapted from IPBES, core glossary).

Benthic
Occurring at the bottom of a body of water; related to benthos (NOAA, 2018a).

Bio-prospectors
Exploration of biodiversity for commercially, scientifically, or culturally valuable genetic and biochemical resources (United Nations Environment Programme & United Nations Environment Programme, 2007).

Biocultural diversity
The diversity exhibited by interacting natural systems and cultural (human) systems. The concept rests on three propositions: firstly, that the diversity of life includes human cultures and languages; secondly, that links exist between biodiversity and human cultural diversity; and finally, that these links have developed over time through mutual adaptation and possibly co-evolution between humans, plants and animals (adapted from IPBES, core glossary).

Biodiversity
The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems (IPBES core glossary, 2021).

Biodiversity conservation
The management of human interactions with genes, species, and ecosystems so as to provide the maximum benefit to the present generation while maintaining their potential to meet the needs and aspirations of future generations; encompasses elements of saving, studying, and using biodiversity (WRI *et al.*, 1992).

Biodiversity hotspot
A generic term for an area high in such biodiversity attributes as species richness or endemism (IPBES core glossary, 2021).

Biodiversity loss
The reduction of any aspect of biological diversity (i.e. diversity at the genetic, species and ecosystem levels) that results from loss in a particular area through death (including extinction), destruction or manual removal; it can refer to many scales, from global extinctions to population extinctions, resulting in decreased total diversity at the same scale, adversely affecting human-environment connections and disrupting the flow of Nature's contribution to people (adapted from IPBES, core glossary).

Biodiversity offset
Measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from development plans or projects after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground with respect to species composition, habitat structure, ecosystem function and people's use and cultural values associated with biodiversity (UNDP, 2016).

Bioeconomy
The bioeconomy is the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy (IACBG, 2020).

Bioenergy
Energy generated by combusting solid, liquid or gas fuels made from biomass feedstocks which may or may not have undergone some form of conversion process (Committee on Climate Change, 2011).

Biofuel
Liquid, solid, or gaseous fuel produced by conversion of biomass. Examples include bioethanol from sugar cane or corn, charcoal or woodchips, and biogas from anaerobic decomposition of wastes (OECD, 2002).

Biogeochemistry
The field of biogeochemistry deals with the effect of biological organisms on the chemistry of the Earth (Jørgensen & Fath, 2008).

Biological resources
Biological resources include genetic resources, organisms or parts thereof, populations, or any other biotic component

of ecosystems with actual or potential use or value for humanity(Convention on Biological Diversity, 1992).

Biological sustainable level (fished within)
In fisheries organizations, biological sustainable levels are usually defined according to MSY, which is the Maximum Sustainable Yield (or catch) that can be continuously taken from a stock under existing environmental conditions without affecting its reproductive potential. Two key levels are considered: to assess the sustainability of fishing on a given stock: FMSY which is the fishing mortality that is consistent with achieving MSY and BMSY that is the biomass that results from fishing at FMSY for a long time.

Biomass (ecology)
The mass of non-fossilized and biodegradable organic material in a given area or volume (adapted from IPBES, core glossary).

Biome
A set of naturally occurring communities of plants and animals occupying an environmental and/or climatic domain, defined on a global scale. IPBES biomes, as used in this assessment, are broader and more aggregated than many purely biological classification systems. Where biomes are transformed into anthromes, the ‘anthropogenic biomes’ of urban areas and cultivated areas have been included. In this assessment we consider (i) wetlands, (ii) inland waters, (iii) coastal systems, (iv) shelf systems, (v) open and deep seas, (vi) urban areas, (vii) rural areas, (viii) grasslands-steppes-savannas, (ix) forests and (x) deserts and mountains (see Chapter 1).

Bioprospecting
The purposeful evaluation of wild biological material in search of valuable new products (Artuso, 2002).

Biosphere
The sum of all the ecosystems of the world. It is both the collection of organisms living on the Earth and the space that they occupy on part of the Earth’s crust (the lithosphere), in the oceans (the hydrosphere) and in the atmosphere. The biosphere is all the planet’s ecosystems (IPBES core glossary, 2021).

Biota
All living organisms of an area; the flora and fauna considered as a unit (IPBES core glossary, 2021).

Biotechnology (modern)
Modern biotechnology means the application of:

a. In vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or
b. Fusion of cells beyond the taxonomic family,

that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection (Convention on Biological Diversity, 2000).

Burden
The resulting negative impacts of ecosystem use and management on people and nature, including distant, diffuse and delayed impacts (modified from Pascual *et al.*, 2017).

Bushmeat
See “wild meat”

Bushmeat hunting
Bushmeat (or wild meat) hunting is a form of hunting that entails the harvesting of wild animals for food and for non-food purposes, including for medicinal use (IPBES core glossary, 2021).

Bycatch
The incidental capture of non-target species. The portion of a commercial fishing catch that consists of marine animals caught unintentionally (Merriam-Webster, 2021b).

C

Canned hunting
Hunting of animals in confined enclosures where they are unable to escape (see Chapter 3).

Capacity-building
Defined by the United Nations Development Programme as “the process through which individuals, organizations and societies obtain, strengthen and maintain their capabilities to set and achieve their own development objectives over time” (IPBES core glossary, 2021).

Carbon cycle
The flow of carbon (in various forms, e.g., as carbon dioxide (CO_2) through the atmosphere, ocean, terrestrial and marine biosphere and lithosphere (IPCC, 2014).

Carbon sequestration
The long-term storage of carbon in plants, soils, geologic formations, and the ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas (IPBES core glossary, 2021).

Carbon storage
The biological process by which carbon in the form carbon dioxide is taken up from the atmosphere and incorporated through photosynthesis into different compartments of ecosystems, such as biomass, wood, or soil organic carbon. Also, the technological process of capturing waste carbon dioxide from industry or power generation, and storing it so that it will not enter the atmosphere (IPBES core glossary, 2021).

Carrying capacity
In ecology, the carrying capacity of a species in an environment is the maximum population size of the species that the environment can sustain indefinitely. The term is also used more generally to refer to the upper limit of habitats, ecosystems, landscapes, waterscapes or seascapes to provide tangible and intangible goods and services (including aesthetic and spiritual services) in a sustainable way (IPBES, 2019).

Ceremonial uses (of wild species)
Ceremonial uses are defined as uses of wild species in spiritual observances and practices valued for their role in maintaining cultural identity and social reproduction.

Certainty
In the context of IPBES, the summary terms to describe the state of knowledge are the following:

- Well established (Certainty term (q.v.)): comprehensive meta-analysis or other synthesis or multiple independent studies that agree.

- Established but incomplete (Certainty term (q.v.)): general agreement although only a limited number of studies exist but no comprehensive synthesis and, or the studies that exist imprecisely address the question.

- Unresolved (Certainty term (q.v.)): multiple independent studies exist but conclusions do not agree.

- Inconclusive (Certainty term (q.v.)): limited evidence, recognizing major knowledge gaps.

(IPBES core glossary, 2021).

Certification (environmental)
A procedure by which a third party gives written assurance that a product, process or service is in conformity with certain environmental standards (Dankers, 2003).

Charismatic species
Species that has a privileged value for a group (academic or not academic) and is used to focus attention on conservation campaigns (in the case of NGOs and environmentalists) or considered as a heritage (3 characters: inherited from ancestor, supposed to be transmitted to the next generation, sustainably managed) and in which the group identifies him-self (Cormier-Salem *et al.*, 2005; Cormier-Salem & Bassett, 2007; Dounias, 2007; Lizet & Milliet, 2012; Posey, 1999).

Citizen science
Citizen science refers to research collaborations in which volunteers and scientists partner to answer real-world questions, typically through a connected interface. A major setback of citizen science projects is that they require some level of computer literacy and network connectivity, both rare in many rural areas of the developing world. Despite the challenge, some researchers have already been successful in implementing interactive multimedia web-based tools for the collection of data based on local monitoring systems (Ens, 2012; Gill & Lantz, 2014; Pulsifer *et al.*, 2010; Stevens *et al.*, 2014).

Climate change
As defined in Article 1 of the United Nations Framework Convention on Climate Change, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPBES core glossary, 2021).

Collapse (socioecological system)
The rapid and durable loss of a defined socio-ecological system as such, resulting in substantial loss of social-ecological capital (e.g., biomass) (Cumming & Peterson, 2017).

Collecting
See "Gathering".

Co-management
Process of management in which government shares power with resource users, with each given specific rights and responsibilities relating to information and decision-making (OECD, 2007a) (also see Chapter 6).

Common Property Theory (CPT)
Common property theory (CPT) refers to a body of cross-disciplinary literature that deals with the historical and contemporary institutional governance and management of valued resources ranging from fisheries and forests to atmospheric sinks, oceans, and genetic materials. CPT was originally developed to understand the problems of managing what are termed common-pool resources (Pokrant, 2011).

Community (ecological)
An assemblage of populations of at least two different species which coexist, and to various degrees interact directly and indirectly within a defined local geographic area and in a particular time; it is characterized in terms of taxonomic and functional composition (the species and functional types present) and richness (e.g., richness, abundance, dominance and distribution of species, or phenotypes) (Stroud *et al.*, 2015).

Community (social)
A group of people who inhabit or perform ongoing activities in a shared geographic space, who interact with one another, share similar values, identity, and heritage that form a basis for communal rules regulating collective behavior (MacQueen *et al.*, 2001; McGoodwin, 2001).

Community forestry
A broad term used to describe models of forest management that give local people the majority say in making decisions. Similar terms include participatory forest management, collaborative forest management, social forestry, and community-based forest management. With an aim to reduce poverty, community forestry is participatory and should serve all community members equitably (IPBES, 2019).

Community-based natural resource management
An approach to natural resource management that involves the full participation of indigenous peoples' and local communities and resource users in decision-making activities, and the incorporation of local institutions, customary practices, and knowledge systems in management, regulatory, and enforcement processes. Under this approach, community-based monitoring and information systems are initiatives by indigenous peoples and local community organizations to monitor their community's well-being and the state of their territories and natural resources, applying a mix of traditional knowledge and innovative tools and approaches (IPBES core glossary, 2021).

Community-based tourism
Community-based tourism is defined as an approach to tourism development which prioritizes the needs and desires of the host community.

Community-managed forests
Decentralized system of forest resource management designed to promote more equitable outcomes for stakeholders' livelihoods changing relationships between stakeholders and government agencies (adapted from Newton *et al.*, 2015).

Conflict
Conflict is defined as when levels of armed violence due to political insecurity, instability, or civil or international war are substantially higher than in non-conflict times. This leads to a disruption of economies, government services and the extensive movement of people to flee conflict zones for personal safety and/or better opportunities (see Chapter 4).

Conservation benefits
The positive impacts on people and ecosystems due to conservation (IPBES, 2019).

Conservation biology
The branch of biological science concerned with the conservation, management, and protection of vulnerable species, populations, and ecosystems. Also see 'Biological conservation' (IPBES, 2019).

Co-production (of contributions between nature and people)
In the context of the IPBES conceptual framework, this is the joint contribution by nature and anthropogenic assets in generating Nature's contributions to people (IPBES, 2016c).

Cross-sectoral
Relating to interactions between sectors (that is, the distinct parts of society, or of a nation's economy), such as how one sector affects another sector, or how a factor affects two or more sectors (IPBES core glossary, 2021).

Cultural change (or cultural transformation)
Cultural change is a continuous process in any society, which can vary from gradual to stochastic, resulting from interactions between processes that are internal (ex. needs, local changes, crisis, mobility, ideas, invention and innovation, conflicts, etc.) and external (ex. diffusion, external agents, political and economic forces, conflicts, etc.) (Berry, 2008; Redfield *et al.*, 1936). Cultural change is interpreted differently depending on theoretical orientation, such as diffusionism, modernization theory, world system theory, neocolonialism, globalization, among others (see Peña, 2005; Rudmin, 2009; Santos-Granero, 2009). Culture change can be selective or systemic and most often involves resistance and conflicts but can also lead to adaptation and resilience in changing contexts and environments.

Cultural ecosystem services
A category of ecosystem services first developed in the Millenium Ecosystem Assessment (2005) to refer to the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values (Millenium Ecosystem Assessment, 2005). In this assessment, cultural ecosystem services are included as part of both material and non-material Nature's contributions to people.

Cultural diversity
As stated in the UNESCO Universal Declaration on Cultural Diversity, "Culture takes diverse forms across time and space. This diversity is embodied in the uniqueness and plurality of the identities of the groups and societies making up humankind. As a source of exchange, innovation and creativity, cultural diversity is as necessary for humankind as biodiversity is for nature. In this sense, it is the common heritage of humanity and should be recognized and affirmed for the benefit of present and future generations...Cultural diversity widens the range of options open to everyone; it is one of the roots of development, understood not simply in terms of economic growth, but also as a means to achieve a more satisfactory intellectual, emotional, moral and spiritual existence." (UNESCO, 2001).

Cultural continuity
Cultural continuity has been conceptualized within Indigenous health research that builds on cultural connectedness to emphasize the importance of intergenerational cultural connectedness, which is maintained through intact families and the engagement of elders, who pass traditions to subsequent generations. Cultural continuity also situates culture as being dynamic through the maintenance of collective memory, which may change over time (Auger, 2016) (see Chapter 3).

Cultural identity
Cultural identity is the identity or feeling of belonging to, as part of the self-conception and self-perception to nationality, ethnicity, religion, social class, generation, locality and any kind of social group that have its own distinct culture. In this way that cultural identity is both characteristic of the individual but also to the culturally identical group that has its members sharing the same cultural identity (see Chapter 3).

Cultural keystone species / culturally important species
Culturally keystone species designate species whose existence and symbolic value shape in a major way and over time, the cultural identity of a people, as reflected in the fundamental roles these species have in diet, materials, medicine, and/or spiritual practices (Cristancho & Vining, 2004; Garibaldi & Turner, 2004).

Cultural landscapes
Cultural landscapes express the long-term co-evolution and relationships between people and nature, influenced by internal and external forces affecting the aesthetic and productive configuration of land management, water bodies, wildlife, property systems, infrastructure and human settlements, and which are both a source and a product of changing social, institutional, economic, and cultural systems (also see World Heritage Centre, 2008).

Cultural values
Cultural values are shared social values and norms, which are learned and dynamic, and which underpin attitudes and behavior and how people respond to events and opportunities, and affects the hierarchy of values people assign to objects, knowledge, stories, feelings, other beings, forms of social expressions, and behaviors (IPBES, 2019).

Culture
Culture is defined as a key determinant of, for example, what is defined as suitable food and preferred approaches to supporting human health.

Customary land tenure
The socially-embedded systems and institutions used within communities to regulate and manage land use and access, and which derive from the community itself rather than from the state (IPBES, 2019).

Customary law / norms
Law consisting of customs that are accepted as legal requirements or obligatory rules of conduct; practices and beliefs that are so vital and intrinsic a part of a social and economic system that they are treated as if they were laws (Convention on Biological Diversity, 2018).

Customary rights
Rights, such as land rights or political rights, that are granted by either customary or statutory law. Customary rights exist where there is a consensus of relevant actors considering them to be 'law' (IPBES, 2019).

Customary sustainable use
Uses of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements (Convention on Biological Diversity, 2018).

D

Decomposition
Breakdown of complex organic substances into simpler molecules or ions by physical, chemical and/or biological processes. (IPBES core glossary, 2021).

Decorative and aesthetic uses
Decorative and aesthetic uses are defined as the uses of wild species in order to produce handicrafts and objects of adornment, beauty, and/or entertainment.

Deforestation
Human-induced conversion of forested land to non-forested land. Deforestation can be permanent, when this change is definitive or temporary when this change is part of

a cycle that includes natural or assisted regeneration (IPBES core glossary, 2021).

Demographic change (or demographic transition)
A model describing transition in demographic profile of a population, which has been associated with the development process that transforms an agricultural society into an industrial one and characterized by a rapid population growth due to a decline in the death rate while fertility remains high initially; the growth rate then declines due to a decline in the birth rate. Before the transition's onset, population growth is low as high death rates tend to offset high fertility. After the transition, population growth is again below replacement level as both birth and death rates reach low levels (Bongaarts, 2009).

Desertification
Desertification means land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities. Desertification does not refer to the natural expansion of existing deserts (UNCCD, 1994).

Dispersal
Movement of individuals (and in some species, their gametes) that has the potential for moving genes through space (Templeton, 2017).

Domesticated species
Species in which the evolutionary process has been influenced by humans to meet their needs (Convention on Biological Diversity, 1992).

Domestication
Evolutionary process driven by human (whether conscious or unconscious) selection but also involving natural processes applied to wild plants or animals and leading to adaptation to cultivation and consumption or utilization. Domestication can be complete, whereby organisms become entirely dependent on humans for their continued existence or can be partial or incipient, whereby they still reproduce independently of human intervention (Gepts, 2014). In traditional systems, farmer practices still shape the genetic structure of crops and their evolution (Vigouroux *et al.*, 2011).

Drivers
For the purpose of this assessment, drivers are defined as the factors that, directly or indirectly influence the sustainability of use of wild species, by changing the abundance or distribution of species in use, altering demand on and consumption of wild species, products derived from wild species and/or changing the (nature, scale, and/or intensity of) interactions with wild species in use (practices). It is recognized that the same factor may influence different components of the system (wild species, practices, Nature's contributions to people); and the interactions among these factors vary across time and space, which can have negative or positive effects on sustainability (see Chapter 4).

Drivers of change
Drivers of change refer to all those external factors that affect nature, and, as a consequence, also affect the supply of Nature's contributions to people. The IPBES conceptual framework includes drivers of change as two of its main elements: indirect drivers, which are all anthropogenic, and direct drivers, both natural and anthropogenic (IPBES, 2019).

Drylands
Drylands comprise arid, semi-arid and dry sub-humid areas. The term excludes hyper-arid areas, also known as deserts. Drylands are characterized by water scarcity and cover approximately 40% of the world's terrestrial surface (IPBES core glossary, 2021).

E

Ecolabelling
Ecolabelling is defined as a voluntary approach to environmental certification practiced around the world. Ecolabel is defined as a product that meets a wide range of environmental performance criteria or standards (Golden *et al.*, 2010).

Ecological footprint
A measure of the amount of biologically productive land and water required to support the demands of a population or productive activity. Ecological footprints can be calculated at any scale: for an activity, a person, a community, a city, a region, a nation or humanity as a whole (IPBES core glossary, 2021).

Ecological (or socio-ecological) breakpoint or threshold
The point at which a relatively small change in external conditions causes a rapid change in an ecosystem. When an ecological threshold has been passed, the ecosystem may no longer be able to return to its state by means of its inherent resilience (IPBES core glossary, 2021).

Economic and financial instruments
see "Policy instruments".

Ecosystem
The ecosystem is defined in this assessment as the largest functional unit that includes both living organisms and the abiotic environment, each influencing the properties of the other, and the two being necessary to maintain life as it exists on Earth (Odum, 1953).

Ecosystem approach
See "Ecosystem-based approach".

Ecosystem degradation
A long-term reduction in an ecosystem's structure, functionality, or capacity to provide benefits to people (IPBES core glossary, 2021).

Ecosystem function
The flow of energy and materials through the biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer (IPBES core glossary, 2021).

Ecosystem ecology
The integrated study of biotic and abiotic components of ecosystems and their interactions within an ecosystem framework. This science examines physical and biological structures and examines how these ecosystem characteristics interact with each other (Simon *et al.*, 2010).

Ecosystem health
Ecosystem health is a metaphor used to describe the condition of an ecosystem, by analogy with human health. Note that there is no universally accepted benchmark for a healthy ecosystem. Rather, the apparent health status of an ecosystem can vary, depending upon which metrics are employed in judging it, and which societal aspirations are driving the assessment (IPBES core glossary, 2021).

Ecosystem management
An approach to maintaining or restoring the composition, structure, function, and delivery of services of natural and modified ecosystems for the goal of

achieving sustainability. It is based on an adaptive, collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework, and defined primarily by natural ecological boundaries (IPBES core glossary, 2021).

Ecosystem services
The benefits people obtain from ecosystems. In the Millennium Ecosystem Assessment, ecosystem services can be divided into supporting, regulating, provisioning and cultural. This classification, however, is superseded in IPBES assessments by the system used under "Nature's contributions to people". This is because IPBES recognizes that many services fit into more than one of the four categories. For example, food is both a provisioning service and also, emphatically, a cultural service, in many cultures (IPBES core glossary, 2021).

Ecosystem-based approach
A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. An ecosystem approach is based on the application of appropriate scientific methods, focused on levels of biological organization that encompass the essential structure, processes, functions and interactions among and between organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems (UNEP, 2012).

Edge effect
A change in species composition, physical conditions or ecological factors at the boundary between two or more habitats (IUCN, 2012a).

El Niño / La Niña
The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Perú, disrupting the local fishery. It has since become identified with a basin-wide warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as the El Niño-Southern Oscillation (ENSO) (IPCC, 2014).

Empowerment
The process by which people gain control over the factors and decisions that shape their lives. It is the process by which they increase their assets and attributes and build capacities to gain access, partners, networks and/or a voice, in order to gain control (WHO, 2010).

Enabling conditions
Enabling conditions are defined as conditions that facilitate approaches to addressing social and ecological challenges. They can be defined as factors that increase the likelihood of an intended change in the governance approach, strategy, or management regime. The presence of enabling conditions can facilitate the emergence of a particular environmental policy, whereas the absence of key enabling conditions can present a barrier to management or sustained policy action (Huber-Stearns *et al.*, 2017). See Chapter 6.

Endangered species
A species at risk of extinction in the wild (IPBES core glossary, 2021).

Endemic species
Species that is native to, and restricted to, a particular geographical region. Highly endemic species, those with very restricted natural ranges, are especially vulnerable to extinction if their natural habitat is eliminated or significantly disturbed (IUCN, 2012a).

Energy security
Access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses (IPBES core glossary, 2021).

Energy source
Primary energy sources take many forms, including nuclear energy, fossil energy -like oil, coal and natural gas- and renewable sources like wind, solar, geothermal and hydropower. These primary sources are converted to electricity, a secondary energy source (US Department of Energy, 2018).

Environmental education
The facilitation of an integrated perception of the problems of the environment, enabling more rational actions capable of meeting social needs to be taken (UNESCO, 1978).

Environmental governance
Environmental governance, as a subclass of the broader governance concept, has been defined as "the set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes" (Lemos & Agrawal, 2006), and it "should be understood broadly so as to include all institutional solutions for resolving conflicts over environmental resources" (Paavola, 2007).

Environmental gradients
Environmental characteristics that explain the distribution of organisms and ecosystems in terms of environmental tolerances (Government of New Brunswick, 2007).

Environmental Impact Assessment
A formal, evidence-based procedure that assesses the economic, social, and environmental effects of public policy or of any human activity (IPBES, 2019).

Environmental justice
The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies (EPA, 2018).

Essential Biodiversity Variables (EBVs)
Essential Biodiversity Variables are promoted by the Group on Earth Observations Biodiversity Observation Network (GEO BON). The idea behind this concept is to identify, using a systems approach, the key variables that should be monitored in order to measure biodiversity change. The Essential Biodiversity Variables are an intermediate layer of abstraction between raw data, from *in situ* and remote sensing observations, and derived high-level indicators used to communicate the state and trends of biodiversity (IPBES core glossary, 2021).

Ethnobiology
The study of dynamic relationships among peoples, biota, and environments, as encoded in the knowledge held by different societies and individuals. Its multidisciplinary nature allows it to examine complex, dynamic interactions between human and natural systems, and enhances our intellectual merit and broader impacts (Society of Ethnobiology, 2018).

Eutrophication
An enrichment of water by nutrients that causes structural changes to the ecosystem, such as: increased production of algae and aquatic plants, depletion of fish species, general deterioration of water quality and other effects that reduce and preclude use (OECD, 1982).

Evolutionary biology
A sub-discipline of the biological sciences concerned with the origin of life and the diversification and adaptation of life forms over time (Nature, 2018).

Exclusive Economic Zone (EEZ)
An Exclusive Economic Zone (EEZ) is a concept adopted at the Third United Nations Conference on the Law of the Sea (1982), whereby a coastal State assumes jurisdiction over the exploration and exploitation of marine resources in its adjacent section of the continental shelf, taken to be a band extending 200 miles from the shore. The Exclusive Economic Zone comprises an area which extends either from the coast or in federal systems from the seaward boundaries of the constituent states (3 to 12 nautical miles, in most cases) to 200 nautical miles (370 kilometers) off the coast. Within this area, nations claim and exercise sovereign rights and exclusive fishery management authority over all fish and all Continental Shelf fishery resources (IPBES core glossary, 2021).

Exploitation
The consumptive use of any natural resources (Groom *et al.*, 2006).

Exploratory scenarios (also known as "explorative scenarios" or "descriptive scenarios")
Scenarios that examine a range of plausible futures, based on potential trajectories of drivers – either indirect (e.g., socio-political, economic and technological factors) or direct (e.g., habitat conversion, climate change) (IPBES, 2016c)

Externality
A positive or negative consequence (benefits or costs) of an action that affects someone other than the agent undertaking that action and for which the agent is neither compensated nor penalized through the markets (IPBES core glossary, 2021).

Extinction
A population, species or more inclusive taxonomic group has gone extinct when all its individuals have died. A species may go extinct locally (population extinction), regionally (e.g., extinction of all populations in a country, continent or ocean) or globally. Populations or species reduced to such low numbers that they are no longer of economic or functional importance may be said to have gone economically or functionally extinct, respectively. Species extinctions are typically not documented immediately: for example, the IUCN Red List categories and criteria require there to be no reasonable doubt that all individuals have died, before a species is formally listed as Extinct (see IUCN Red List) (IUCN, 2012b).

Extractive practices
Extractive practices are defined as the temporary or permanent removal of organisms, part of them or materials derived from them, and may result in mortality of the individual to be used (e.g., hunting or whole plant harvest), but does not necessarily do so (e.g., limited collection of plant propagules or shearing and releasing of vicuna) (see Chapter 1).

F

Fallow
Land normally used for production and left to recover for part or all of a growing season (more in the case of swidden agriculture) (Gleave, 1996; United Nations, 1997).

Feedback
The modification or control of a process or system by its results or effects (IPBES core glossary, 2021).

Feral
Species are considered to be feral if they or their ancestors were formerly domesticated, but they are now living independently of humans (modified from FAO, 2021)

Fishery
Generally, a fishery is an activity leading to harvesting of fish. It may involve capture of wild fish or raising of fish through aquaculture (FAO, 2021). Note that in this definition, the term fish includes all types of marine animals, fish, but also crustaceans, mollusks, echinoderms etc.

Fishing
Fishing is defined as the removal from their habitats of aquatic animals (vertebrates and invertebrates) that spend their full life cycle in water (e.g., fish, some marine mammals, shellfish, shrimps, squids, corals). Fishing most often results in the death of the aquatic animal, but it may not in some cases. To reflect both situations, fishing has been sub-divided into a lethal and a "non-lethal" category. Lethal fishing is defined as the general and more usual meaning of fishing that leads to the killing of the animal, such as in traditional commercial fisheries. "Non-lethal fishing is defined as the temporary or permanent capture of live animals from their habitat without intended mortality, such as in aquarium fish trade or catch and release. However, unintended mortality may occur in "non-lethal" fishing and the term "non-lethal" is therefore put in quotes. The killing of species that spend part of their life cycle in terrestrial environments (e.g., walrus, sea turtles) is encompassed by the definition of hunting (see Chapter 1).

Fitness (ecology)
Fitness involves the ability of organisms— or populations or species— to survive and reproduce in the environment in which they find themselves, and thus contribute genes to the next generation (Orr, 2009).

Folk medicine
Folk medicine is defined as the mixture of traditional healing practices and beliefs that involve use of algae, animals, fungi, and plants, spirituality and manual therapies or exercises in order to diagnose, treat or prevent an ailment or illness (adapted from WHO, 2008).

Food security
The World Food Summit of 1996 defined food security as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (IPBES core glossary, 2021).

Food-web
An important ecological concept representing feeding relationships within a community and implying the transfer of food energy from its source in plants through herbivores to carnivores; normally, food webs consist of a number of food chains meshed together (Hui, 2012).

Forest
A vegetation type dominated by trees. Definitions of forest varies according to the use of parameters such as biogeography, physiognomy, biomass, human management, species dominance and composition, among others, therefore affecting estimates of extent and type of change (also see IPCC, 2014).

Forest degradation
A process leading to a temporary or permanent deterioration in the density or structure of vegetation cover or its species composition. It is a change in forest attributes that leads to a lower productive capacity caused by an increase in disturbances. Continued degradation of the forests can destroy the entire forest cover and biodiversity, and it mainly occurs because of environmental and anthropogenic changes (Tejawasi, 2007).

Forest management
Forest management is defined as a practice about managing, using, conserving and repairing forest, woodlands and associated resources. Objectives and goals are fulfilled by implementing and regulating tree management and harvesting practices stipulated in forest management plans (see Chapter 3).

Fossil fuel
Fossil fuels are derived from the remains of ancient plant and animal life: coal, oil and natural gas. In common dialogue, the term fossil fuel also includes hydrocarbon-containing natural resources that are not derived from animal or plant sources (OECD, 2001a).

Free, prior and informed consent (FPIC)
Free implies that Indigenous Peoples and Local Communities are not pressured, intimidated, manipulated or unduly influenced and that their consent is given, without coercion; prior implies seeking consent or approval sufficiently in advance of any authorization to access traditional knowledge respecting the customary decision-making processes in accordance with national legislation and time requirements of Indigenous Peoples and Local Communities; informed implies that information is provided that covers relevant aspects, such as: the intended purpose of the access; its duration and scope; a preliminary assessment of the likely economic, social, cultural and environmental impacts, including potential risks; personnel likely to be involved in the execution of the access; procedures the access may entail and benefit-sharing arrangements; consent or approval is the agreement of the Indigenous Peoples and Local Communities who are holders of traditional knowledge or the competent authorities of those Indigenous Peoples and Local Communities, as appropriate, to grant access to their traditional knowledge to a potential user and includes the right not to grant consent or approval. (modified from Convention on Biological Diversity, 2018).

Functional diversity
The range, values, relative abundance and distribution of functional traits in a given community or ecosystem (Díaz *et al.*, 2007).

Functional group
A collection of organisms with similar suites of co-occurring functional attributes. Groups are traditionally associated with similar responses to external factors and/or effects on ecosystem processes. A functional group is often referred to as 'guild', especially when referring to animals, e.g., the feeding types of aquatic organisms having the same function within the trophic chain (De Bello *et al.*, 2010).

G

Gathering
Gathering is defined as the removal of terrestrial and aquatic algae, fungi, and plants (other than trees) or parts thereof from their habitats. Gathering may, but often does not, result in the death of the organism. Gathering includes whole plant harvest and removal of above and/or below ground plant parts, as well as the fruiting bodies of macrofungi. It also includes removal of non-woody portions of trees (e.g., leaves, propagules, and bark). Where removal of propagules or death of an individual plant occurs (e.g., whole plant and root removal) effects on population sustainability are contingent upon factors including timing, frequency, and intensity of harvest. The harvest of wood and woody parts of trees is encompassed by the definition of logging (see Chapter 1).

Gender
The term gender refers to the socially-constructed expectations about the characteristics, aptitudes and behaviors associated with being a woman or a man. Gender defines what is feminine and masculine. Gender shapes the social roles that mean and women play and the power relations between them, which can have a profound effect on the use and management of natural resources.

Gender is not based on sex or the biological differences between women and men; rather, gender is shaped by culture and social norms. Thus, depending on values, norms, customs and laws, women and men in different parts of the world have adopted different gender roles and relations. Within the same society, gender roles also differ by race/ethnicity, class/caste, religion, ethnicity, age and economic circumstances. Gender and gender roles then affect the economic, political, social, and ecological opportunities and constraints faced by both women and men (Convention on Biological Diversity, 2017). The framing of sex and gender as binaries is in fact a cultural ideology. The empirical reality is that sex is a spectrum, manifesting in a wide array of sex variance. Some people don't neatly fit into the categories of "man" or "woman," or "male" or "female." For example, some people have a gender that blends elements of being a man or a woman, or a gender that is different than either male or female. Some people don't identify with any gender, or their gender changes over time.

Gene
The basic physical and functional unit of heredity. Genes are made up of DNA, and occupy a fixed position (locus) on a chromosome. Genes achieve their effects by directing the synthesis of proteins (Encyclopaedia Britannica, 2018).

Generalist species
A species able to thrive in a wide variety of environmental conditions and that can make use of a variety of different resources (for example, a flower visiting insect that lives on the floral resources provided by several to many different plants) (IPBES, 2019).

Genetic diversity
The variation at the level of individual genes, which provides a mechanism for populations to adapt to their ever-changing environment. The more variation, the better the chance that at least some of the individuals will have an allelic variant that is suited for the new environment, and will produce offspring with the variant that will in turn reproduce and continue the population into subsequent generations (NBII, 2011).

Genetic manipulation or genetic engineering
The artificial manipulation, modification, and recombination of DNA or other nucleic acid molecules in order to modify an organism or population of organisms (IPBES, 2019).

Genetic resources
Genetic material of actual or potential value (Convention on Biological Diversity, 1992).

Genetically Modified Organism (GMO)
The Cartagena Protocol on Biosafety defines 'living modified organism' as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology (Convention on Biological Diversity, 2000).

Global commons or global common pool resources (CPR)
Global commons are resources at a planetary scale that are outside national jurisdictions. International law identifies four global commons: the high seas; the atmosphere; Antarctica; and outer space, which are recognized as the common heritage of humankind (UNEP Division of Environmental Law and Conventions) (Nakicenovic *et al.*, 2016).

Global North – Global South
The Global South and the Global North is a terminology that distinguishes not only between political systems or degrees of poverty, but between the victims and the benefactors of global capitalism (Wolvers *et al.*, 2015).

Good Quality of Life (GQL)
Within the context of the IPBES Conceptual Framework – the achievement of a fulfilled human life, a notion which may varies strongly across different societies and groups within societies. It is a context-dependent state of individuals and human groups, comprising aspects such as access to food, water, energy and livelihood security, and also health, good social relationships and equity, security, cultural identity, and freedom of choice and action. "Living in harmony with nature", "living-well in balance and harmony with Mother Earth" and "human well-being" are examples of different perspectives on a "Good quality of life" (IPBES core glossary, 2021).

Governance
A comprehensive and inclusive concept of the full range of means for deciding, managing, implementing and monitoring policies and measures. Whereas government is defined strictly in terms of the nation-state, the more inclusive concept of governance recognizes the contributions of various levels of government (global, international, regional, sub-national and local) and the contributing roles of the private sector, of nongovernmental actors, and of civil society to addressing the many types of issues facing the global community (IPCC, 2018).

Governance (modes of)
'Modes of governance' have been conceptualized in different ways, from hierarchies (state centric governance), networks or co-governance (a constellation of actors in varying partnership arrangements), markets (market-based instruments and incentives), voluntarism (non-binding agreements and instruments) and self-governance (including customary governance) (Sowman & Wynberg, 2014).

Grabbing (of wild species and spaces)
Actions, policies or initiatives by which use and access rights of resources and spaces are transferred and re-allocated from collective entity to private or public entity, leading to IPLC dispossession, marginalization and exclusion and, consequently, the unsustainability of use system (Acheson, 2015; Fairhead *et al.*, 2012; National Research Council & National Research Council (U.S.), 2002). These processes of control (whether through ownership, lease, concession, contracts, quotas, or general power) as well as commons enclosure, have two main purposes: on the one hand, productivist exploitation (speculation, extraction, land stewardship, food sovereignty); on the other hand, conservation (e.g. Protected Areas, no-take' conservation areas, restoration of endangered habitat, resource control or nature commodification, Biodiversity offsets, REDD+, etc.), qualified either green for land conservation (Benabou, 2014), or blue for ocean conservation (Bennett *et al.*, 2020; Clark Howard, 2018; Cormier-Salem & Bassett, 2007). Moreover, the commons, or common pool resources, cover a large set of assets, from wild species to habitats and institutions, either terrestrial and referred as large-scale land acquisition (Baker-Smith & Attila, 2016) and land grabbing, or aquatic, oceanic and coastal and referred as water (Duvail *et al.*, 2012) or ocean grabbing (Artaud & Surrallés, 2017; Bennett *et al.*, 2020).

Grassland
Type of biome characterized by a more or less closed herbaceous (non-woody) vegetation layer, sometimes with a shrub layer, but – in contrast to savannas – without, or with very few, trees. Different types of grasslands are found under a broad range of climatic conditions (modified from IPBES, core glossary).

Grazing
Feeding on growing herbage, attached algae, or phytoplankton (Merriam-Webster, 2021a).

Green bonds
A mode of private financing that tap the debt capital market through fixed income instruments (i.e., bonds) to raise capital to finance climate-friendly projects in key sectors of, but not limited to, transport, energy, building and industry, water, agriculture and forestry and waste (OECD, 2015).

Green hunting
Green hunting occurs with tranquilizer dart guns and the animals are released alive. This is typically performed for veterinary procedures or translocation, and has been suggested as an alternative to lethal forms of hunting (Greyling *et al.*, 2004).

Green Revolution
Period of food crop productivity growth that started in the 1960s due to a combination of high rates of investment in crop research, infrastructure, and market development and appropriate policy support, and whose environmental impacts have been mixed: on one side saving land conversion to agriculture, on the other side promoting an overuse of inputs and cultivation on areas otherwise improper to high levels of intensification, such as slopes (Pingali, 2012).

Greenhouse gases (GHGs)
Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2014).

H

Habitat
The place or type of site where an organism or population naturally occurs. Also used to mean the environmental attributes required by a particular species or its ecological niche (IPBES core glossary, 2021).

Habitat degradation
A general term describing the set of processes by which habitat quality is reduced. Habitat degradation may occur through natural processes (e.g., drought, heat, cold) and through human activities (forestry, agriculture, urbanization). It is sometimes used as a synonym of habitat deterioration or nature deterioration (IPBES, 2019).

Habitat fragmentation
A general term describing the set of processes by which habitat loss results in the division of continuous habitats into a greater number of smaller patches of lesser total and isolated from each other by a matrix of dissimilar habitats. Habitat fragmentation may occur through natural processes (e.g., forest and grassland fires, flooding) and through human activities (forestry, agriculture, urbanization) (IPBES core glossary, 2021).

Habitat loss
A general term describing the set of processes by which habitat quality is reduced. Habitat degradation may occur through natural processes (e.g., drought, heat, cold) and through human activities (forestry, agriculture, urbanization) (IPBES core glossary, 2021).

Harmonization
The process of bringing together, and comparing, models or scenarios to make them compatible or consistent with one another (IPBES core glossary, 2021).

Hazard
A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. Hazards that this assessment discusses are mostly environmental hazards (chemical, natural and biological hazards), while cognizant that many hazards are socio-natural, in that they are associated with a combination of natural and anthropogenic factors. Natural hazards are predominantly associated with natural processes and phenomena, including geological or geophysical hazards that originate from internal earth processes (earthquakes, volcanic activities, landslides, tsunamis), and hydrometeorological hazards, which are of atmospheric, hydrological or oceanographic origin (tropical cyclones, floods, drought; heatwaves, and storm surges). Biological hazards are of organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins and bioactive substances. Examples are bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants and mosquitoes carrying disease-causing agents (UNISDR, 2015).

Homegarden
Yard areas surrounding a house for vegetable and fruit production and keeping of domestic animals. In many regions homegardens contain wild species utilized as medicinal plants, timber or other uses (M. Walker *et al.*, 2009).

Homogenization
When used in the ecological sense "homogenization" means a decrease in the extent to which communities differ in species or functional composition (IPBES core glossary, 2021).

Human history
A general term used to refer to pre-historical and historical periods describing the development of humanity. Different classifications of periods exist reflecting different interpretation of human history (IPBES, 2019).

Horticulture
High investment crop production using resources intensively for high value product (FAO, 2013).

Hypoxia
Low dissolved oxygen levels in coastal and oceanic waters (<2mL per liter of water), either naturally occurring or as a result of a degradation (e.g., eutrophication) (Altieri *et al.*, 2017; Diaz & Rosenberg, 2008).

I

Identity
The ways in which people understand who they are, their belonging and role in society, and their relation to their broader environment (Fearon, 1999; Ingalls & Stedman, 2017).

Illegal practices
Illegal is defined in the context of this assessment when it violates laws and regulations.

Illegal, unreported and unregulated (IUU) fishing
A broad term which includes: fishing and fishing-related activities conducted in contravention of national, regional and international laws; non-reporting, misreporting or under- reporting of information on fishing operations and their catches; fishing by "Stateless" vessels; fishing in convention areas of Regional Fisheries Management Organizations (RFMOs) by non-party vessels; fishing activities which are not regulated by States and cannot be easily monitored and accounted for (FAO, 2016).

Impact assessment
A formal, evidence-based procedure that assesses the economic, social, and environmental effects of public policy or of any human activity (IPBES core glossary, 2021).

***In situ* conservation of biodiversity**
The conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties (Convention on Biological Diversity, 1992).

Indicators
A quantitative or qualitative factor or variable that provides a simple, measurable and quantifiable characteristic or attribute responding in a known and communicable way to a changing environmental condition, to a changing ecological process or function, or to a changing element of biodiversity (IPBES core glossary, 2021).

Indigenous and local knowledge (ILK)
Indigenous and local knowledge (ILK) refers to dynamic bodies of integrated, holistic, social and ecological knowledge, practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments (IPBES, 2021).

Indigenous Peoples' and Local Community Conserved Areas and Territories (ICCAs)
Indigenous Peoples' and Local Community Conserved Areas and Territories, referred to as ICCAs, are natural and/or modified ecosystems containing significant biodiversity values, ecological services and cultural values, voluntarily conserved by Indigenous peoples and local communities, both sedentary and mobile, through customary laws or other effective means. ICCAs can include ecosystems with

minimum to substantial human influence as well as cases of continuation, revival or modification of traditional practices or new initiatives taken up by communities in the face of new threats or opportunities. Several of them are inviolate zones ranging from very small to large stretches of land and waterscapes (ICCA Consortium, 2012).

Indigenous peoples and local communities (IPLCs)
The term "indigenous peoples and local communities" and its acronym "IPLC" are widely used by international organizations and conventions to refer to individuals and groups who self-identify as indigenous or as members of distinct local communities. We adopt this terminology in this assessment, with particular emphasis on those who "maintain an inter-generational historical connection to place and nature through livelihoods, cultural identity, languages, worldviews, institutions, and ecological knowledge" (see Chapter 1 and IPBES, 2020).

Indirect drivers
See "Drivers".

Individual transferable quotas (ITQs)
A type of quota (a part of a Total Allowable Catch) allocated to individual fishermen or vessel owners and which can be sold to others (OECD, 2005).

Industrial fisheries or large-scale fisheries
Industrial fisheries are defined as a category of capture fishery that generally present (some of) the following characteristics: (i) high capital equipment and expenditure, (ii) highly level of mechanization, motorization and onboard processing, (iii) large vessel size (> 24 m and > 50 GT), (iv) based on a business more vertically integrated, with generally global market access, (v) operating offshore on a multi-days basis (see Chapter 1).

Institutions
Institutions are defined as encompassing all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed (IPBES, 2019). This includes sets of rules, norms, values and procedures, which shape human interactions and with human interactions with nature (Brechin, 2003; McCay & Jentoft, 1996).

Institutional arrangements
Institutional arrangements can be seem as different (in)formal regimes and coalitions for collective action and inter-agent coordination, ranging from public-private cooperation and contracting schemes to organizational networking and policy arrangements (Geels, 2004; Klijn & Teisman, 2000).

Intellectual property rights
Intellectual property rights are the rights given to persons over the creations of their minds. They usually give the creator an exclusive right over the use of his/her creation for a certain period of time. Intellectual property rights are customarily divided into two main areas: rights related to copyright and industrial property (World Trade Organization, 2018).

Inter-generational equity
Inter-generational equity stipulates the rights and obligations of the current and future generations regarding the use of the environment. In the context of sustainable development, the Brundtland Report conceptualized it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (IPBES, 2018).

Intra-generational equity
Intra-generational equity relates to notions of fairness and justice across the communities and states within the present generation. Inter-generational equity stipulates the rights and obligations of the current and future generations regarding the use of the environment. In the context of sustainable development, the Brundtland Report conceptualized it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (IPBES, 2018).

Invasive alien species (IAS) / invasive species
Species whose introduction and/or spread by human action outside their natural distribution threaten biological diversity, food security, and human health and well-being. "Alien" refers to the species' having been introduced outside its natural distribution ("exotic", "non-native" and "non-indigenous" are synonyms for "alien"). "Invasive" means "tending to expand into and modify ecosystems to which it has been introduced". Thus, a species may be alien without being invasive, or, in the case of a species native to a region, it may increase and become invasive, without actually being an alien species (IPBES core glossary, 2021).

IPBES Conceptual Framework
The Platform's conceptual framework has been designed to build shared understanding across disciplines, knowledge systems and stakeholders of the interplay between biodiversity and ecosystem drivers, and of the role they play in building a good quality of life through Nature's contributions to people (IPBES core glossary, 2021).

IUCN Red list
The IUCN Red List is an indicator of the health of biodiversity. It provides taxonomic, conservation status and distribution information on plants, fungi and animals that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction, and the main purpose of the IUCN Red List is to catalogue and highlight those plants and animals that are facing a higher risk of global extinction (IUCN, 2012b)

K

Keystone species
A species whose impact on the community or ecosystem is disproportionately large relative to its abundance. Effects can be produced by consumption (trophic interactions), competition, mutualism, dispersal, pollination, disease, or habitat modification (non-trophic interactions) (Millenium Ecosystem Assessment, 2005).

Knowledge System
A body of propositions that are adhered to, whether formally or informally, and are routinely used to claim truth. They are organized structures and dynamic processes (a) generating and representing content, components, classes, or types of knowledge, that are (b) domain-specific or characterized by domain-relevant features as defined by the user or consumer, (c) reinforced by a set of logical relationships that connect the content of knowledge to its value (utility), (d) enhanced by a set of iterative processes that enable the evolution, revision, adaptation, and advances, and (e) subject to criteria of relevance, reliability, and quality (IPBES core glossary, 2021).

L

Land cover
The physical coverage of land, usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, land use (Millenium Ecosystem Assessment, 2005).

Land degradation
Refers to the many processes that drive the decline or loss in biodiversity, ecosystem functions or their benefits to people and includes the degradation of all terrestrial ecosystems. See 'Habitat degradation' (IPBES, 2019).

Land grabbing
See 'Grabbing (of wild species and space)'.

Land use
The human use of a specific area for a certain purpose (such as residential; agriculture; recreation; industrial, etc.). Influenced by, but not synonymous with, land cover. Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover (IPBES core glossary, 2021).

Landscape
An area of land that contains a mosaic of ecosystems, including human dominated ecosystems (IPBES, 2019).

Landscape heterogeneity
Landscape heterogeneity is a complex phenomenon involving the size, shape and composition of different landscape units and the spatial (and temporal) relations between them (G. Cale & J. Hobbs, 1994).

Large scale land acquisition (LSLA)
See 'Grabbing (of wild species and space)'

Law of the Sea
The United Nations Convention on the Law of the Sea (UNCLOS), in force since 1994, defines the rights and obligations of nations (167 at present) with regard to the use of the world's oceans and their resources, and the protection of the marine and coastal environment. The UNCLOS also defines national marine jurisdiction on maritime territories and provides guidelines related to the use and management of marine environment and resources (IPBES, 2019).

Legal and regulatory instruments
see "Policy instruments".

Legal pluralism
Legal pluralism is a sensitizing concept for situations in which people draw upon several legal systems, irrespective of their status within the state legal system (Benda-Beckmann & Turner, 2018).

Learning (traditional and formal)
Learning refers to the process of knowledge and skills acquisition. Studies on learning have payed attention to the different ways people acquire knowledge, practices, and beliefs (i.e., imitation, copying, trial-and-error), but also to the dynamics of knowledge transmission, or the different sources from which knowledge, practices, and beliefs are passed from one individual to another (i.e., from parents, peers, teachers, prestigious peoples, media, etc.). Social learning is defined as the acquisition of new information by copying others, and it is a key human strategy that allows for the accumulation of culturally transmitted knowledge (Boyd & Richerson, 2005; Boyd & Silk, 2014).

Livelihood diversification
Livelihood diversification is defined as the process by which rural families construct a diverse portfolio of activities and social support capabilities in their struggle for survival and in order to improve their standards of living" (Ellis, 1998).

Living in harmony with nature
Within the context of the IPBES Conceptual Framework – a perspective on good quality of life based on the interdependence that exists among human beings, other living species and elements of nature. It implies that we should live peacefully alongside all other organisms even though we may need to exploit other organisms to some degree (IPBES core glossary, 2021).

Local communities
Local communities" refers to non-indigenous communities with historical linkages to places and livelihoods characterized by long-term relationships with the natural environment, often over generations (see Chapter 1 and IPBES, 2020).

Local ecological knowledge (LEK)
Knowledge about nature, including organisms (animals and plants), ecosystems and ecological interactions, held by local people who interact with and use natural resources. This is a manifestation of indigenous local knowledge (ILK), but includes also knowledge held by those local people who may not be officially recognized as indigenous (in legal terms). Like traditional ecological knowledge, LEK can be seen as a knowledge-practice-belief complex. In other words, it is a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission (Berkes, 2012). This encompasses ways of knowing and doing, which are dynamic concepts relying on building on experience and adapting to changes, thereby imbibe a strong learning-by-doing component (Berkes, 2015).

Local economies
Local economies and subsistence economies are defined as those that are small in scale and in which the use of resources (including wild species) are limited and exclusively used to meet local needs rather than accumulated or sold for profit (Emery & Pierce, 2005; Natcher, 2009; Schumann & Macinko, 2007).

Logging
Logging is defined as the removal of whole trees or woody parts of trees from their habitat. Logging generally results in the death of the tree, but also includes cases in which it may not, such as coppicing. Logging occurs in forests that may be classified as primary, naturally regenerating, planted, and plantation. This assessment does not address logging from plantation forests except as it has bearing on the practice in the other forest types. Harvest of non-woody parts of trees (e.g., leaves, propagules and bark) are here defined as gathering (see Chapter 1).

M

Malnutrition
Malnutrition refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients. The term malnutrition covers 2 broad groups of conditions. One is 'undernutrition'—which includes stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and micronutrient deficiencies or insufficiencies (a lack of important vitamins and minerals). The other is overweight, obesity and diet-related noncommunicable diseases (such as heart disease, stroke, diabetes and cancer) (WHO, 2016).

Management of wild species
The management of wild species is the management process influencing

interactions among and between wild species, its habitats and humans to achieve predefined impacts valued by stakeholders. It attempts to balance the needs of wild species and the preservation of the ecosystems they inhabit with the needs of humans, using the best available sources of knowledge (Wikipedia, 2021).

Mangrove
Group of trees and shrubs that live in the coastal intertidal zone. Mangrove forests only grow at tropical and subtropical latitudes near the equator because they cannot withstand freezing temperatures (IPBES core glossary, 2021).

Marginal lands
Land having limitations which in aggregate are severe for sustained application of a given use. On these lands, options are limited for diversification without the use of inputs; inappropriate management of lands may cause irreversible degradation (CGIAR, 1999).

Marginalization
Marginalisation is a complex and multidimensional concept, which simply cannot be seen as a state of being (e.g., a condition of low income or food insecurity) but needs to be considered a process over time with several inter-related elements interacting with social and economic conditions, political standing, and environmental health. A full understanding of the term marginalisation needs to be based on the view that the best judge of poverty and marginalisation are the people experiencing it (Nayak & Berkes, 2010).

Marginalized community
Marginalized communities, peoples or populations are groups and communities that experience discrimination and exclusion (social, political and economic) because of unequal power relationships across economic, political, social and cultural dimensions (National Collaborating Centre for Determinants of Health (Canada), 2021).

Mariculture
A branch of aquaculture involving the culture of organisms in a medium or environment which may be completely marine (sea), or sea water mixed to various degrees with fresh water, including brackish water areas (Sivalingam, 1981).

Megadiverse country
Countries (17) which have been identified as the most biodiversity-rich countries of the world, with a particular focus on endemic biodiversity (UNEP-WCMC, 2014).

Meta-analysis
A quantitative statistical analysis of several separate but similar experiments or studies in order to test the pooled data for statistical significance (IPBES core glossary, 2021).

Micronutrients
Substances that are only needed in very small amounts but essential to organisms to produce enzymes, hormones and other substances fundamental for proper growth and development (WHO, 2015).

Millennium Ecosystem Assessment
The Millennium Ecosystem Assessment is a major assessment of the human impact on the environment published in 2005 (IPBES core glossary, 2021).

Mitigation
In the context of IPBES, an intervention to reduce negative or unsustainable uses of biodiversity and ecosystems (IPBES core glossary, 2021).

Models
Qualitative or quantitative representations of key components of a system and of relationships between these components (IPBES, 2016c).

Monitoring
Monitoring is the repeated observation of a system in order to detect signs of change (IPBES core glossary, 2021).

Mother Earth
An expression used in a number of countries and regions to refer to the planet Earth and the entity that sustains all living things found in nature with which humans have an indivisible, interdependent physical and spiritual relationship (IPBES core glossary, 2021).

Muti-use system
Multi-use systems are defined as socio-ecosystems in which occur more than one use or practice (e.g., fishing and logging in mangroves) (see Chapter 4).

Multidisciplinary Expert Panel (MEP)
The IPBES Multidisciplinary Expert Panel is a subsidiary body established by the IPBES Plenary which oversees the scientific and technical functions of the Platform, a key role being to select experts to carry out assessments (IPBES core glossary, 2021).

N

Nagoya protocol
The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) is a supplementary agreement to the 1992 Convention on Biological Diversity. It provides a transparent legal framework for the effective implementation of one of the three objectives of the CBD: the fair and equitable sharing of benefits arising out of the utilization of genetic resources, thereby contributing to the conservation and sustainable use of biodiversity. The Nagoya Protocol aims to create greater legal certainty and transparency for both providers and users of genetic resources by establishing more predictable conditions for access to genetic resources and helping to ensure benefit-sharing when genetic resources leave the country providing the genetic resources. The Nagoya Protocol on ABS was adopted on 29 October 2010 in Nagoya, Japan and entered into force on 12 October 2014 (IPBES, 2019).

National biodiversity strategies and action plans (NBSAPs)
The Convention on Biological Diversity calls on each of its Parties to prepare a National Biodiversity Strategy and Action Plan (Article 6a) that establishes specific activities and targets for achieving the objectives of the Convention. These plans mostly are implemented by a partnership of conservation organizations. Species or habitats which are the subject of NBSAPs are the governments stated priorities for action and therefore raise greater concern where they are threatened. NBSAPs do not carry legal status and listed species and habitat types are not necessarily protected (although some are covered by other legislation) (Hesselink *et al.*, 2007).

Native species
Indigenous species of animals or plants that naturally occur in a given region or ecosystem (IPBES core glossary, 2021).

Natural capital
A concept referring to the stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people (UNDP, 2016b). Within the IPBES conceptual framework, it is part of the "nature" category, representing an economic-utilitarian perspective on nature, specifically those aspects of nature that people use (or anticipate to use) as

source of Nature's contributions to people (IPBES, 2019).

Natural disaster
The effects of natural hazards, which are natural processes or phenomena occurring in the biosphere that may constitute a damaging event. Natural disasters can be for instance: earthquakes, floods, landslide, volcanic eruption, etc. (adapted from FAO, 2021).

Natural habitat
Areas composed of viable assemblages of plant and/or animal species of largely native origin and/or where human activity had not essentially modified an area's primary ecological functions and species composition (UNEP-WCMC, 2014).

Natural heritage
Natural features, geological and physiographical formations and delineated areas that constitute the habitat of threatened species of animals and plants and natural sites of outstanding universal value from the point of view of science, conservation or natural beauty (UNESCO, 1978).

Naturalized species
A species that, once it is introduced outside its native distributional range, establishes self-sustaining populations (IPBES core glossary, 2021).

Nature
In the context of IPBES, refers to the natural world with an emphasis on its living components. Within the context of western science, it includes categories such as biodiversity, ecosystems (both structure and functioning), evolution, the biosphere; humankind's shared evolutionary heritage, and biocultural diversity. Within the context of other knowledge systems, it includes categories such as Mother Earth and systems of life, and it is often viewed as inextricably linked to humans, not as a separate entity (see "Mother Earth") (IPBES core glossary, 2021).

Natural area or natural environment
Regions that have not been significantly altered by humankind. (Newsome *et al.*, 2013).

Nature-based recreation
Nature-based recreation may be defined as all forms of leisure that rely on the natural environment (Jacobs & Cottrell, 2015). In the context of this assessment, it may involve extractive practices (i.e., fishing, gathering, terrestrial animal harvesting) or non-extractive practices (i.e., observing).

Nature-based solutions
Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham *et al.*, 2016).

Nature-based tourism
Nature-based tourism is the activities of persons traveling to natural areas outside their usual environment for leisure and other purposes (based on UNWTO, glossary).
In the context of this assessment, it may involve extractive practices (i.e., fishing, gathering, terrestrial animal harvesting) or non-extractive practices (i.e., observing).

Nature's Contributions to People (NCP)
Nature's contributions to people (NCP) are all the contributions, both positive and negative, of living nature (i.e., all organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life. Beneficial contributions include e.g., food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include e.g., disease transmission and predation that damages people or their assets. NCP may be perceived as benefits or detriments depending on the cultural, temporal or spatial context (Díaz *et al.*, 2018).

IPBES considers a gradient of approaches to NCP, ranging from a purely generalizing approach to a purely context-specific one. Within the generalizing approach, IPBES identifies 18 categories of NCP, organized in three partially overlapping groups:

- Material contributions are substances, objects or other material elements from nature that directly sustain people's physical existence and material assets. They are typically physically consumed in the process of being experienced, for example when organisms are transformed into food, energy, or materials for clothing, shelter or ornamental purposes.

- Non-material contributions are nature's effects on subjective or psychological aspects underpinning people's quality of life, both individually and collectively. Examples include forests and coral reefs providing opportunities for recreation and inspiration, or particular organism (animals, plants, fungi) or habitat (mountains, lakes) being the basis of spiritual or social-cohesion experiences.

- Regulating contributions are functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people, and/or regulate the generation of material and non-material contributions. Regulating contributions frequently affect quality of life in indirect ways. For example, people directly enjoy useful or beautiful plants, but only indirectly the soil organisms that are essential for the supply of nutrients to such plants. (IPBES, 2019).

Nexus
A perspective which emphasizes the inter-relatedness and interdependencies of ecosystem components and human uses, and their dynamics and fluxes across spatial scales and between compartments. Instead of just looking at individual components, the functioning, productivity and management of a complex system is taken into consideration. In such complex systems there are trade-offs as well as facilitation and amplification between the different components. A nexus approach can help address synergies and trade-offs among multiple sectors and among various Sustainable Development Goals and biodiversity targets simultaneously (adapted from (UNU-FLORES, 2018).

Niche (ecological)
A species' position within an ecosystem. This definition includes both the abiotic and biotic conditions necessary for the species to be able to persist (e.g., temperature range, food sources) and its ecological role, function or "job" (Polechová & Storch, 2019).

Nitrogen deposition
The nitrogen transferred from the atmosphere to the Earth's surface by the processes of wet deposition and dry deposition (IPCC, 2014).

Nitrogen-fixing species
Plants, such as legumes, living in symbiosis with micro-organisms in their roots that can perform biological nitrogen fixation, i.e., convert atmospheric nitrogen (N_2) to ammonia (NH_3). Plants can then assimilate NH_3 to produce biomolecules (Wagner, 2011).

Non-Indigenous Species or Non-native species or Alien species
See “Invasive alien species”.

Non-extractive practices
Non-extractive practices are defined as practices based on the observation of wild species in a way that does not involve the harvest or removal of any part of the organism. The observation can imply some interaction with the wild species, such as the activities of wildlife and whale watching or no interaction with the wild species, such as remote photography (see Chapter 1).

Non-lethal harvest
Non-lethal harvest is defined as the temporary or permanent capture of live animals from their habitat without mortality, such as for the aquarium trade, pet trade or zoos, tag and release activities. Non-lethal harvest of animals also includes the parts or products of animals that do not lead to the mortality of the host, such as vicuna fiber, swift nests or wild honey (see Chapter 1).

Nutrient cycling
The processes by which elements are extracted from their mineral, aquatic, or atmospheric sources or recycled from their organic forms, converting them to the ionic form in which biotic uptake occurs and ultimately returning them to the atmosphere, water, or soil (Millenium Ecosystem Assessment, 2005).

O

Observing
Observing is defined as a non-extractive practice that is based on the observation of wild species. The observation can imply some interaction with the wild species, such as the activities of wildlife tourism and whale watching or no interaction with the wild species, such as photography (see Chapter 1).

Ocean acidification
A reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean. Anthropogenic ocean acidification refers to the component of pH reduction that is caused by human activity (IPCC, 2014).

Oligotrophic
Nutrient-poor environment (IUCN, 2012a).

Overexploitation
Overexploitation means harvesting species from the wild at rates faster than natural populations can recover. Includes overfishing, and overgrazing (IPBES core glossary, 2021).

Overgrazing
Overgrazing occurs when plants are exposed to intensive grazing for extended periods of time, or without sufficient recovery periods. It can be caused by either livestock in poorly managed agricultural applications, game reserves, or nature reserves. It can also be caused by immobile, travel restricted populations of native or non-native wild animals (IPBES, 2018).

P

Participatory methods
Participatory research methods are a variety of qualitative and quantitative methods “geared towards planning and conducting the research process with those people whose life-world and meaningful actions are under study” (Bergold & Thomas, 2012). Participatory methods acknowledge the possibility, the significance, and the usefulness of involving research partners in the knowledge-production process (Bergold, 2007).

Participatory process
Specific methods employed to achieve active participation by all members of a group in a decision-making process (Chatty *et al.*, 2003).

Participatory governance
A variant or subset of governance which puts emphasis on democratic engagement, in particular through deliberative practices (IPBES core glossary, 2021).

Pathways
In the context of the IPBES global assessment, trajectories toward the achievement of goals and targets for biodiversity conservation and management of nature and Nature’s contributions to people (IPBES core glossary, 2021).

Payment for ecosystem services (PES)
Payments for Ecosystem Services (PES) are a specific class of approach, used to facilitate voluntary transaction between a provider and a user of a service, conditioned on natural resource management rules for dealing with environmental externalities (Wunder, 2015). PES is created to deal with market failures, environmental externalities, property rights problems and asymmetric information between economic actors.

Peatlands
Wetlands which accumulate organic plant matter *in situ* because waterlogging prevents aerobic decomposition and the much slower rate of the resulting anaerobic decay is exceeded by the rate of accumulation (IPBES core glossary, 2021).

Pelagic
Occurring or living in open waters or near the surface with little contact with or dependency on the bottom (IUCN, 2012a).

Persistent organic pollutants (POPs)
Organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. POPs persist in the environment for long periods, are capable of long-range transport, bioaccumulate in human and animal tissue and biomagnify in food chains, and have potentially significant impacts on human health and the environment. Exposure to POPs can cause serious health problems including certain cancers, birth defects, dysfunctional immune and reproductive systems, greater susceptibility to disease and even diminished intelligence (Stockholm Convention Secretariat, 2017).

Phenology
The study of the relationship between climate and the timing of periodic natural phenomena such as migration of birds, bud bursting, or flowering of plants (IUCN, 2012a).

Phenotype
The characteristics of an individual resulting from interaction between its genotype (genetic constitution) and its environment (IUCN, 2012a).These characteristics often include behavior, physiology (e.g., oxygen consumption, heart rate), life history (e.g., body size, age, offspring number), or morphology (e.g., body proportions).

Phenotypic attributes (biodiversity)
A distinct variant of a phenotypic characteristic of an organism; it may be either inherited or determined environmentally, but typically occurs as a combination of the two (Lawrence, 2005).

Phylogenetic diversity
Although species richness is a commonly used measure of biodiversity, it fails to capture the reality that species without

close relatives contribute more uniqueness than do species with many close relatives. Phylogenetic diversity is used as a general term for a range of measures that consider the total length of all the branches linking a set of species on their phylogeny ("evolutionary tree") and so reflect species' evolutionary uniqueness. One of the first such measures (Faith, 1992) is simply the sum of the branch lengths.

Plankton
Aquatic organisms that drift or swim weakly. Phytoplankton are the plant forms of plankton (e.g., diatoms), and are the dominant plants in the sea. Zooplankton are the animal forms of plankton. Picoplankton are all forms of plankton which size is comprised between 0.2 and 2 micrometers (mostly bacteria) (Mullin, 2001).

Plenary
Within the context of IPBES – the decision-making body comprising all of the members of IPBES (IPBES core glossary, 2021).

Poaching
Poaching is defined as the illegal removal of wild species from a place where such practices are specially reserved or forbidden.

Policy instrument
Policy instruments can be defined as "the set of techniques by which governmental authorities wield their power in attempting to ensure support and effect or prevent social change (Vedung, 2017). In this assessment, the following four categories of policy instruments are identified:

- **Legal and regulatory instruments:** legal and regulatory instruments include legislation, standards, regulations, rules, agreements, planning and so on.

- **Economic and financial instruments:** economic and financial instruments include traditional fiscal instruments, including for example taxes (and tax reliefs), subsidies and charges and conditional and voluntary incentive scheme such as payment for environmental services (PES). What we term economic and financial instruments are any policy options that use prices as a basis for the governance of wild species.

- **Social and Instruments:** Social and information-based instruments include community-based instruments, education/training, counselling, certification schemes, ecolabels, corporate social responsibility, and so on

- **Rights-Based and Customary Instruments:** Right-based instruments include human rights, customary norms and traditional knowledge. The unwritten, negotiable and relational nature of customary law is an important determinant for programming, as is the variety in normative beliefs and practices within customary communities. Customary norms are formulated, renegotiated and flexibly applied in administrative structures and dispute settlement institutions. (IPBES, 2021)

Policy options
(for the use of wild species)
Policy options are defined as potential policies in terms of their ability to achieve the stated policy goals. Chapter 6 present the range of policy options available to support the sustainable use of wild species, at a range of spatial scales (local, national, international), and across five key practices (fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices). Four groups of policy instruments are explored: i) legal and regulatory, ii) economic and financial, iii) social and information based, and iv) rights-based and customary instruments (see Chapter 6, section 6.4).

Policy Support Tools
Approaches and techniques based on science and other knowledge systems that can inform, assist and enhance relevant decisions, policy making and implementation at local, national, regional and global levels to protect nature, thereby promoting Nature's contributions to people and a good quality of life (IPBES core glossary, 2021).

Pollination
The transfer of pollen from an anther to a stigma. Pollination may occur within flowers of the same plant, between flowers of the same plant, or between flowers of different plants (or combinations thereof) (IPBES, 2016a).

Pollution
Pollution is the introduction of contaminants into the natural environment that cause adverse change (IPBES, 2018).

Polycentric governance
An organizational structure where multiple independent actors mutually order their relationships with one another under a general system of rules (Ostrom, 2010).

Poverty
Poverty is a pronounced deprivation of well-being related to lacking the means of material subsistence. Its manifestations include hunger and malnutrition, limited access to education and other basic services. Other corollaries of poverty are social discrimination and exclusion as well as the lack of participation in decision-making (adapted from (IPBES core glossary, 2021).

Practices (type of wild species practices)
See "gathering", "fishing", "terrestrial animal harvesting", "logging", "non-extractive practices" and "non-lethal harvest".

Primary production
The conversion of energy to organic substances by photosynthetic and chemosynthetic autotrophic organisms (IPBES, 2018).

Prior informed consent (PIC)
See "Free, prior and informed consent (FPIC)".

Precautionary principle
Pertains to risk management and states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is not harmful, the burden of proof that it is not harmful falls on those taking an action. The principle is used to justify discretionary decisions when the possibility of harm from making a certain decision (e.g., taking a particular course of action) is not, or has not been, established through extensive scientific knowledge. The principle implies that there is a social responsibility to protect the public from exposure to harm, when scientific investigation has found a plausible risk or if a potential plausible risk has been identified (IPBES core glossary, 2021).

Protected area
A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IPBES core glossary, 2021).

Provisioning services
The products people obtain from ecosystems; may include food, freshwater, timber, fibers, medicinal plants (IPBES, 2018).

R

Ramsar Convention on Wetlands
The Convention on Wetlands, called the Ramsar Convention, of International Importance especially as Waterfowl Habitat, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources (IPBES, 2018).

Ramsar site(s)
A Ramsar site is a wetland site designated of international importance especially as Waterfowl Habitat under the Ramsar Convention, an intergovernmental environment treaty established in 1975 by UNESCO, coming into force in 1975. Ramsar site refers to wetland of international significance in terms of ecology, botany, zoology, limnology or hydrology. Such site meets at least one of the criteria of Identifying Wetlands of International Importance set by Ramsar Convention and is designated by appropriate national authority to be added to Ramsar list (IPBES core glossary, 2021).

Rangeland
Natural grasslands used for livestock grazing (IPBES core glossary, 2021).

Rebound effect
The pattern by which resource users tend to compensate for improved efficiency by shifting behavior towards greater consumption, which undermines apparent gains. For example, an increased fuel saving of motor vehicle tends to be compensated by spending more money on other resources or by driving more (Alcott, 2005).

Recreational uses (of wild species)
Recreational uses are defined as uses of wild species in which enjoyment is considered a primary value.

Recruitment
The influx of new members into a population by reproduction or immigration (IUCN, 2012a).

Reduced impact logging (RIL)
The intensively planned and carefully controlled implementation of timber harvesting operations to minimize the environmental impact on forest stands and soils (FAO, 2021).

Reducing emissions from deforestation and forest degradation (REDD+)
Mechanism developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It creates a financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. Developing countries would receive results-based payments for results-based actions. REDD+ goes beyond simply deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (IPBES core glossary, 2021).

Reforestation
Planting of forests on lands that have previously contained forests but that have been converted to some other use (IPCC, 2014).

Regime
A long-term qualitative behavior where the system's dynamics tend to stabilize, at different spatial and temporal scales in marine, terrestrial and polar systems (Rocha *et al.*, 2015).

Regime shift
Substantial reorganization in system structure, functions and feedbacks that often occurs abruptly and persists over time (IPBES core glossary, 2021).

Rehabilitation
Rehabilitation refers to restoration activities that move a site towards a natural state baseline in a limited number of components (i.e., soil, water, and/or biodiversity), including natural regeneration, conservation agriculture, and emergent ecosystems (IPBES core glossary, 2021).

Relational value
See "Values".

Remote sensing
Methods for gathering data on a large or landscape scale which do not involve on-the ground measurement, especially satellite photographs and aerial photographs; often used in conjunction with Geographic Information Systems (IUCN, 2012a).

Resilience
The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (B. Walker *et al.*, 2004).

Resolution (spatial or temporal)
See "scales"

Restoration
Any intentional activities that initiate or accelerate the recovery of an ecosystem from a degraded state (IPBES core glossary, 2021).

Richness (biodiversity)
The number of biological entities (species, genotypes, etc.) within a given sample. Sometimes used as synonym of species diversity (IPBES core glossary, 2021).

Rights-Based and Customary Instruments
See "Policy instruments".

Ritual uses (of wild species)
See "Ceremonial uses"

Roundwood (industrial)
Industrial round wood is defined as all roundwood used for any purpose other than energy. It comprises pulpwood, sawlogs and veneer logs (see Chapter 3).

Rules and regulations
Set of rules to govern the work and decision making of its formal settings (United Nations Environment Programme & United Nations Environment Programme, 2007).

Rural development
Rural development is the process of improving the opportunities and well-being of rural people. It is a process of change in the characteristics of rural societies. In addition to agricultural development, it involves human development and social and environment objectives, as opposed to just economic ones. Therefore, rural development encompasses health, education, and other social services. It also uses a multisector approach for promoting agriculture, extracting minerals, tourism, recreation, and niche manufacturing (IFAD, 2004).

S

Sacred groves
A particular type of sacred natural sites represented by patches of forest revered

as sacred (Bhagwat & Rutte, 2006). Sacred groves may be revered e.g., as burial grounds (Mgumia & Oba, 2003) or sites of ancestral or deity worship (Ramakrishnan *et al.*, 1998). There are locally-established rules that regulate how sacred groves can be used (Hughes & Chandran, 1998). Observation of those rules often contributes to the biodiversity conservation on those sites (Bhagwat & Rutte, 2006).

Sacred natural sites
Areas of land or water that have special spiritual significance to peoples and communities (Verschuuren *et al.*, 2010). They consist of natural features, ranging from entire ecosystems, such as mountains, forests or islands, to single natural features such as a tree, spring or boulder, and are very important for the conservation of nature and culture. Sacred natural sites have been managed based on indigenous and local knowledge systems, developed over long periods of time, and are source of cultural identity.

Savanna
Biome characterized by a continuous layer of herbaceous plants, mostly grasses, and a discontinuous upper layer of trees that may vary in density (modified from IPBES, core glossary).

Sawnwood
Sawnwood is defined as planks, sleepers (cross-ties), beams, joists, boards, rafters, 1679 scantlings, laths, boxboards and lumber that exceed 5 mm in thickness (see Chapter 3).

Scale
Definitions of scale abound. For purposes of this assessment, scale is defined as the spatial or temporal extent of an object, event, or phenomenon and/or the unit of measure used in its analysis.

The temporal scale is comprised of two properties:

- temporal extent – the total length of the time period of interest for a particular study (e.g., 10 years, 50 years, or 100 years);

- temporal grain (or resolution) – the temporal frequency with which data are observed or projected within this total period (e.g., at 1-year, 5-year or 10-year intervals).

The spatial scale is comprised of two properties:

- spatial extent – the size of the total area of interest for a particular study (e.g., a watershed, a country, the entire planet);

- spatial grain (or resolution) – the size of the spatial units within this total area for which data are observed or predicted (e.g., fine-grained or coarse-grained grid cells) (IPBES core glossary, 2021).

Scenarios
Representations of possible futures for one or more components of a system, particularly, in this assessment, for drivers of change in nature and nature's benefits, including alternative policy or management options.

- Exploratory scenarios (also known as "explorative scenarios" or "descriptive scenarios") are scenarios that examine a range of plausible futures, based on potential trajectories of drivers – either indirect (e.g., socio-political, economic and technological factors) or direct (e.g., habitat conversion, climate change).

- Target-seeking scenarios (also known as "goal-seeking scenarios" or "normative scenarios") are scenarios that start with the definition of a clear objective, or a set of objectives, specified either in terms of achievable targets, or as an objective function to be optimized, and then identify different pathways to achieving this outcome (e.g., through backcasting).

- Intervention scenarios are scenarios that evaluate alternative policy or management options – either through target seeking (also known as "goal seeking" or "normative scenario analysis") or through policy screening (also known as "ex-ante assessment").

- Policy-evaluation scenarios are scenarios, including counterfactual scenarios, used in ex-post assessments of the gap between policy objectives and actual policy results, as part of the policy-review phase of the policy cycle.

- Policy-screening scenarios are scenarios used in ex-ante assessments, to forecast the effects of alternative policy or management options (interventions) on environmental outcomes (IPBES, 2016b; IPBES core glossary, 2021).

Sea ice
Any form of ice found at sea which has originated from the freezing of sea water (sea ice does not include superstructure icing). Ice formed from the freezing of the waters of the Great Lakes will be considered the same as sea ice (NOAA's National Weather Service, 2009).

Seascape
Seascape can be defined as a spatially heterogeneous area of coastal environment (i.e., intertidal, brackish) that can be perceived as a mosaic of patches, a spatial gradient, or some other geometric patterning. The tropical coastal "seascape" often includes a patchwork of mangroves, seagrass beds, and coral reefs that produces a variety of natural resources and ecosystem services (IPBES core glossary, 2021).

Sector
A distinct part of society, or of a nation's economy (IPBES core glossary, 2021).

Second-growth forest
Regenerating forest after disturbance, such as fire or clear-cutting (IUCN, 2012a).

Selective hunting
Selective hunting, in this assessment, refers to situations where hunters focus on particular species, or on individual animals within a population that have particular attributes, e.g., large size, large horns or antlers.

Semi-natural ecosystems
An ecosystem with most of its processes and biodiversity intact, though altered by human activity in strength or abundance relative to the natural state (IPBES core glossary, 2021).

Sense of place
Characteristics that make a place special or unique, as well as to those that foster a sense of authentic human attachment and belonging (Casey, 2001).

Shamanism
A system that links people to the vital forces of nature, especially the soul or inner-self of non-humans or nature spirits, through the mediation of a specialist, the shaman. Shamans are generally trained through enduring experiences including the consumption of psychotropic substances that lead them to experience spiritual connections that are mobilized to combat

illness and any dangers that may affect their community (IPBES, 2019).

Shared socio-economic pathways (SPPs)
Shared Socio-economic Pathways (SSPs) describe alternative socioeconomic futures in the absence of climate policy intervention, comprising sustainable development (SSP1), regional rivalry (SSP3), inequality (SSP4), fossil–fuelled development (SSP5) and middle-of-the-road development (SSP2). The combination of SSP-based socio-economic scenarios and Representative Concentration Pathway (RCP)-based climate projections provides an integrative frame for climate impact and policy analysis (IPCC, 2018).

Shifting cultivation
An agricultural system in which plots of land are cultivated temporarily, then abandoned to regenerate soil fertility by the regeneration of natural vegetation. The system involves 1) the removal of the natural vegetation (usually forest or shrub land) in most cases (though not exclusively) by cutting and subsequent burning, mulching, or their combinations (such as in slash-and-burn, slash-and-mulch); 2) an alternation between a short duration of cultivation and a comparatively long duration of bush or forest fallow (such as in swidden agroforestry); and 3) the regular, in most cases cyclical, shifting of field (Erni, 2015). Shifting cultivation systems are found around the world, particularly in tropical areas, in a wide range of soils and vegetation types, under a diversity of land and resource management, using different crops and cultivation methods, and are practiced by innumerous Indigenous Peoples and Local Communities (Heinimann *et al.*, 2017; Nye & Greenland, 1960).

Silviculture
The art and science of controlling the establishment, growth, composition, health and quality of forest and woodlands to meet the targeted diverse needs and values of landowners and society on a sustainable basis (FAO, 2006).

Slash-and-burn agriculture
See 'Shifting cultivation'.

Small-scale or non-industrial fisheries
Small-scale fisheries are defined as a category of capture fishery that generally present (some of) the following characteristics: (i) low capital investment, (ii) high labor activities often family or community-based, (iii) no vessel or small size vessel (< 12m and < 10 GT), (iv) relatively low production, which is household consumed or locally and directly sold and (v) operating close to the shoreline on a single day basis (see Chapter 1).

Social capital
As used in the global assessment, social capital refers to networks together with shared norms, values and understandings that facilitate co-operation within or among groups. Put together, these networks and understandings engender trust and so enable people to work together (OECD, 2007b).

Social norms
A social norm is what people in some group believe to be normal in the group, that is, believed to be a typical action, an appropriate action, or both (Gerry Mackie *et al.*, 2015).

Social and cultural based Instruments
see "Policy instruments".

Social safety net
Social welfare services provided by a community of individuals at the state and local levels. These services are geared toward eliminating poverty in a specific area. These services may include housing re-assignment, job placement, subsidies for household bills, and other cash equivalents for food. Social safety net works in conjunction with a number of other poverty reduction programs with the primary goal of reducing/preventing poverty (UNESCWA, 2015).

Social welfare
The condition of a society emphasizing happiness and contentment; social welfare relates to how individuals use their relationships to other actors in societies for their own and for the collective good; it has both material elements and wider spiritual and social dimensions (Adger, 2003).

Socio-ecological production landscapes and seascapes (SEPLS)
Dynamic mosaics of habitats and land uses where the harmonious interaction between people and nature maintains biodiversity while providing humans with the goods and services needed for their livelihoods, survival and well-being in a sustainable manner (IPSI, 2018).

Social-ecological or Socio-ecological system
Social-ecological systems are complex adaptive systems in which people and nature are inextricably linked, in which both the social and ecological components exert strong influence over outcomes. The social dimension includes actors, institutions, cultures and economies, including livelihoods. The ecological dimension includes wild species and the ecosystem they inhabit.

Soil fertility
The capacity of a soil to receive, store and transmit energy to support plant growth. It is the component of overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own reserves and through external applications for crop production (FAO, 2018b).

Soil organic matter (SOM)
Matter consisting of plant and/or animal organic materials, and the conversion products of those materials in soils (FAO & ITPS, 2015).

Soil quality
Soil quality is a measure of the soil's ability to provide ecosystem and social services through its capacities to perform its functions under changing conditions. Soil quality reflects how well a soil performs the functions of maintaining biodiversity and productivity, partitioning water and solute flow, filtering and buffering, nutrient cycling, and providing support for plants and other structures (IPBES core glossary, 2021).

Species
An interbreeding group of organisms that is reproductively isolated from all other organisms, although there are many partial exceptions to this rule in particular taxa. Operationally, the term species is a generally agreed fundamental taxonomic unit, based on morphological or genetic similarity that once described and accepted is associated with a unique scientific name (Millenium Ecosystem Assessment, 2005).

Species composition
The array of species in a specific sample, community, or area (IPBES core glossary, 2021).

Species distribution models
Species distribution models relate field observations of the presence/absence of a species to environmental predictor variables,

based on statistically or theoretically derived response surfaces, for prediction and inference. The predictor variables are often climatic but can include other environmental variables (IPBES core glossary, 2021).

Species richness
The number of species within a given sample, community, or area (IPBES core glossary, 2021).

Species traits
The morphological, physiological, phonological or behavioral characteristics of an organism, that typically inform about its response to the environment and effects on the ecosystem (Lavorel & Garnier, 2002; Violle *et al.*, 2007).

Spillover effects
Human impacts or natural disturbances beyond system boundaries. These effects can be positive or negative, socioeconomic or/and environmental and can be much more profound than the effects within the focal system (Liu *et al.*, 2013).

Stability (socio-ecological system)
The degree to which a system can continue to function if inputs, controls, or conditions are disrupted. It is a reflection of how minor a perturbation is capable of rendering the system inoperable or degraded; the types of perturbation to which the system is especially vulnerable; whether the system can "ignore" certain stresses; and the degree to which the system can be altered by surprise (Kerner & Thomas, 2014).

Stakeholders
Any individuals, groups or organizations who affect, or could be affected (whether positively or negatively) by a particular issue and its associated policies, decisions and action (IPBES core glossary, 2021).

State (socio-ecological system)
The collection of variables that describe the whole of the social–ecological system, including the attributes of ecosystem service providers and beneficiaries (Harrington *et al.*, 2010).

Status
Based in actual observations (data) (IPBES, 2016c)

Stewardship practices
The responsible use and protection of the natural environment through conservation actions, active restoration and the sustainable use and management of resources (Bennett *et al.*, 2018).

Subsistence
Subsistence is defined as the livelihood uses in which a species is used or consumed directly by the individual who obtained it from the wild and his/her/their direct social network (see Chapter 1).

Succession (ecological)
The process whereby communities of plants, animals and microorganisms are replaced by others, usually more complex, over time as an area is colonized. Primary succession occurs on bare ground (e.g., after a volcanic eruption); secondary succession follows the interruption of a primary succession, e.g., after disturbances such as logging, ploughing or burning (Lawrence, 2005).

Summary for Policy-makers
A component of any report, providing a policy-relevant but not policy prescriptive summary of that report (IPBES core glossary, 2021).

Sustainable development
Development that meets the needs and aspirations of the current generation without compromising the ability to meet those of future generations (Hesselink *et al.*, 2007).

Sustainable Development Goals (SDGs)
A set of goals adopted by the United Nations on September 25, 2015 to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years (IPBES, 2018).

Sustainable livelihood
Sustainable livelihoods is defined as the ability of the users to cope with and respond to the stresses and shocks related to fluctuations in the Nature's contribution to people that adversely impact their material, relational and subjective dimensions of life and create vulnerabilities, develop their capabilities to strengthen access and entitlements to the variety of livelihood resources, without unnecessarily undermining the natural resource base (the wild species and its natural environment), so as to achieve a desirable standard of living that befits them as humans and also approved by the measures of wellbeing and human development (Allison & Horemans, 2006; Chambers & Conway, 1992).

Sustainable use
Sustainable use is defined by the Convention on Biological Diversity since 1992 as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations." This assessment notes that sustainable use is also an outcome of social-ecological systems that aim to maintain biodiversity and ecosystem functions in the long term, while contributing to human well-being. It is a dynamic process as wild species, the ecosystems that support them and the social systems within which uses occur, change over time and space.

This assessment notes the social, economic, and environmental dimensions of sustainability as identified by the 2030 Agenda for sustainable development and its Sustainable Development Goals.

Synergies
The interaction or cooperation of two or more agents to produce a combined effect greater than the sum of their separate effects (IPBES, 2018).

Synthetic biology
Adopted as a working definition definition by the Convention on Biological Diversity AHTEG on Synthetic Biology, Synthetic biology was defined as "a further development and new dimension of modern biotechnology that combines science, technology, and engineering to facilitate and accelerate the understanding, design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems" (CBD, 2016).

Systematic review
Collation and critical analysis of multiple research studies or papers, using a structured methodology (IPBES, 2018).

T

Taboo
A social or religious custom prohibiting or restricting a particular practice or forbidding association with a particular person, place, or behavior (IPBES, 2019).

Target-seeking scenarios
See "scenarios"

Taxon/Taxonomic group
A category applied to a group in a formal system of nomenclature, e.g., species, genus, family etc. (plural: taxa) (IPBES core glossary, 2021).

Telecoupling
Socioeconomic-environmental interactions over distances (Liu *et al.*, 2013). It is an umbrella concept that encompasses various types of distant interactions, such as international trade, tourism, migration, foreign investment, species invasion, payments for ecosystem services, water transfer, information dissemination, knowledge transfer, and technology transfer (Liu *et al.*, 2015).

Temporal Scales
Measurements or other observations reported along a time series (IPBES, 2018).

Tenure
Tenure systems define who can use which Nature's contributions to people, for how long and under what conditions.

Three related aspects of tenure offer a comprehensive understanding of the term. They include (1) tenure as a set of rights, (2) key responsibilities in relation to tenure, and (3) enabling conditions that facilitate governance of tenure. From this combined perspective, tenure is understood as the combination of a set of specific rights that connect the resource users with various aspects of the resource and puts the control and decision-making power in their hands. These rights span social, ecological, economic, and political aspects of tenure, and help provide directions to moving toward effective governance. Rights are connected with responsibilities that range from the duties of the users to maintain the resource to the duties to be performed by the state, and those jointly by both. The exercise of tenure rights can only be possible if certain conditions are meaningfully met because they offer the much required social, ecological, and political environment for the operationalization of tenure rights, performance of the tenure related duties, and necessary security and protection against tenure violations.

From an integrated social-ecological (human-environmental) systems perspective, tenure is defined as relationships (also interactions and connections) between people (the users) who seek tenure and between the people (users) and the environment (includes the resource) to which tenure is being sought. Governance of tenure is then about the manner in which these host of relationships, interactions, and connections are addressed and promoted. Tenure in the context of sustainable use of wild species is not a static concept and, therefore, can be best understood as a process and its governance as continuous (Díaz *et al.*, 2018; FAO, 2015; IPBES core glossary, 2021; Nayak, 2017).

Tenure security
An agreement between an individual or group to land and residential property, which is governed and regulated by a legal and administrative framework includes both customary and statutory systems (Payne & Durand-Lasserve, 2012).

Terrestrial animal harvesting
Terrestrial animal harvesting is defined as the removal from their habitat of animals (vertebrates and invertebrates) that spend some or all of their life cycle in terrestrial environments. As for fishing, terrestrial animal harvesting often results in the death of the animal, but it may not in some cases. To reflect both situations, terrestrial animal harvesting has been sub-divided into a lethal and a "non-lethal" category. Hunting is defined as the lethal category of terrestrial animal harvesting which leads to the killing of the animal, such as in trophy hunting. "Non-lethal" terrestrial animal harvesting is defined as the temporary or permanent capture of live animals from their habitat without intended mortality, such as pet trade, falconry or green hunting. Non-lethal harvest of animals also includes removal of parts or products of animals that do not lead to the mortality of the host, such as vicuña fiber or wild honey. Unintended mortality may however occur in this category and the term "non-lethal" is therefore put in quotes. (see Chapter 1).

Territorial use rights in fisheries (TURFs)
The restriction of access to, and use of, a particular fishing ground or site to a small group or an individual. This group can determine how to harvest fish from the site and to whom the fish is allocated (Ward *et al.*, 2004).

Threatened species
In the IUCN Red List terminology, a threatened species is any species listed in the Red List categories Critically Endangered, Endangered, or Vulnerable (IPBES core glossary, 2021).

Threshold effect
Harmful or fatal effect of a small change in environmental conditions that exceeds the limit of tolerance of an organism or population of a species (Miller & Spoolman, 2009).

Tipping point
A set of conditions of an ecological or social system where further perturbation will cause rapid change and prevent the system from returning to its former state (IPBES core glossary, 2021).

Total allowable catch (TAC)
The total catch allowed to be taken from a resource within a specified time period (usually a year) by all operators; designated by the regulatory authority. Usually allocated in the form of quotas (IUCN, 2012a).

Totemism
A principle or an ontology found within societies that differentiate different sections of the society, according to the attachment of these sections to animal or plant tutelar spirits. In other words, totemism defines discontinuities in social order according to each group's attachment to a specific animal or plant spirit that is perceived as having similar features to this section (or clan) and an inner-self that also resembles people in this section (and reciprocally) (IPBES, 2019).

Trade (formal or informal)
Trade is defined in formal markets as the exchanges in which records are kept and statistics generated. It is expected that currency is the medium of exchange in formal markets. Trade in informal markets encompasses exchanges in which neither records nor statistics are generated; the medium of exchange may be currency or goods and/or services (see Chapter 1).

Trade-off
A trade-off is a situation where an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of a different aspect. Trade-offs characterize most complex systems, and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes. Trade-offs are distinct from synergies (the latter are also referred to as "win-win" scenarios): synergies arise when the enhancement of one desirable outcome leads to enhancement of another (IPBES, 2019).

Traditional and community-based management systems
Resource management strategies and practices based on accumulated indigenous and local knowledge acquired through community-based learning processes and transmitted between successive generations (IPBES, 2019).

Traditional Knowledge (TK)
The concept of Traditional Knowledge (TK) in the Convention for Biological Diversity (CBD) has two characteristics. Firstly, CBD defines TK as one kind of knowledge, innovations and practices which is helpful to conservation and sustainable use of biodiversity. Secondly, CBD limits the TK to link with indigenous peoples and local communities (IPLCs) embodying traditional lifestyles, i.e., these TK were created and preserved by IPLCs and they are accumulated, developed and inherited generation by generation (IPBES, 2018).

Traditional Ecological Knowledge (TEK
Traditional Ecological Knowledge (TEK) is a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. Further, TEK is an attribute of societies with historical continuity in resource use practices; by and large, there are non-industrial or less technologically advanced societies, many of them indigenous or tribal (Berkes, 1993).

Traditional medicinal practice
Traditional medicine is the sum total of the knowledge, skill, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness (WHO, 2008, 2013).

Transboundary
Flows, interactions, relationships across boundary, in reference to jurisdictions, political units, physical nature features (IPBES, 2018).

Transformative change
Transformative change is defined in line with previous work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services approved by its Plenary, as a fundamental, system-wide reorganization across technological, economic and social factors, including paradigms, goals and values (IPBES, 2019), needed for the conservation and sustainable use of biodiversity, good quality of life and sustainable development.

Trends
The general direction in which the structure or dynamics of a system tends to change, even if individual observations vary (IPBES, 2016c).

Trophic cascades
The chain of knock – on extinctions observed or predicted to occur following the loss of one or a few species that play a critical role (e.g., as a pollinator) in ecosystem functioning (IPBES core glossary, 2021).

Trophic level
The level in the food chain in which one group of organisms serves as a source of nutrition for another group of organisms (e.g., primary producers, primary or secondary consumers, decomposers) (IPBES, 2019).

Trophy hunting
Trophy hunting is defined as the hunting for one or more individuals of a particular species with specific desired characteristics (such as large size or antlers) with the payment of a fee by a hunter for a hunting experience and trophy. The most common trophy is the mounted head with horns or antlers, although other parts of animal body (e.g., skins, tails, teeth, heads) or even the whole bodies can be also appreciated as a trophy (see Chapter 3).

U

Uncertainty
Any situation in which the current state of knowledge is such that:

1. the order or nature of things is unknown,
2. the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, and
3. credible probabilities to possible outcomes cannot be assigned.

Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty can be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts) (IPBES core glossary, 2021).

Units of analysis
The IPBES Units of Analysis result from subdividing the Earth's surface into units solely for the purposes of analysis. The following have been identified as IPBES units of analysis globally:

Terrestrial:

- Tropical and subtropical dry and humid forests
- Temperate and boreal forests and woodlands
- Mediterranean forests, woodlands and scrub
- Tundra and High Mountain habitats
- Tropical and subtropical savannas and grasslands
- Temperate Grasslands
- Deserts and xeric shrublands
- Wetlands – peatlands, mires, bogs
- Urban/Semi-urban
- Cultivated areas (incl. cropping, intensive livestock farming etc.)

Aquatic, including both marine and freshwater:

- Cryosphere
- Aquaculture areas
- Inland surface waters and water bodies/freshwater
- Shelf ecosystems (neritic and intertidal/littoral zone)
- Open ocean pelagic systems (euphotic zone)
- Deep-Sea
- Coastal areas intensively used for multiple purposes by humans

These IPBES terrestrial and aquatic units of analysis serve as a framework for comparison within and across assessments and represent a pragmatic solution. The IPBES terrestrial and aquatic units of analysis are not intended to be prescriptive for other purposes than those of IPBES assessments. They are likely to evolve as the work of IPBES develops (IPBES core glossary, 2021).

Upwelling

A process in which deep, cold water rises toward the surface replacing warmer water pushed away by winds. Water that rises to the surface as a result of upwelling is typically colder and rich in nutrients, which "fertilize" surface waters, meaning that these surface waters often have high biological productivity (NOAA, 2018b).

Urbanization
The increase in the proportion of a population living in urban areas; the process by which a large number of people becomes permanently concentrated in relatively small areas, forming cities (OECD, 2001b).

Use of wild species
The wild species uses are defined through the practices of fishing, gathering, terrestrial animal harvesting, logging, and non-extractive practices. For the purposes of this assessment, the use of wild species have been divided into different categories, which are not mutually exclusive: ceremony and ritual expression, decorative and aesthetic, energy, food and feed, learning and education, materials and construction, medicine and hygiene, recreation and other: e.g., companionship (see Chapter 1).

V

Values
Value systems: Set of values according to which people, societies and organizations regulate their behavior. Value systems can be identified in both individuals and social groups (Pascual *et al.*, 2017).

- Value (as principle): A value can be a principle or core belief underpinning rules and moral judgments. Values as principles vary from one culture to another and also between individuals and groups (IPBES, 2015).

- Value (as preference): A value can be the preference someone has for something or for a particular state of the world. Preference involves the act of making comparisons, either explicitly or implicitly. Preference refers to the importance attributed to one entity relative to another one (IPBES, 2015).

- Value (as importance): A value can be the importance of something for itself or for others, now or in the future, close by or at a distance. This importance can be considered in three broad classes. 1. The importance that something has subjectively, and may be based on experience. 2. The importance that something has in meeting objective needs. 3. The intrinsic Please do not cite, quote or circulate 1733 value of something (IPBES, 2015).

- Value (as measure): A value can be a measure. In the biophysical sciences, any quantified measure can be seen as a value (IPBES, 2015).

- Non-anthropocentric value: A non-anthropocentric value is a value centered on something other than human beings. These values can be non-instrumental or instrumental to non-human ends (IPBES, 2015).

- Intrinsic value: This concept refers to inherent value, that is the value something has independent of any human experience or evaluation. Such a value is viewed as an inherent property of the entity and not ascribed or generated by external valuing agents (Pascual *et al.*, 2017).

- Anthropocentric value: The value that something has for human beings and human purposes (Pascual *et al.*, 2017).

- Instrumental value: The value attributed to something as a means to achieving a particular end (Pascual *et al.*, 2017).

- Non-instrumental value: The value attributed to something as an end in itself, regardless of its utility for other ends.

- Relational value: The values that contribute to desirable relationships, such as those among people or societies, and between people and nature, as in "Living in harmony with nature" (IPBES, 2015).

- Integrated valuation: The process of collecting, synthesizing, and communicating knowledge about the ways in which people ascribe importance and meaning of Nature's contributions to people, to facilitate deliberation and agreement for decision making and planning (Pascual *et al.*, 2017).

Vulnerable population
Those individuals or groups who have a greater probability than the population as a whole of being harmed and experiencing an impaired quality of life because of social, environmental, health, or economic conditions or policies (FAO, 2021).

W

Welfare
See 'Social welfare'.

Well-being (human)
Human well-being is a state in which there is opportunity for satisfying social relationships and "where human needs are met, where one can act meaningfully to pursue one's goals and where one enjoys a satisfactory quality of life" (Gough & McGregor, 2007). Also see "Good Quality of Life".

Western science
(Also called modern science, Western scientific knowledge or international science) is used in the context of the IPBES conceptual framework as a broad term to refer to knowledge typically generated in universities, research institutions and private firms following paradigms and methods typically associated with the 'scientific method' consolidated in Post-Renaissance Europe on the basis of wider and more ancient roots. It is typically transmitted through scientific journals and scholarly books. Some of its central tenets are observer independence, replicable findings, systematic scepticism, and transparent research methodologies with standard units and categories (IPBES core glossary, 2021).

Wetlands
Areas that are subject to inundation or soil saturation at a frequency and duration, such that the plant communities present are dominated by species adapted to growing in saturated soil conditions, and/or that the soils of the area are chemically and physically modified due to saturation and indicate a lack of oxygen; such areas are frequently termed peatlands, marshes, swamps, sloughs, fens, bogs, wet meadows, etc. (IPBES core glossary, 2021).

Wild food
Wild foods are food products obtained from non-domesticated species (FAO, 2019).

Wild habitat
See "Natural habitat"

Wild meat
Wild meat is defined as meat for human consumption derived from wild species (see Chapter 3).

Wild relative
Wild species related to crops, including crop progenitors (FAO, 2018a).

Wild species
Wild species refers to populations of any species that have not been domesticated through multigenerational selection for particular traits, and which can survive independently of human intervention that may occur in any environment. This does not imply a complete absence of human management and recognizes various intermediate states between wild and domesticated. This assessment excludes feral and introduced populations (see Chapter 1, the definition is further explored in section 1.3.2).

Wild species watching (or wildlife watching)
Wild species watching is defined as a non-extractive practice where humans observe, and in some cases interact, with wild species in their natural environment in a way that does not involve the harvest or removal of any part of the organism. Wild species watching activities vary greatly in the level of wild species involvement, ranging from photographing animals from afar to more invasive practices of habituating, feeding and touching animals (UNEP/CMS, 2006, p. 2006). Wild species watching also is an economically important segment of nature-based tourism (see Chapter 2).

Wilderness
Ecosystems, landscapes and seascapes with a very low degree of human influence, at present with full recognition that they are often inhabited and managed by people, and have been so for centuries or millennia, often at low population densities, and therefore their native biodiversity and ecological and evolutionary processes have not been reconfigured by human drivers to a significant degree (Kormos *et al.*, 2017; Potapov *et al.*, 2017; Watson *et al.*, 2016). Not all areas designated as wilderness conform to this definition, especially in Europe where abandoned agricultural areas 'managed' by 'wild living' large herbivores are also called wilderness. Some wilderness areas in the world show transition to cultural landscapes with low human influence.

Willingness-to-accept (WTA)
Estimate of the amount people are prepared to accept in exchange for a certain state or good (e.g., WTA for protection of an endangered species) (IUCN, 2012a).

Willingness-to-pay (WTP)
Estimate of the amount people are prepared to pay in exchange for a certain state or good (e.g., WTP for protection of an endangered species) (IUCN, 2012a).

Worldviews
Worldviews defined by the connections between networks of concepts and systems of knowledge, values, norms and beliefs. Individual person's worldviews are molded by the community the person belongs to. Practices are embedded in worldviews and are intrinsically part of them (e.g., through rituals, institutional regimes, social organization, but also in environmental policies, in development choices, etc.) (IPBES, 2019).

Z

Zoonotic disease
Zoonotic disease or zoonoses are directly transmitted from animals to humans *via* various routes of transmission (e.g., air – influenza; bites and saliva – rabies) (IPBES core glossary, 2021).

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We would like to thank all of the IPBES Multidisciplinary Expert Panel members and the Bureau – both past and current – for submitting comments during the internal and external expert review stages. We would also like to thank the members of the technical support units on policy support tools and on knowledge and data for their inputs when reviewing the drafts of the chapters and summary for policymakers. A special thanks to the indigenous and local knowledge technical support unit who submitted comments from the dialogue workshops.

All of the following expert reviewers listed below submitted comments on the chapters, summary for policy makers and/or glossary of the assessment on the sustainable use of wild species, and were not involved in the writing of the assessment.

We would like to acknowledge the following governments (including the national focal point) for submitting comments on the IPBES assessment on the sustainable use of wild species:

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