Chapter 6[1]: Governance and policy options for the management of biological invasions

Supplementary materials

[1] This is the final text version of the supplementary material of Chapter 6 of the IPBES Thematic Assessment Report on Invasive Alien Species and their Control (https://doi.org/10.5281/zenodo.7430682)

Supplementary material 6.1. Invasive Alien Species in the Antarctic: Policy and Governance

This supplementary material complements **Box 6.10**.

The Broader Antarctic Region and its Governance Arrangements

Policies that are relevant to biodiversity and to ecosystem services in the Antarctic region are developed, usually independently, by the Antarctic Treaty Consultative Parties (ATCPs), the Commission for the Conservation of Antarctic Living Resources (CCAMLR), and by the States responsible for the islands north of 60°S. The ATCPs are advised by the Committee for Environmental Protection (CEP), established by the Protocol on Environmental Protection to the Antarctic Treaty of 1991 (hereafter the Protocol), and by the Scientific Committee on Antarctic Research (SCAR), a committee of the International Science Council (Protocol Article 10.2).

Article 4 of Annex II to the Protocol on Environmental Protection (hereafter Article 4; ATCM, 2009) concerns the Introduction of Non-Native Species and Diseases. Article 4 prohibits the introduction of living organisms not native to the Antarctic Treaty Area onto land or ice shelves, or into water, expect in accordance with a permit. It also prohibits the introduction of non-sterile soil, live poultry, and other living birds. Article 4 also requires that Antarctic Treaty Parties should to the maximum extent practicable ensure that non-sterile soil is not accidentally imported into the region.

Permits may be issued for the importation of alien cultivated plants and their propagules for controlled use, and for species of living organisms for controlled experimental use. Prior to expiration of permits, the organisms have to be removed from the Treaty area or disposed of by incineration or an equally effective measure. Article 4 also requires that any species not native to the Antarctic Treaty area that is introduced to the area without a permit be removed, wherever feasible, unless removal poses a greater environmental impact. Article 4 also requires that all reasonable steps be taken to control the consequences of an introduction to avoid harm to fauna and flora.

The CAMLR Convention recognizes the conservation significance of the effect of the introduction of alien species (Article II.3.c), but has no further detail about them. Nonetheless, Article V acknowledges the obligations and responsibilities of the ATCPs for the protection and preservation of the environment of the Antarctic Treaty area. Contracting Parties to the CAMLR Convention must also abide by the Protocol on Environmental Protection to the Antarctic Treaty and its annexes and other measures. Antarctic Specially Protected Areas (ASPAs) can, and frequently do, include provisions to limit the introduction of alien species. Resolution 28/XXVII on Ballast Water Exchange in the Convention Area was adopted in 2008 by the CAMLR Convention Contracting Parties to limit the introduction of alien marine species.

The Agreement on the Conservation of Albatrosses and Petrels (ACAP) applies to many species in the broader Antarctic region (ACAP, 2018). Section 1.4.1 of Annex 2 specifies that Parties shall take all feasible action to prevent the introduction, deliberately or otherwise, of alien taxa of animals, plants or hybrids or disease-causing organisms that may be detrimental to populations of albatrosses and petrels. Section 1.4.2 commits Parties to take measures to the extent feasible to

control and, where possible, eradicate alien taxa of animals or plants, or hybrids thereof, that are, or may be, detrimental to populations of albatrosses or petrels.

Invasive Alien Species Policy Implementation in the Antarctic

Based on the advice of the CEP, the ATCPs have a significant focus on reducing Invasive Alien Species introductions to and impacts on the area south of 60°S. Current guidance for doing so is encapsulated in the CEP Non-Native Species Manual (ATCM, 2019; hereafter the Manual).

Article 4 of Annex II to the Protocol does not consider unintentional introductions specifically (Hughes et al., 2015). Nor does have it have provisions concerning species transfers between Antarctica's very different ecoregions. The Manual, however, covers both unintentional introductions and transfers between regions, largely because of the effective translation of recent research (e.g., Hughes & Convey, 2010, 2012; J. E. Lee & Chown, 2011) to policy through the CEP. Although the pace of such translation and uptake has been criticized (Hughes & Pertierra, 2016), the rate of development of responses within the ATS has been relatively rapid, with these responses exceeding those typically expected elsewhere, as measured through a comparison with international responses to the relevant Aichi Targets of the CBD Strategic Plan for Biodiversity 2011-2020 (Chown et al., 2017). The Manual has also been supplemented by other practical guidance for those operating in the region. Perhaps the best example is the COMNAP/SCAR Non-Native Species Voluntary Checklists for Supply Chain Managers (SCAR & COMNAP, 2019), which provides practical guidance (and the evidence underlying it) to prevent the introduction of non-indigenous species to Antarctica. Other organizations, such as the Antarctic tourism industry body, the International Association of Antarctica Tour Operators (IAATO), have similar guidance for its members (IAATO, 2020). In the 2018/2019 season, more than 50 000 tourists visited Antarctic and numbers are expected to rise.

Two further complexities of invasive alien species policy implementation in the Antarctic Treaty Area are that: (i) Article 7 of Annex III, on Waste Disposal and Management, to the Protocol, precludes the use of pesticides (other than those required for scientific, medical or hygiene purposes) south of 60°S; (ii) Annex I to the Protocol requires that all activities to be undertaken in the Antarctic Treaty area require some level of impact assessment. Those expected to have less than a minor or transitory impact can proceed, those with a minor impact require an Initial Environmental Evaluation, and those with a greater than minor or transitory impacts require a Comprehensive Evaluation (Hughes et al., 2015). The legal language in the Protocol and its Annexes make many of the required assessments complicated because of the lack of clear and objective language (Hughes et al., 2015; Hughes & Pertierra, 2016).

Although the Manual makes reference to marine invasions, and in particular the Practical Guidelines on Ballast Water Exchange in the Antarctic Treaty Area (ATCM, 2006), what is made most clear is the absence of guidelines for the prevention of the introduction of marine invasive alien species and the absence of clear guidance as to the approach required if marine alien species or invasions are detected. The Manual is similarly largely silent about the continental water bodies of the Antarctic south of 60°S. By contrast, a great deal of advice is provided for terrestrial systems, including flow charts on how to respond to introductions. Notwithstanding all of the advice and agreements, Antarctic Treaty policy implementation proceeds through implementation in national law, which is highly variable between the nations

which operate in the Antarctic and which are party to the Treaty and Protocol (Hughes & Pertierra, 2016). Moreover, any nation that is not a Party to the Treaty or the Protocol cannot be prevented from operating in Antarctica.

The sub-Antarctic and maritime Antarctic islands under national control differ from the areas south of 60°S precisely because these islands fall within national jurisdictions. Thus, international conventions which apply to nations apply strictly to these areas too. Thus, national plans to give effect to the requirements of these conventions must necessarily include the sub-Antarctic and maritime Antarctic islands under the control of the particular nations, and this is often done. Indeed, in many cases, proactive approaches to conservation are taken. For example, of the sub-Antarctic islands, the Crozet archipelago, the Kerguelen islands, Heard and McDonald Islands, Macquarie Island and the New Zealand sub-Antarctic islands have all been accepted onto the Word Heritage List (World Heritage Committee, 1997, 1998, 2019).

As a consequence of differences in national requirements, a variety of approaches to the prevention and control of alien and invasive alien species have been implemented. The majority of the islands have management plans or equivalent guidance which specify the approach to prevention of introductions, the responses required if introductions are detected, and requirements for eradications (**Figure SM.6.1**). For all of the islands, it is clear that the threats posed by invasive alien species are well appreciated (De Villiers et al., 2006).

The implementation of policy to prevent introductions varies considerably. For example, extensive biosecurity requirements exist and inspections are mandatory for all ships and cargo departing for or arriving in South Georgia, including private yachts, as well as for storage facilities used to ship materials to the territory (GSGSSI, 2019). By contrast, specific biosecurity procedures have not been implemented for storage facilities and cargo supplying the Crozet and Kerguelen islands, and private vessels visiting these islands are not subject to biosecurity inspection (TAAF, 2017). Similarly, fresh produce may not be taken ashore to either of the Prince Edward Islands (CIB, 2010, section 5.2.2), but this may be done under strict conditions for Heard Island (Australian Department of the Environment, 2014, section 5.4.12), and routinely for the Crozet and Kerguelen islands (Hughes et al., 2011).

Policies to eradicate or control invasive alien species, where practicable, are common to all management plans for the sub-Antarctic islands. On several of the islands, extensive eradication programmes have either been undertaken or are planned (Bester et al., 2000; Chapuis et al., 2004; Headland, 2012; Martin & Richardson, 2019; Preston et al., 2019; Springer, 2016). In several cases, however, alien species eradications are listed as low management priorities, either because these measures are currently infeasible, likely to be too costly, or because there is a lack of information about the potential consequences of invasive species removal, which has previously caused unintended issues in sub-Antarctic ecosystems (Bergstrom et al., 2009).

Policy Harmonization Across the Antarctic and Antarctic Treaty System

Because governance of the Antarctic falls within the ATS, and the application of its instruments (such as CCAMLR, the Protocol) often fall within the same government departments, harmonization of approaches across the region can be considered reasonably well advanced. However, substantial differences in implementation do exist among nations (e.g., Hughes &

Pertierra, 2016; Peter et al., 2013). Nonetheless, what should be done to limit the impacts of invasive alien species and the reasons for doing so, are uniformly articulated to the ATCPs. A clear example is provided by the CEP Non-Native Species Manual (ATCM, 2019). Considerable progress has therefore been made in addressing the requirements for reducing the introduction and spread of invasive alien species, in monitoring the situation, and in responding to new incursions and developing eradication approaches (Hughes & Convey, 2012; McGeoch et al., 2015).

Much of the policy for areas south of 60°S and for the sub-Antarctic islands and Maritime Antarctic islands north of this parallel is similar, though implementation for the sub-Antarctic is often more stringent because agreement on policy is more straightforward for a single country than for many countries within a single forum (such as the Antarctic Treaty Consultative Meetings; Leihy et al., 2020). Three primary reasons can be readily identified for the similarities in policy, and in some aspects in implementation, for regions north and south of 60°S. (1) The same individuals are involved in the research on invasive alien species and in developing policy advice and deliberating on it in the appropriate forums in both areas. (2) Science in, from and about Antarctica and the Southern Ocean, including the sub-Antarctic islands, is coordinated and facilitated by the SCAR, which has included a focus on invasive alien species for several decades (Kennicutt et al., 2019; Walton et al., 2018). (3) The science-policy interface in the Antarctic Treaty setting has been reasonably effective, especially for invasive alien species management, at least until now (Hughes et al., 2018). That situation may be changing as external and internal challenges to the ATS grow (Chown & Brooks, 2019).

Future Invasive Alien Species Policy Options for Antarctica and the sub-Antarctic Islands

The broader Antarctic region is changing rapidly as a consequence of global climate change (Le Roux & McGeoch, 2008; Lebouvier et al., 2011; Rintoul et al., 2018; Swart et al., 2018), with most analyses indicating that risks of establishment, spread and impact of alien species will increase (Aronson et al., 2015; Duffy et al., 2017; Frenot et al., 2005; McCarthy et al., 2019; McClelland et al., 2018; Pertierra et al., 2020). Human activity in the region is also growing due to growth in scientific stations and numbers of science and support personnel, and in numbers of tourists (Chown & Brooks, 2019). Thus, invasive alien species policy requirements for the future will have to focus especially on what these changes mean for introductions from elsewhere into the Antarctic region. Distinguishing introductions from range shifts will remain a major challenge (Hughes & Convey, 2012; S. Y. Lee et al., 2014). Transfers of species among these regions, as a consequence of direct or indirect human actions, are not yet the subject of adequate policy consideration (Hughes et al., 2019; Hughes & Pertierra, 2016). At the heart of the challenge lies an inadequate understanding of biodiversity variation across Antarctica and the Southern Ocean, and how species are responding to changing conditions (Chown et al., 2015; Gutt et al., 2015; Kennicutt et al., 2019).

In the face of these challenges, a focus on better biosecurity measures, for prevention, and the development of clear surveillance policy and practices to identify and characterize new establishments as they occur is essential, especially for marine systems (Aronson et al., 2015; Hughes et al., 2015; Hughes & Pertierra, 2016). Extension of protected areas with strict biosecurity policies, and recognition that protected areas are connected to their surrounding systems is essential (Shaw et al., 2014). Concerted eradication actions will also be required given

recent developments. For example, as a consequence of changing climates, mice (alien) are proliferating on sub-Antarctic Marion island, decimating native invertebrates, and now switching to predation on albatross chicks and adults (Dilley et al., 2016; Jones et al., 2019; McClelland et al., 2018).

Although these requirements have variously been identified by the Antarctic Treaty Consultative Parties (ATCM, 2019) and by CCAMLR, they are not yet being given the practise-led research attention they deserve. At present the CEP has little means by which to provide financial support for such work (Liggett et al., 2017). SCAR does facilitate such work, and in the past has been responsible for great strides forward in practise-led research outcomes (Hughes et al., 2010), but relies on national science programmes to provide the majority of support.

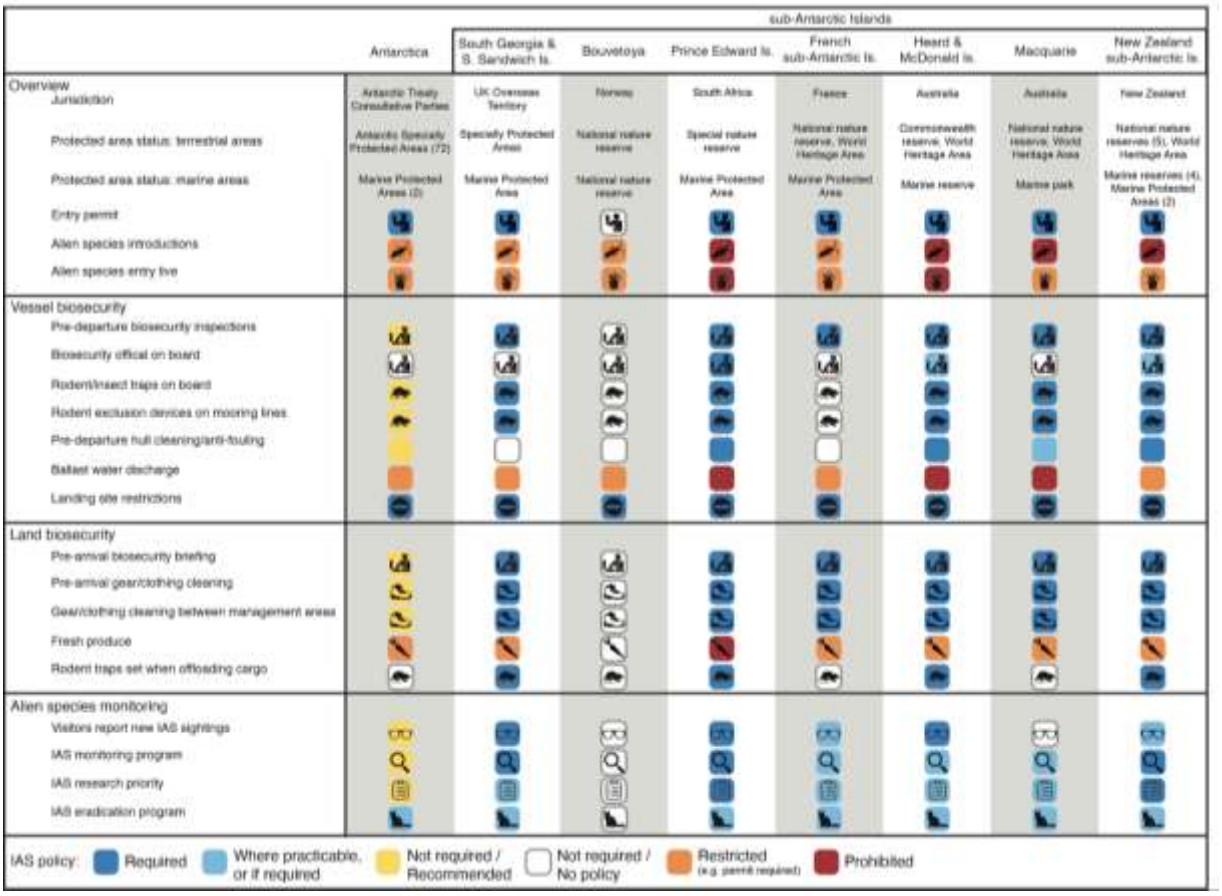

Figure SM.6.1. Biosecurity and invasive alien species (IAS) monitoring and eradication measures in place across Antarctica and the sub-Antarctic islands.

Acronyms

ATCPs	Antarctic Treaty Consultative Parties
CCAMLR	Commission for the Conservation of Antarctic Living Resources
CEP	Committee for Environmental Protection
SCAR	Scientific Committee on Antarctic Research

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Supplementary material 6.2. Table of knowledge and data gaps

This supplementary material complements **section 6.6**.

Synthesis of the most important knowledge and data gaps identified and collated through the assessment. Confidence levels in the summary for policymakers were allocated with full consideration of these gaps, which, if closed, would strengthen the understanding of biological invasions. Experts have assessed the estimated research costs, scientific challenge to close these gaps, as well as the potential gain in increasing understanding and tackling biological invasions successfully globally (from very low to very high). The listed gaps may not be relevant at local or regional scales. Data management report available at: https://doi.org/10.5281/zenodo.7840018

CATEGORY	GAP	IMPLEMENTATION CHALLENGE		POTENTIAL GAIN	
		Estimated research cost	Estimated scientific challenge	For taking management action	For better understanding biological invasions
Interoperable data for monitoring invasive alien species and effects of drivers of biodiversity change	Incomplete data and understanding of the conditions that facilitate successful integration of policy developments into management plans {6.6.1.4}				
	Lack of indicators of the various dimensions of biological invasion that are policy-relevant, sensitive, reliable, relevant at national and global scales, sustained for medium-to-long-term tracking of progress and part of a responsive policy environment {6.6.3}				
Gaps in how invasive alien species affect nature's contributions to people	Incomplete data on impacts on nature's contributions to people and good quality of life {4.7.2}				
Management and policy approaches	Lack of control options for marine invasive alien species and invasive alien microbial fungal pathogens of plants and animals {5.6.1.1}				
	Lack of agreed-upon methods of supporting management decision-making for invasive alien species with both positive and negative impacts {5.6.1.2}				
	Lack of methods of managing pathways for invasive alien species arriving as contaminants, or through shipping containers, e-commerce (legal/illegal), biofouling or ports, and across land borders and along trade supply chains {Table 5.11, 5.6.2.4}				
	Lack of methods for adaptive management of invasive alien invertebrates and plants using alternative approaches given the declining number of chemical control options {5.6.2.5}				
	Lack of eradication guidelines and strategies for generalist invasive alien invertebrates, diseases and hard-to-detect freshwater and marine invasive alien species {5.6.2.1, Table 5.11}				
	Lack of scenarios and models of invasive alien species that consider interactions with other drivers of global change {2.6.5, 6.6.1.6}				
	Missing information on the implementation of adaptive-collaborative governance for biological invasions and factors important to the success of that governance strategy {6.4.4.5}				
	Incomplete data on the effectiveness of policies, management strategies and actions related to biological invasions {6.1.3, 6.6.3}				
Gaps to fill to support the implementation of policy and management	Lack of tools and frameworks to predict biological invasions {6.2.1, 6.6.1.6, 6.7.2.7}				
	Lack of tools to reduce the barriers to information-sharing within and across countries {6.6.2}				
	Lack of research and data on how best to implement integrated governance systems to manage biological invasions {6.6.1.3, 6.6.1.4, 6.6.2}				
	Design principles for an integrated governance system to manage biological invasions {6.7.2.3, 6.7.3}				
	Lack of mechanisms that allow effective collaboration among different elements of the socioecological systems {Figure 6.7, 6.7}				

CATEGORY	GAP	IMPLEMENTATION CHALLENGE		POTENTIAL GAIN	
		Estimated research cost	Estimated scientific challenge	For taking management action	For better understanding biological invasions
Gaps in biomes, units of analysis and species groups	Incomplete or lack of inventories of invasive alien species in marine, tropical and Arctic ecosystems {2.5.2.1, 2.5.2.4, 2.5.2.5, 2.5.4}				
	Incomplete or lack of inventories of invasive alien microorganisms and invertebrates {2.3.1.11, 2.3.3.3}				
	Lack of understanding of the drivers of change that facilitate biological invasion for some animal groups (notably invertebrates), fungi and microbes {3.6.1}				
	Lack of understanding and synthesis of the impacts of invasive alien microbes {4.7.2}				
	Poor understanding of drivers of change that facilitate biological invasions in aquatic and marine systems {3.6.1}				
	Lack of data on successful restoration attempts in terrestrial and marine systems {5.5.6, 5.6.2.1}				
Regional gaps in data and knowledge	Comparatively incomplete inventories of invasive alien species in Africa and Central Asia {2.4.2.5, 2.4.5.5}				
	Comparative lack of understanding of the drivers of change that facilitate biological invasions in developing economies {Box 3.12}				
	Lack of data and knowledge of the drivers of biological invasions in sub-Saharan Africa, tropical Asia and South America {3.6.1}				
	Incomplete data on the impacts of invasive alien species across Africa and Central Asia {4.7.2}				
Interoperable data for monitoring invasive alien species and effects of drivers of biodiversity change	Lack of standardization of terminology for invasive alien species monitoring {2.4.4.5, 6.6.2.3, 6.6.2.7}				
	Lack of information on the role of indirect drivers, especially governance and sociocultural drivers, in affecting biological invasions {3.1.5, 3.6.1, Box 3.13}				
	Lack of understanding of the net effects of multiple interacting drivers in shaping and promoting biological invasions {3.5, Box 3.10, 3.6.1, Box 3.13}				
	Lack of knowledge on interactions and feedback across drivers in promoting invasions {3.1.5, 3.6.1}				
	Lack of integration of impact data and knowledge sources across languages {4.7.2}				
	Incomplete data to undertake risk management, cost-effective species-based surveillance and detection of fungi, microbes and marine pests {Table 5.11}				
	Incomplete data to prioritize biological invasion management under climate, sea- and land-use change {5.6.1.3}				
	Lack of inventories at fine scales and for specific taxon and biome contexts to support decision-makers in determining when to implement species-based or site-based management (or both) {5.6.2.1, 5.7}				
	Incomplete data to develop pathway risk assessments and management for different taxonomic groups and biomes {Table 5.11, 5.6.2.5}				
	Incomplete data and understanding of site-based and ecosystem-based management concepts {5.6.2.1}				

CATEGORY	GAP	IMPLEMENTATION CHALLENGE		POTENTIAL GAIN	
		Estimated research cost	Estimated scientific challenge	For taking management action	For better understanding biological invasions
Gaps in knowledge on invasive alien species of particular relevance to Indigenous Peoples and local communities	Lack of information on invasive alien species status and trends on land and water managed by Indigenous Peoples and local communities {Box 2.6}	High	High	High	High
	Lack of information on Indigenous and local knowledge, values and culture regarding the drivers and impacts of invasive alien species on land and water managed by Indigenous Peoples and local communities {1.6.7.1, Box 3.12}	High	High	Very high	Very high
	Lack of understanding of and mechanisms for sharing knowledge on invasive alien species and their drivers, impacts, management and governance among Indigenous Peoples and local communities and researchers and other outsiders {6.6.1.5}	High	High	Very high	Very high
	Lack of consideration of the knowledge and perceptions of Indigenous Peoples and local communities in scenarios and models {1.6.7.3, 4.7.1, 6.6.1.6}	High	High	High	Intermediate

* A headline indicator has been adopted for planning and tracking of progress towards Target 6 of the Kunming-Montreal Global Biodiversity Framework, with opportunities to build on existing indicators for biological invasions {6.6.3}.

Supplementary material 6.3. Some examples of professional networks working towards the collection of empirical data related to biological invasions across geographic scales and habitats

This supplementary material complements **section 6.6.2.2**.

Name of professional networks (website and key citations)	IPBES regions	Biomes	Nature of data	Year of establishment	Impacts
Mountain Invasive Research Network (MIREN) (https://www.mountaininvasions.org/)	All except Antarctica	Terrestrial (Mountain regions)	Change in species occurrence over time (repeat sampling) and space (elevation)	2005	Greater understanding of biological invasions in mountains which are otherwise considered as immune to biological invasions
Global Garlic Mustard Field Survey (GGMFS) (Colautti et al., 2014)	Americas, Europe and Central Asia	Terrestrial	Field survey data for performance analysis, and collection of germplasm of a single invasive species: *Alliaria petiolata* (garlic mustard) across its native and introduced range	2009	Greater understanding of the traits responsible for higher invasiveness of species and test of Evolutionary Increased Competitive Ability (EICA) hypothesis

Phragmites Network (PhragNet) (Hunt et al., 2017)	Americas	Freshwater	Environmental and genetic samples, habitat data, and management information	2012	Improved understanding of invasion ecology of one of the most problematic wetland invasive grass *Phragmites australis* (common reed) in Americas, and inform adaptive management decisions
Global Invader Impact Network (GIIN) (Barney et al., 2015)	All	Terrestrial	Experiments for the study of ecological impacts of invasive plants	2013	Development and use of standardized methods for impact studies.
International Plant Sentinel Network (Mainly focused to botanical gardens and arboreta) (https://www.plantsentinel.org/introduction/, Barham et al., 2016)	All	Terrestrial	Providing early warning system for new and emerging plant pest and pathogens	2013	Early detection of plant pest and pathogens in botanic gardens
InvaCost	All	Terrestrial,	Global estimate of	2014	Most up-to-date

(http://invacost.fr/en/accueil/; Diagne et al., 2020)		Freshwater, Marine	the economic cost associated with biological invasions		data, and standardized methods for estimating economic cost
SynHab (Macroecology of Plant Invasions: Global Synthesis across habitats) (https://www.synhab.com/)	All	Terrestrial, Freshwater	Global database of habitat affiliations of naturalized and invasive alien plants in their native and introduced range	2019	Data not yet published

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