FISH AS FOOD

Anthropological and Cross-disciplinary Perspectives

Edited by

Helen Macbeth, Iain Young and Diana Roberts

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Cover photograph:

Carp filled with salmon, Moscow

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FISH AS FOOD:
Anthropological and Cross-disciplinary Perspectives

Smoked herring for human consumption
(Clupea harengus)

Photograph © Frédéric Duhart

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The International Commission on the Anthropology of Food and Nutrition

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This richly illustrated, free online e-book is aimed at both specialist and general readers alike. In anthropological and cross-disciplinary chapters it explores 'Fish as Food' in the context of its place in culture, nutrition and as a potentially sustainable food source, against a shifting background of climate change and environmental degradation.

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PREFACE

The International Commission on the Anthropology of Food and Nutrition (ICAF) promotes cross-disciplinary discussion by bringing together contributors from different sub-disciplines within Anthropology and beyond, both from other academic disciplines and from relevant professions and organisations, in meetings about food-related topics.

This volume arises from such a meeting, an ICAF conference entitled *Fish as Food: Lifestyle and a Sustainable Future*, hosted by the University of Liverpool and held virtually in September 2021 during the months when in-person meetings were restricted due to COVID-19. Papers from that conference are published here within the ICAF series, *Alimenta Populorum*, developed as a sustainable tool to communicate science in a world where access to expensive books and journals remains a serious problem for many students and the general public. This series has an online format that is designed to be easy to use, with full colour illustrations and a font size readable even on a tablet.

The editors wish to thank the University of Liverpool for hosting the conference online in 2021. We also express our thanks to all the contributors at the conference, and we wish to thank those who have contributed papers as chapters in this book, both for the texts and for their patience with our comments and the delays in finalising this electronic book.

We are very grateful to the two referees for their very positive support of this work and the constructive points they made. We thank Frédéric Duhart for so many of the photographs that illustrate this book. Other photographs and figures were provided by the contributors and editors and all figures are attributed. Finally, we are indebted to Izidora Rowe for her thorough work checking references and copy-editing the style of referencing throughout, which was a significant task.

HMM, ISY and DCR
July 2024

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INTRODUCTION:
FISH AS FOOD FOR HUMANS

by Helen Macbeth, Iain Young and Diana Roberts

Introducing concepts

This book is about fish as food for humans. Humans have had exceptional evolutionary successes resulting in an ever-increasing population that has spread to all areas of our world and exploits a great deal of its resources. Some consequences of these successes are widescale environmental damage and massive loss of biodiversity. Now, the pollution caused by the technologies achieved by humans is damaging the air, the land and the sea and, by altering atmospheric chemistry, is driving climate change leading to global warming – melting ice caps and glaciers and causing floods, storms and fires. These, in turn, impact the capability of the planet to support the provision of food for humans.

The International Commission on the Anthropology of Food and Nutrition (ICAF), as its name implies, is devoted to studies of human food and nutrition. By emphasising both *food* and *nutrition* immediately two concepts are highlighted, the food itself and the physiological effects of its consumption. This is important because there are so many aspects to study about both. Food must be foraged, hunted, grown or produced, then usually prepared before being consumed by humans. Once consumed many factors impact nutrition such as dietary balance, nutrient content, bioavailability, individual dietary needs, cultural preferences, cooking methods, and the impact of lifestyle and health conditions on nutrient absorption and utilisation. Because there is so much variation in these topics, specialists in different fields of study have been concerned with diverse areas of expertise, including the biochemistry of the food, the physiology of its consumption, the ethnographic observations of the foraging and/or agricultural technologies of different human groups, etc. The myriad different cultures and social patterns affect not just these habits and technologies but also food availability, sharing, marketing and beliefs about the edibility of items.[1] What

[1] Whilst different sources discuss the meaning of the words *edible* and *eatable* (and how they differ), and their opposites, *inedible* and *uneatable*, they are not consistent. In this book we have kept to the words, *edible* and *inedible*, using them to include diverse perceptions of what is or is not suitable for human consumption.

is clear is that concepts about edibility are affected by many factors, including individual preferences, whether learned or seemingly innate, how the food items look or smell or even the wording used in the marketing, and of course the social settings in which the food may be prepared and consumed. One can continue any of the above lists about perspectives to consider and realise the multiplicity of aspects within them to study about human food and nutrition.

Added to this diversity are ‘economic differences’, a dry phrase which insufficiently emphasises the extent of the topic. At one extreme, food deprivation for the world’s poorest, whether due to severely adverse environmental conditions or to socioeconomic conditions in complex, probably urban or conflict, situations, contrasts with the malnutrition of excess or poor food choices that affect those comfortably able to access foods of all sorts, resulting in high levels of obesity and associated health issues. The complexity of such sociocultural and economic factors is unique to the human species, and must not be neglected when considering human nutrition.

Exacerbating this, global human population numbers continue to rise (Adam 2022; Ritchie et al. 2023),[2] while many environments are deteriorating in their capacity to sustain human food production. This is particularly so where, for example, there is increasing desertification and soil erosion or the pollution of land and water courses, rivers and seas. This in turn has detrimental effects on populations of other species, further exacerbating changes in pre-existing balances in nature. Whereas global warming is now acknowledged, it continues not to be adequately addressed by politicians or the public alike.

Thus, the sources of food and its acceptability in different cultures have many aspects to be studied when concerned about adequate nutrition for the global human population. On these such different topics, the tendency for specialisation in academic studies needs to be recognised and acknowledged but this should also be overcome with cross-disciplinary reviews, or at least, as in this book, the juxtaposition of quite different perspectives in one volume.

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[2] ‘In 1800, there were one billion people. Today there are more than 8 billion of us, But, after a period of very fast population growth, demographers expect the world population to peak by the end of this century.’ (Ritchie et al. 2023, p.1).

In the context of global considerations regarding sufficient human food and nutrition two pivotal concepts come to the forefront: ‘food security’ and ‘food insecurity’. The United Nations Committee on World Food Security defined that an individual attains the status of being ‘food secure’ when they possess physical, social and economic access to adequate, safe and nutritious food that aligns with their dietary requirements and preferences, fostering an active and healthy life (World Food Summit 1996). This definition underscores the multifaceted nature of food security, transcending mere caloric intake to encompass broader dimensions of well-being. The United Nations (UN) also emphasises the importance of a sustainable food system, defining this as one that ensures food and nutrition security for all while preserving the economic, social and environmental foundations essential for future generations (Food and Agriculture Organization 2018). This holistic approach emphasises the need for a balance that not only meets current needs but also safeguards the ability of the planet to provide for the nutritional requirements of generations to come.

Fish as Food

For thousands of years, those human communities close to sea, lakes or rivers have exploited the nutritious food source supplied by catching wild fish and other waterborne species including crustaceans, molluscs and cephalopods as well as plant matter, such as seaweed. Within the chapters of this book there are references to various named species of marine and fresh-water finfish, crustaceans, molluscs and cephalopods, which, for simplicity’s sake, we frequently wrap up together within the word ‘fish’, in the same way that a fishmonger’s shop may sell such a variety of edible species; others use the word ‘seafood’ in a similarly all-inclusive manner.

It is difficult to calculate the importance of ‘fish as food’ for humans. Indeed, it has been hypothesised that the diverse freshwater fish species endemic to the African Great Lakes contributed to the rapid evolution of hominid brain growth around 2.5 million years ago; this is an interesting perspective. The idea suggests that the availability of these fish all year round could have played a significant role in providing a consistent source of high-quality protein and essential polyunsaturated fatty acids, particularly docosahexaenoic acid (DHA) – a crucial component of neural tissues and associated with cognitive function (Bradbury 2011) – and arachidonic acid (AA). Both DHA and AA are critical for brain development (Broadhurst et al. 1998). This idea aligns with the broader understanding of the importance of nutrition in human evolution, especially in relation to the development of the hominid brain. It is important to note that the field of human evolution is complex and multiple factors were likely to have contributed to the evolution of the larger brains in hominids. Environmental changes, dietary shifts, tool use, social interactions and other ecological and behavioural factors may have all played roles in shaping hominid evolution.

Yet, currently in many parts of the world, humans have been over-exploiting fish as a wild resource. This, at the same time as other anthropogenic environmental changes, such as acidification and other pollution of waters, has had and is having profound implications for fish populations.

Overfishing, driven by the growing demand for fish as a food source for humans, has serious consequences for fish populations and the ecosystems they inhabit. The excessive removal of fish to below their sustainable population levels disrupts the balance within marine food webs. This depletion not only affects the species that we eat but also has cascading effects on other marine life dependent on them. Overfishing can lead to the decline of fish stocks, compromising the livelihoods of those who depend on fishing and threatening their food security. A particularly damaging form of overfishing, often illegal but still widespread throughout South East Asia, is dynamite fishing. For this, explosives are used to stun the fish making them easy to collect but this also causes serious long-term damage to the underlying environment, particularly where there are coral reefs.

At the same time, acidification poses a significant threat to marine ecosystems, notably coral reefs, marshes, seagrass beds and mangroves. Coral reefs serve as vital habitats for a diverse range of fish species, providing shelter, breeding grounds and feeding areas. As the oceans become more acidic, due to increased carbon dioxide absorption, linked with climate change, coral reefs face degradation, impacting the availability of these habitats for fish. Seagrass beds, marshes and mangroves serve as nurseries for many fish species, but they too are sensitive to changes in acidity, which in turn affects the survival and growth of juvenile fish.

Pollution, from contaminants such as plastics (Figure 0.1), heavy metals and chemicals, has detrimental effects on aquatic ecosystems.

Figure 0.1: Plastic rubbish in water accumulated beyond the litter containment barrier, Sungei Buloh Wetland Reserve, Singapore, 2014

Photograph © Frédéric Duhart

It can directly harm fish populations through toxicity and through indirect impacts which disrupt their habitats and/or their food sources. Additionally, pollutants can accumulate in fish tissues, in turn posing risks to human health when consumed. This further emphasises the interconnectedness of environmental health and human well-being.

Humans rely on such populations of fish for food, and so the repercussions extend beyond ecological concerns for the marine ecosystems to impact food security, livelihoods and the overall health of the humans. Addressing these challenges requires concerted efforts in sustainable fisheries management, habitat conservation and pollution control to ensure the resilience of fish populations and the ecosystems they inhabit. Globally, the critical importance of overfishing is well recognised and is regulated. The Food and Agriculture Organization of the United Nations (FAO) has a Code of Conduct for Responsible Fisheries (Food and Agriculture Organization 1995) which defines principles and standards to guide sustainable fisheries and aquaculture practices and addresses issues such as overfishing, environmental impacts and responsible fishery management. The Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas is also an instrument under the auspices of the FAO and aims to promote responsible fishing practices on the high seas (Food and Agriculture Organization 1993). Whereas regional fisheries management organisations are international (e.g., Cullis-Suzuki and Pauly 2010), other bodies manage fisheries resources in specific regions, such as the Western and Central Pacific Fisheries Commission and the Northwest Atlantic Fisheries Organization.

The European Union (EU) and the United Kingdom (UK) each have specific instruments and regulations governing fisheries within their jurisdictions. These include the Common Fisheries Policy – a comprehensive framework that sets out the rules for managing fisheries in EU waters and includes regulations on fishing quotas, conservation measures and efforts to achieve sustainable fisheries. Following the UK's departure from the EU, the UK introduced the Fisheries Act 2020, which provides the legal framework for managing fisheries in UK waters. It grants the UK control over access to its waters and the setting of fishing quotas.

Although rearing fish, crustaceans and molluscs for food has a long history, only quite recently, compared to other forms of agriculture, have modern technologies been developed to manage the rearing of salt- and fresh-water species for human consumption. The word aquaculture is now used for this. Aquaculture has the potential to increase production. It provides a controlled environment for the cultivation of fish, shellfish and other aquatic organisms, enabling increased production and enhancing food security by providing a reliable and year-round source of fish and seafood, reducing dependence on wild fisheries, and helping to meet nutritional needs. Aquaculture can also create jobs and economic opportunities in coastal and rural communities supporting livelihoods for fish-farmers, processors, distributors and others involved in the aquaculture value chain. Sustainable aquaculture practices can also help alleviate pressure on wild fisheries, preventing overfishing and promoting the conservation of marine ecosystems. It allows for the cultivation of a diverse range of aquatic species, including fish, shrimp, molluscs and algae, contributing to biodiversity in aquaculture systems. Ongoing research and technological advancements in aquaculture contribute to improved fish farming practices, disease control and resource efficiency.

At this point, we also mention the managed reproduction of edible plant species in suitably nourished water, called hydroponics, illustrated by this 'edible wall' of ZipGrow™ (Figure 0.2) that the manufacturers say produce

Figure 0.2: An edible wall of lettuce in a ZipGrow™ tower

Photograph © Laurence Anderson

higher yields of crops faster, using far less water and less space than traditional methods. This leads us into the final chapters in this book, which discuss a technology called 'aquaponics' which amalgamates a system of aquaculture in conjunction with hydroponics with a view to achieving a more or less closed and circular system in order to convert unwanted 'waste' from the aquaculture part of the system to become valuable nutrients for the hydroponics component. This is a key advantage of aquaponics. Compared to traditional agriculture, aquaponics typically requires less land and water, and it eliminates the need for synthetic fertilisers. The closed-loop system minimises environmental impact by recycling nutrients and reducing water consumption. In addition, aquaponics systems can operate year-round, providing a consistent supply of fresh produce regardless of seasonal variations contributing to food security and stability in supply chains.

Aquaponics systems can be set up in various environments, including in urban areas with limited space. Vertical farming and other innovative designs maximise space utilisation. Furthermore, they are often used in educational settings to teach principles of biology, ecology and sustainable agriculture. Additionally, community-based aquaponics projects can empower local communities and promote sustainable food production. Aquaponics thus allows for the simultaneous cultivation of both fish and plants, providing a diverse range of products for markets. This diversification can enhance economic resilience for farmers. Both aquaculture and aquaponics have the potential to contribute to meeting global food demands sustainably while minimising environmental impact. Therefore, in this volume about fish as food for humans it is a topic of contemporary significance, but it is also crucial that all such systems for long-term sustainability are continuously improved.

The framework of this book

Readers will find that the variety of topics and manner of discussing them are diverse in this book, but we hope all are found to be interesting. This diversity is to be expected for the reasons discussed above about academic specialisms and the many perspectives that are relevant to the topic of 'Fish as Food'. Yet, there is a sense of progression from Chapter 1, which provides extensive and contemporary information on local and global needs, efforts, organisations, problems, and aspirations on the topic of how fish support or could support human food security, to the latter chapters, which consider the need for farming fish to increase the amount of fish available for human consumption, the environmental problems associated with this, and discuss in detail different aspects of aquaculture and aquaponics.

In the first chapter, Ellen Messer introduces how broad the anthropological perspectives on fish as food are, but she also surveys not just that breadth but also its relevance globally to human nutrition and locally to both nutrition and welfare of fishing communities. Messer is a well-recognised and important anthropologist, whose contribution to the anthropology of food and nutrition is significant. She recognises the need to cross the boundaries between academic disciplines (as developed and defined in earlier decades) in her concern with food security and human nutrition in different circumstances.

Having suggested that this topic of fish as food has been insufficiently studied within anthropology, she reveals the enormity of the topic and stresses the importance of the issues with her coverage of this, including the need for both global and local approaches. In discussing global approaches, she introduces the work of intergovernmental organisations including the UN and the FAO as well as international bank-funded organisations and non-governmental organisations that drive the world food policy agenda. Yet, she emphasises the equally urgent need that these large-scale perspectives must connect to local food systems. This local connection must be supported by a detailed understanding of the conditions and practices at a very local level of those who catch, prepare, purchase and consume fish and of their communities, and that contemporary changes are affecting their lifestyles. Importantly, Messer introduces the idea that fish are key for reducing hunger and malnutrition, again emphasising the need to connect global and local perspectives. In very different ways, the chapters in this volume exemplify and add colour to her theme.

Following Messer's discussion of the global approaches, it is important to read, in Chapter 2, Brittany Carol Rapone's informative analysis of the difficult issues that occur in interpreting and trying to make international comparisons of data on fish caught and sold in different areas. Thereafter, she considers the topic of acceptability of different fish and seafood for human consumption. Cultural diversity in views on this is her central theme, written in an interesting style that includes four brief 'anecdotal' sections of her personal experiences as an American in Japan. Using the word 'fish' to include fin fish, crustaceans, molluscs and cephalopods (Figures 0.3 to 0.6),

Example of

Fin fish

Figure 0.3:
Haddock
(*Melanogrammus aeglefinus*)
Photograph © Frédéric Duhart

Example of

Crustaceans

Figure 0.4:
Langoustines
(*Nephrops norvegicus*)
Photograph © Helen Macbeth

Example of

Molluscs

Figure 0.5:
Mussels
(*Mytilus edulis*)
Photograph © *Frédéric Duhart*

Example of

Cephalopods

Figure 0.6:
Common octopus
(*Octopus vulgaris*)
Photograph © Frédéric Duhart

Examples of fin fish, crustaceans, molluscs and cephalopods

she writes both broadly and in detail on cultural differences around the world about what is considered edible, not only due to what *can be* eaten without ill effect, but also how cultural factors other than taste affect concepts of edibility or disgust, such as how the fish is served on the plate or presented for sale (e.g., with or without its head and *its eyes*), how it smells, colours and even marketing phrases used.

Rapone also introduces the concept of sustainability from the perspective of food waste: the proportion and parts of a fish consumed versus that which is wasted. Globally, this varies widely with high-income countries consuming more processed fish and therefore much less of the fish may be eaten compared to low-income countries tending to consume more fresh fish including more parts of the fish. Whereas her chapter gives specific examples from Japan, her discussion of acceptability and the factors that affect acceptability of fish as food is far wider. With reference to scallops (Figure 0.7) she introduces, in biological detail, the different anatomical parts of this mollusc and then goes on to describe cultural differences around the world about which of these biological parts are considered edible and which are not, the latter being generally jettisoned even before reaching land. In so doing, her chapter demonstrates biological, cultural and even psychological perspectives as regards such foods and their acceptability.

Figure 0.7: Scallop (*Pecten maximus*) on a breeding rope

Photograph © Frédéric Duhart

In Chapter 3 Vincent Nijman continues to integrate perspectives from different disciplines in his discussion of a significant change of attitude to the consumption of eels in Indonesia since 2014. His chapter starts with an overview of the international eel trade driven by the popularity of eels as food in Europe, North America and East Asia, and how recent trading protection in the main eel production areas had diminished global trade.

His focus is on Indonesia, where there are some eight native species of eel, and in particular, he reports on the growth of eel exports from Indonesia to East Asia. Yet, traditionally eel had not been a popular dish in Indonesia itself because it was frequently seen as forbidden due to uncertainties under Islamic Law. However, around 2013, local Muslim clerics and scholars agreed that consuming eel was permissible. So, eel can now be deemed halal. Nijman focuses on the impact of this change in acceptability of eel in Indonesia. Whereas in 2014 he had searched and found only a rare restaurant serving any eel dish, since then he has found that this has changed considerably. With the increase of the exportation of eels from Indonesia, he describes how the development not only of eel wild capture but also of eel aquaculture for export has helped to open up a domestic market for local consumption. Now, the health benefits of eel are proclaimed in Indonesia, and some eel aquaculture farms have even been opened for tourists to visit. In this way, Nijman's chapter considers eels in Indonesia, aspects of global trade and changing local demand due to change of cultural view and the acceptability of eel as edible and how these changes, in turn, have driven changes in the eel fishery and the development of and investment in aquaculture.

Figure 0.8:
Cured mullet roe

Photograph© Frédéric Duhart

Eric Cheng has researched urban to rural 'return migration' in Taiwan, and his Chapter 4 of this book starts with information about a gift of 'mooncakes' with a mullet roe filling instead of the more traditional salted-duck-egg filling. A (rural to urban) return migrant he knows had developed a small aquaculture business in rural Taiwan, producing grey mullet (*Mugil cephalus*) primarily for their roe. He briefly mentions the importance of mullet roe in Taiwan and Japan. Much of his chapter is devoted to the producer's environmentally conscious methods of the different stages of raising mullet, their roe (Figure 0.8) and the bakery of the innovative mooncakes, and then to the use of social media for local advertising.

At one level this chapter is about the success of one local product, mooncake with a mullet roe centre, details about these fish and their roe and more generally the social economics of return migration. Yet at another level it is about the increasing cultural interest of producers and consumers in environmental issues, and so the marketing possibilities for foods produced with minimal harm to the environment. In this way Cheng demonstrates the reality of viewing such an operation holistically across perspectives of fish production, marketing economics and cultural change both in consumer choices and in urban to rural return migration in Taiwan.

Both the style of writing and the content change yet again in Chapter 5 by Mary Margaroni. Her theme is firmly based within one discipline, linguistics and the teaching of Greek as a secondary language to foreign residents newly arrived in Greece. This produces an unusual and interesting background theme for a comprehensive and wide-ranging discussion of many topics related to fish as food in Greece, including examples from antiquity to contemporary culinary and restaurant observations, from archaic objects and beliefs to the current state of the Mediterranean Sea. Her material is varied and well-illustrated, while her excuse for the wide coverage of examples is the value of out-of-class real-life experiences in teaching adults on short courses. In this case, all those 'experiences' chosen for the students to discuss relate to fish and its consumption in Greece, whether studied in *tavernas*, kitchens or museums. One becomes intrigued by this mode of teaching while reading a broad selection of interesting material relevant to this book.

Starting with a call to get tickets for a party in Curaçao in 2019, Vincent Nijman pursues another 'fish-as-food' topic in Chapter 6 with information on the annual celebration of the first herring of the year to arrive from Holland. His chapter includes history, culture, trade and information about herring, as he explains the reasons why this contemporary Caribbean celebration mirrors annual events in Holland. After introducing the Atlantic herring species, *Clupea harengus,* which reach Northern Europe from more temperate waters in spring, and after describing the 'correct' way to eat them, filleted, salted and dripping with vinegar and onions, he then outlines the history of international herring trading by the Dutch from the sixteenth century. To trade such fish at the time, preservation methods were essential and this required salt. It was this need for salt that led to the Dutch interest in the Caribbean and the links with Curaçao and Bonnaire from the seventeenth century onwards. Although there is exploitation and slavery in this history, the herring parties today, celebrated in both Holland and the Caribbean, gain funds which are directed towards charitable giving and benefits.

In Chapter 7, Mariette Risse, with personal knowledge and photographs, writes about wild-catch fishing in Dhofar, Oman. With detailed information about those fishermen who go out in boats to fish, those who set fish traps and those who fish close to shore, she gives an ethnographic report as though from an economic and financial point of view, which provides precise information on the costs in terms of both time and money. However, it is in discussing the dispersal of the fish, that the family and social benefits are so clearly explained as significant beyond the monetary details. Some fish are given as recompense for work in catching them or for other favours received, some are kept for the fishermen's family household and others are presented as gifts, generally to family connections, demonstrating generosity. After all this, a portion will be sold for money. The chapter thus uses detailed ethnography of local fishing practices in Dhofar to emphasise a sociocultural context beyond monetary economics, in which the fish destined to be eaten lubricate a whole system of social exchanges, only part of which involves the use of money.

Echoing points by Messer in Chapter 1, Christina O'Sullivan, Lia ni Aodha and Lucy Antal in Chapter 8 consider both the use of wild-caught fish of lesser commercial value as feed in contemporary salmon farming and also the opportunities for aquaculture in the sea off coastal areas where feed for farmed fish occurs naturally. The first situation is exemplified with a West African situation where wild-caught fish, traditionally nourishing people in the locality, are now converted to fish meal and exported to feed salmon farms in Scotland. They point out that few who today purchase their salmon in UK supermarkets understand the farmed origin of much of it. Even if they do, they are unlikely to know that these salmon are fed imported fish meal with an overall loss of vital nutrients to humans, because the farmed salmon provide less of these nutrients than the original wild fish would … and provide them to a generally better fed population.

In contrast, they also suggest other aquaculture methods, such as developing oysters (Figure 0.9) and mussels in coastal and estuary situations where natural feed for the molluscs remains available. For this their example is in the estuary of the Mersey, where such opportunities are not exploited now as they had been in the past, but their suggestion that they could be brings environmental optimism into their consideration of aquaculture and so differs from the first part of their chapter.

Figure 0.9: European flat oysters (*Ostrea edulis)*

Photograph © Frédéric Duhart

The possibility of this Merseyside example echoes Messer's reference to the opportunities for aquaculture being explored and initiated on the Atlantic coast of Maine. As filter feeders, bivalves, such as oysters and mussels filter out suspended sediments, algae and other contaminants from the water they live in. Furthermore, this natural filtration removes suspended solid matter and helps purify the water. Further, it is suggested that the cultivation and harvesting of bivalves are effective at removing nitrogen and phosphorus, entering waterways because of run-off from surrounding agricultural land (Petersen et al. 2016; Kotta et al. 2020) and help prevent or ameliorate eutrophication. Oysters have proved to be effective at removing nitrate and ammonia, both linked to issues like algal blooms and oxygen depletion. In addition, the reefs, formed as oysters grow and multiply, provide habitat for various other marine organisms, in turn contributing to increased biodiversity and creating a healthier marine ecosystem. They can also act as natural breakwaters, providing protection against erosion and storm surges and carbon is sequestered in the growth of the shell assisting in reducing carbon levels in the surrounding environment, potentially contributing to climate change mitigation efforts (Marine Management Organisation 2016; Filippini et al. 2023).

Kieran Magee and Iain Young, in Chapter 9, return to concerns considered in earlier chapters regarding food security for an ever-increasing world population and the relevance of fish for human consumption and nutrition. After an overview of world land use, they provide data regarding the total utilised agricultural area (UAA) used for cattle, sheep, goats, pigs and chickens, and they contrast this with fish from fresh and sea waters, identifying the different protein and vitamin benefits that fish can provide for human nutrition. They then compare the percentages of world increases in fish consumption with those of different terrestrial meats over recent years. They refer to protein values, introducing and comparing the protein conversion ratio or feed conversion ratio (FCR) for several fish species with terrestrial animal types, going on to emphasise their different environmental impacts, including the current stress on several wild-caught fish species stocks due to over-fishing. This leads to a comparison of contemporary situations for wild-caught fish with farmed fish, including an analysis of different forms of aquaculture, bearing in mind several risks to the environment caused by some issues that can arise from fish farming. Yet, their concluding point includes stressing that ‘fish are very nutritious, and aquaculture can be highly sustainable’.

In the following chapter, Chapter 10, the same authors, Magee and Young, continue with a discussion of the feed for farmed fish, which in some earlier chapters is highlighted as an environmental and sometimes human problem. After introducing that farmed fish can be ‘unfed’, i.e. nourished by nutrients in their natural surroundings (Figure 0.10), or ‘fed’ when the nutrition is provided for them by humans, their chapter focuses on the latter.

Figure 0.10: Tilapia farming with nutrients from natural surroundings in Presa Malpaso, Chiapas, Mexico.

Photograph © Frédéric Duhart

At time of writing, much of this feed originates from marine capture fish, but the chapter considers options, explaining the relevant nutrients valuable for fish for human nutrition, and how these are derived from the different fish species.

However, the chapter is also concerned with how appropriate nutrients are needed in the feed for each different fish species farmed; for example, that the exact ratio of the correct amino acids is relevant for the ideal feed for each species to maximise their growth, whereas incorrect ratios lead to lower growth and waste of amino acids that are excess to their needs and excreted, thereby entering the effluent. As well as the amino acids making up the protein chains, essential fatty acids, lipids, carbohydrates and fibre, and the values of each, are discussed in this chapter, since these are relevant to finding the best sources of feed when seeking feed sourced other than from wild-caught fish. The possible sources of these become a fascinating part of this chapter, for example fish meal made from the larvae of the black soldier fly as discussed in Chapter 12. The point on which they conclude is that there is now an urgent need to find the appropriate feeds for aquaculture from new and sustainable sources, as wild-fish stocks in salt and fresh water become threatened.

Another problem in aquaculture, touched on in the previous chapter, is the possibly disadvantageous effects on the environment of the effluent from fish farms flowing into ground water and streams. Laurence Anderson and Iain Young in Chapter 11 introduce recirculating aquaculture systems (RAS), which first filter and then recirculate the water around fish tanks, thus not only reducing water used but also retaining it in a closed system. Yet, the drawback of RAS is that the systems are costly in capital, staff and energy use. So, the authors go on to introduce aquaponic systems, which link RAS with hydroponics, causing the nitrogen and phosphate in the fish tank effluent to be taken up in the next tank by plants grown hydroponically. This not only reduces unacceptable discharge into the environment, but produces income from the hydroponically grown vegetable or salad foods sold for human consumption. Their chapter continues with detailed information on the development of the aquaponic industry around the world, diversity in systems, constraints and issues and yet the possibility for the future of such systems.

After a detailed analysis of the economics, relevant factors to consider are identified, such as location and climate, lighting needed, type of building for different settings, all directed at reducing the costs of light and heating. They further identify certain risks, challenges and possible sources of catastrophe. Yet, after the fish tank effluent has benefitted the hydroponic tanks, for it to be made ready for the recirculating to fish tanks, further waste, such as solids both from the water and from parts of plants, must be removed. This last material can then be prepared for use as fertiliser or for anaerobic digestion and mineralisation for further use. An overview of the economics is considered for the future of hydroponics, including whether the fish, vegetables and salad foods would become accepted by the public, especially if more expensive.

Putting together so many aspects and aspirations of this book, and especially of the previous chapter, Chapter 12 by Juan Sierra de la Rosa, Nora Restrepo-Sánchez, Carlos Peláez, Joe Sánchez and Carlos Uribe, starts with projections about human population figures globally. They point out that these will require increases in water, food and energy and the technological improvements needed to achieve these. They significantly introduce that the project area of their chapter was developed by a multidisciplinary group. This project in Colombia had finance from several different sources, including the local city council of Medellín, as it was within an environmental conditioning agreement for the Morro Moravia, 'a 35-metre-tall mound comprising 1.5 million tons of waste that were deposited in a landfill between 1972 and 1984' (p256). Their cross-disciplinary project integrates aquaponics, anaerobic digestion producing biogas and insect farming and was started in 2014. It is impossible to reduce to one paragraph here the relevant disciplines involved and the holistic approach to their work and their environmental ambitions.

In short, this scheme had started with ideas for the beneficial use of a fifty-year-old landfill mound, already supported environmentally by the local city council and covered with soil and plant life. Then, for this project the organic fraction of municipal solid waste became an input which was treated to produce biogas,[3] 'biol' (or slurry) and compost containing frass,[4] but also as a site for farming black soldier fly larvae as fish feed. The biogas produces the energy for the system, the biol, frass and compost act as fertilizer and the water is recirculated. The chapter is then devoted to details of the aquaponic system, producing Nile tilapia (*Oreochromis niloticus*) vegetables and salad as human food. In their Conclusion, such factors as local cultural traditions, nutritional values and temperature conditions are all considered to emphasise the interdisciplinary concepts, while the biodigestion of urban waste, the insect farming for fish feed and the aquaponics integrate into a viable recirculating environmental system, producing fish and plant food for humans. In this Introduction we leave the Epilogue within their chapter to be read only when it is reached.

In conclusion, the diverse topics in the chapters of this book highlight the multidimensional significance of 'Fish as Food' from anthropological, cultural, biological, environmental, social and economic perspectives. Messer sets the stage, highlighting the global relevance of fish consumption to human nutrition and welfare and advocating a holistic approach that

[3] Biogas is a mixture of gases, including methane, produced when organic matter is broken down by microorganisms in the absence of oxygen (anaerobic digestion). Biogas is regarded as a renewable fuel.
[4] Frass is the term given to the droppings/faeces of insect larvae.

bridges global policies with local food systems. Each subsequent chapter delves deeper into specific aspects of our central theme, including the impact of cultural acceptability of different fish species and fish parts as food, to the changing attitudes towards eel consumption in Indonesia. Nijman and Cheng provide insights into cultural shifts and economic dynamics surrounding fish consumption, whereas Margaroni and Risse offer ethnographic narratives that underscore the social and familial dimensions of fishing practices.

Our theme includes discussion on the environmental sustainability of aquaculture, explored by Magee and Young, considering the complex, and often controversial, relationship between food security, nutritional benefit and ecological impact. This theme of farming fish is extended as Anderson and Young discuss the potential of innovative aquaculture systems, raising the argument for an urgent need for sustainable practices to mitigate environmental degradation.

After showcasing the interdisciplinary collaboration of Sierra de la Rosa et al.'s work, which demonstrates in a living laboratory approach, the potential of integrated approaches, such as aquaponics, bioenergy and insect farming, to address environmental challenges while promoting food security and economic development, we close our book with an Epilogue.

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CHAPTER 1
FISH AS FOOD: CROSS-DISCIPLINARY AND GLOBAL-TO-LOCAL PERSPECTIVES

by Ellen Messer

Prelude

The anthropology of fishing, ethnoichthyology and maritime anthropology are topics underexplored in professional theory, policy and practice, which predominantly emphasise terrestrial livelihoods and their transformations.

This chapter first draws critical attention to substantial recent anthropological reviews and the topics they highlight. It then considers ethnographic history of fisherfolk, fishing livelihood continuities and change, in the contexts of international nutritional science and policy concerns with sustainability, national political-economic developments, globalised food systems, revaluation of fish as part of heart-healthy and nutritious diets, and disruptions associated with liberal economic policies, political violence and climate change. The discussion includes contributions of fisherfolk to international sustainable networking and discourse of food systems, especially the 2021 UN Food System Summit (UN FSS) (United Nations 2021), the WorldFish 2021 World Food Prize Laureate[5] and related research and policy processes.

Introduction:

This chapter considers fish as food in cross-disciplinary and global-to-local perspectives. The approach, based on a literature review of anthropological and online multidisciplinary policy sources, positions ‘fish as food’ research and practice within an anthropological food-systems perspective.[6] This food

[5] See https://worldfishcenter.org/publication/2021-world-food-prize-laureate

[6] The topic is a response to conference co-organiser Helen Macbeth’s request for me to put ‘fish as food’ research into an anthropological food-systems perspective. I professionally identify as a food and nutrition anthropologist who embraces a bio-cultural, food-systems approach. My 1970’s ethnographic studies concerned the evolution of food systems focused on particular food crops, particularly maize and later potatoes. Adopting an anthropological ‘food systems’ framework, in 1984, I produced an *Annual Review of Anthropology* synthesis of ‘Anthropological Perspectives on Diet’. My science-and-policy research on the causes and consequences of hunger since the 1980s conceptualises the impacts of global food-and-nutrition policies at multiple scales, with special emphases on breaking the links between conflict and food-insecurity. Advancing the human right to food, in ways that connect local sociocultural perspectives to national and international legal and political-economic approaches have been an additional, ongoing professional project.

systems approach, at multiple scales, clarifies connections between the ecology and social organisation of production; market and cultural economy of fish value chains and distribution; social and cultural dimensions of food habits, preferences and preparations; and nutritional and health consequences of such choices and behaviours. It also considers the impact of global processes of environmental and economic change on local patterns of production, livelihoods, diets and health.

Local food systems, as an approach to understanding community management of their food environments, have long been a priority area of study by anthropologists and other ethnographers (Messer 1984). Yet, arguably, these local subsistence and dietary studies analysing customary economic activities and related food and nutrition habits, neglect water-based livelihoods and give predominant attention to land-based resources because cultivation, foraging and distribution of terrestrial grains, legumes, tuber crops and livestock account for such a large proportion of total and local food.

Fish as food, according to conventional anthropology and policy sources, is an understudied topic also because water-based resources and livelihoods entail different access rules, private property rights and social and cultural formations of production, processing, marketing and control over products (McCormack and Ford 2020).

Predominant emphasis on land-based over water-based food resources prevails also in national and international food-systems analyses, which guides official 2020's food-policy agendas of United Nations (UN) agencies and International Agricultural Research Centers (IARCs). These inter-governmental organisations and international bank-funded institutions, in partnership with national governments and non-governmental organisations (NGOs), have been designing and implementing plans to achieve the 2030 Sustainable Development Goals (SDGs).[7] SDG#2, the second of 17 SDGs, aims at 'Zero hunger' through targeted advances in agricultural production, trade and aid to improve food access, and nutrition interventions, some aimed specifically at undernourished women and children. Commensurate with

[7] See: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

their relative contributions to human nutriture, plant foods and livestock dominate these world food policy agendas.

Such ostensible omissions notwithstanding, a background search for terms such as ‘aquatic’, ‘maritime’, ‘ichthyology’ or related terms in food research reveals considerable and expanding attention to fisherfolk livelihoods and fish as nourishment at multiple scales, local-to-global in both directions. A good example is a relatively recent anthropological review on ‘Fishing’ by McCormack and Forde (2020), which covers global-to-local topics ranging from cultural symbolism to climatic and political-economic displacements. Local-to-global ethnographic case studies of fish as food are also multiplying, as shown by the dedicated volume, *Seafood: Ocean to the Plate* edited by Hamada and Wilk (2019), and innovative cultural historical analyses tracing internal (local) and external (global) drivers of change in fish-focused food systems. Some examples illustrate new ways to document topics, such as decline of fisheries and fishing cultures in traditional (Japanese) settings (Fukushima 2021) and global-to-local drivers of changing technologies and tastes for fermented fish products in modern Philippines (Narciso n.d.).

Fish as food, analogously, is increasingly visible in larger scale, global food and nutrition policy in at least four major institutional contexts. The first is the above-mentioned international Sustainable Development Goals (SDG) Framework, where fish surfaces under SDG#14 (‘life under water’) after being omitted in SDG #2 (Zero Hunger). The second are within UN food-systems activities leading up to the United Nations Food Systems Summit (UN FSS) (United Nations 2021). Although this process again favoured terrestrial-food livelihoods, the preparatory activities gave abundant attention to water-based resource sustainability and related ecological and human population displacement concerns, especially across Asian and African river systems (Boyd et al. 2020; Naylor et al. 2021). Contributing to fish databases, the Consultative Group on International Agricultural Research (CGIAR) is a third context, which funds major international agricultural research centres dedicated to specific crops, livestock, food-policy and water management and supports the WorldFish Center, with its multiple national nodes dedicated to aquatic foods. Additional UN agencies and high-level expert panels add to these knowledge bases: e.g., the Food and Agriculture Organization of the UN (FAO), dedicates special divisions and programmes to aquatic resources. Aquaculture in particular drives up-to-date reviews regarding sustainability (Boyd et al. 2020) and contributions to ecosystem management and nutrition (Naylor et al. 2021). Overall, these analyses update a UN High Level Panel of Experts (HLPE) on Food Security and Nutrition of the Committee on World Food Security (HLPE 2014) report on *Sustainable Fisheries and Aquaculture for Food Security and Nutrition* that followed in the wake of the world food crisis of 2008. Increasing attention to deteriorating situations of small-scale fisherfolk and fisheries also forms part of growing global concerns over smallholder vulnerabilities and ways to address them (Islam and Chuenpagdee 2022).

In view of this counterevidence, two goals here are to highlight where fish as food enters these high-level agendas, and to indicate how these high-level policy processes connect to local food-systems and the people who champion them. Where does fish as food fit into agendas expressed alternatively as 'think local, act global' or 'think global, act local'? Some related questions to be considered when reading themes and case studies in this volume are: How do local or multi-level ethnographic findings link up with global food and nutrition policy efforts regarding fish as food and sustainable livelihoods? How can global researchers and policy makers most effectively engage participation by local peoples reliant on biologically and culturally diverse water-based dietary resources and livelihoods? As corollaries, in what ways do UN and CGIAR food-planning efforts demonstrate inclusive perspectives by integrating social and cultural analyses of fishing and aquatic food-value chains? Do they thereby propose sustainable futures for fisherfolk, including healthy diets for all who rely on fish for food and livelihood? Finally, are there identifiable ways to improve transdisciplinary local-to-global and global-to-local understandings and better integrate 'fish as food' into world food system planning?

The timely contexts for this inquiry and discussion are the 2021 UN FSS and the 2021World Food Prize award to WorldFish laureate, Shakuntala Haraksingh Thilsted. The UN summit, emphasising food-systems, addressed world food security in multiple disciplinary ways that could better meet SDGs for ending hunger and poverty. Aquatic resources and fisherfolk formed part of official and NGO summit processes, and the organisers, albeit with difficulty, made efforts to include representatives of small-scale and indigenous societies in their discussions. Thilsted, an interdisciplinary aquatic-resource researcher and policy planner, served as a leader of UN FSS (United Nations 2021) Action Track 4, *Advance Equitable Livelihoods* and also was a member of the High Level Panel of Experts on Food Security and Nutrition and advisor to the High Level Panel for a Sustainable Ocean Economy. She was honoured, significantly, for her achievements in holistic design of fish-based food systems (Figure 1.1) that aim to improve nutrition, health and livelihoods of small- and medium-scale fisherfolk especially in South and Southeast Asia.

Figure 1.1: ▸ Dr. Shakuntala Thilsted at a Fish market.

Photograph credit: WorldFish (with permission), licensed with Creative Commons

Her lifelong work and recent projects promoting diversification of aquaculture systems contribute to knowledge and practice advancing ‘fish as food’ for low- and middle-income fisherfolk, who are targets of SDG efforts to eliminate poverty, improve nutrition and protect the environment. These projects highlight women’s work, the gendered dimensions of fishing, fish processing and marketing that add income and nutritional impacts to biodiverse fishing practices and demonstrate fish as nourishment, not only for protein but also for essential fatty acids and micronutrient contributions to nutrient-poor diets.

Small- to medium-size fisheries, as a result, are on the policy agendas for livelihood and nutritional developments in many countries. Multi-level aquatic food-value chains that consider multiple fish species, markets and consumption patterns, are climbing higher on ocean and freshwater sustainability agendas. It remains to be seen by what measures the award of this prestigious World Food Prize to a WorldFish food policy planner and researcher in nutritional public health can help raise the profile of fish as nutrition and spotlight fisherfolk in national and international food and nutrition planning,

The sections below pinpoint recent topics in ethnographic and policy research that highlight paths for adding or integrating fish as food into UN FSS and SDG processes. Additional integration of fish as food into SDG and UN FSS research and policy promise additional inclusive actions. In particular, Thilsted's reframing of fish as *nourishment* is central; how will her position as World Food Prize Laureate position her to expand influence in this direction?

These high-level policy actions offer opportunities to think through anthropological 'food systems' contributions concerning 'fish as food' to global, summit-level processes. They also encourage re-examination of the 'think local, act global' theme to a 'think global, act local' paradigm for current food policy and practice (Figure 1.2).

Figure 1.2: 'Think local, act global' was the maxim of ecological anthropologists in the 1960s and 1970s, theorising the contributions of local ethnography to global studies of ecology and political economy, in professional streams that over time identified with human ecology, cultural ecology, political ecology and environmental anthropology. All coalesced around emerging concerns with sustainability in the late 1980s and following. These transitions over the 1980s through 1990s also occasioned a reversal in emphasis from 'think local, act global' to 'think global, act local,' in view of ethnographic evidence that showed the incremental and cumulative impacts of global processes on local societies that encouraged multi-levelled systems research and policy engagement.

Given word/page limits of the chapter, issues of conservation, local control over fishing grounds and species, environmental and political refugees who have been thrust out of their traditional fishing zones by political-economic factors and climate change, will not be discussed further here, although such cases are much in the news, particularly in South and Southeast Asia, which are of special interest to the World Food Prize honouree.

Background: Aquatic Resources in Food and Nutrition Research and Policy:

Fishing, at all spatial scales, constitutes a significant sociocultural and economic occupational category; fish, in addition, contribute essential nutrition for millions, especially low-income people lacking entitlements to terrestrial food resources or income to purchase nutritionally adequate food. Global numbers show that some 800 million people worldwide depend on small-scale aquaculture and fisheries for livelihood, and some 3.3 billion get at least 20 percent of their animal protein from aquatic resources. Aquatic resources are estimated to supply 17 percent of animal protein worldwide plus essential fatty acids and micronutrients that are particularly important for cognitive growth of very young children. Nutritional analyses emphasise, in addition, the superior nutrient composition of small and wild-caught ('capture') fish species as compared with large-scale aquaculture products. They spotlight significant contributions of small-scale fisheries and locally processed small indigenous species to livelihoods and local nourishment of women and children, in particular, who may not have easy access to comparable sources of protein, essential fatty acids and micronutrients (Bogard et al. 2017; WorldFish 2020; Thilsted 2021).

Although sustainable food systems initiatives have tended to omit seafood and fresh-water resources, this picture, as indicated above, may be changing alongside efforts to move fisheries research away from almost exclusive emphasis on production of fish as a commodity for multiple end uses to more holistic 'fish as food' analysis that connects production to processing, provisioning and human consumption. Holistic fisheries research and policy, furthermore, challenge conventional separations of wild-capture from aquaculture fish supply and reframe 'fish' in sustainable-development conversations from an exclusive focus on a single large species (such as carp, Cyprinidae) production quantity to a more holistic interest concerned with total species contributions to dietary nutritional quality. They move the research and policy conversation from food security to nutrition security, which includes the critical dietary and livelihood contributions of major and minor fish species within a single biodiverse system that encompasses micronutrients and protein in addition to total fish weight or calories.

Such reframings implicitly or explicitly advance policy research in the direction of entitlements (e.g., Sen 1986) and right-to-food: who controls resource endowments, production and marketing of fish? And how do fish processing and exchange of fish products add to the household income available to buy food and access additional nourishment, especially for vulnerable women and children? Holistic production-through-consumption, systems-based understandings of aquatic-resource procurement, processing and utilisation, as a corollary, encourage international and national policy makers to respect and protect small-scale fisheries, biodiverse fish stocks, and the significant roles of women in food provisioning along all steps of processing through distribution, safe preservation and cooking preparation, and consumption. The professional challenge for policy makers is to find ways, simultaneously, to scale up production, provisioning and consumption of fish as food but scale down recommendations to support better local-level fisheries, sustainable household livelihoods and nourishment from manifold species resources (WorldFish 2020; Thilsted 2021).

Definitions and Taxonomies

World policy makers promoting fish as food define:

- ***fish*** as all animal products (including crustaceans, molluscs, cephalopods and other marine invertebrates) harvested from aquatic systems, both marine and freshwater (e.g., Bennett et al. 2021, footnote[5] above).
- ***aquatic livelihoods*** add in all plant resources (e.g., algae, kelp) to fish, shellfish and other invertebrates that contribute food as part of water-based livelihoods and nutrition from traditional or Blue Revolution/Blue Transformation water-based livelihoods (e.g., Battista 2021). A UN World Food System Summit brief encompasses: ‘fish, invertebrates, algae and aquatic plants captured or cultured in

freshwater and marine ecosystems' (Leape et al. 2021).[8] Such inclusive concepts and definitions contrast with linguistic and cultural classifications, which distinguish and differentiate 'fish' from 'shellfish' and other invertebrates, and both from other edible products from the sea or inland waters; whereas 'seafood' ordinarily encompasses all the animal, but not the plant matter.

What is not easily discernible in these sources is whether or how cultural definitions and distinctions matter for research and policy purposes; for example, whether there are culturally distinct names and property rights asserted for 'farmed fish' in contrast to wild? Professionals for policy purposes ordinarily distinguish wild-capture from farmed fish (aquaculture) and prioritise production of targeted farmed fish species (e.g., carp, Figure 1.3) from other smaller indigenous species which may be discarded as waste, a practice fought by food-system researchers whose economic, cultural and nutritional analyses find that these so-called waste species are significant for local livelihoods and nutritional security (Thilsted 2021).

Figure 1.3: Common carps (*Cyprinus carpio*)

Photograph © Frédéric Duhart

[8] These qualifications are astutely chronicled in the (2020) animal taxonomy history/biography/memoir, *Why Fish Don't Exist* that describes the evolution of water-based zoological life form terminologies and taxonomies (Miller 2020).

Nomenclatures matter for purposes of literature review and cross-cultural comparison where particular occupational (maritime or fishing) livelihoods are targets for sustainability and livelihood research and policy. Framings also matter where certain demographic groups are targets of concern (e.g., coastal populations), especially where they are particularly vulnerable due to planned or emergency 'migration and displacement'. Such migration may be due to conflict or deteriorating environment, whether of a resource base or of safe habitations, or of any combination of these. Concerns for regulators surround 'polluted and degraded fisheries', especially regarding poisonous shellfish from overfished, polluted waterways, contaminated with concentrated toxic minerals such as methylmercury or a variety of microbes. A relatively new policy term is 'climigration' with emphasis on the North American Northwest Coast, especially due to the loss of salmon and herring resulting in dietary deterioration, exacerbated by an increase in non-local processed foods. This is also a term used for the Arctic, Pacific Islanders, Southeast and South Asian fishing-culture displacements due to floods, water and land degradation and loss of aquatic resources. In this mix are also human-rights concerns, such as harmful fishing subsidies (Skerritt 2021) that undermine 'marine justice', environmental stewardship and indigenous knowledge (Parsons and Taylor 2021).

Significant framing language also distinguishes studies of 'indigenous' or 'artisan' fisheries from larger scale 'Blue Economy' assessments. Recent analyses calculating nutritional benefits of small fish biodiversity, for example, consider positive social components, including female householders who process fish as 'assets', and add value to the small indigenous species they manage for dietary purposes. Anthropologists, in particular, examine these local fish ecologies or 'food fish systems', from systemic perspectives, and contribute understandings of these local food-systems in relationship to environmental change, political-economic globalisation, and multiple levels of food policies that reduce access to traditionally diverse fish resources. Like fellow advocates for indigenous artisan fisheries, anthropologists seek to respect, protect and learn from local cultural knowledge and diets of these traditional fisherfolk, whose food systems have been undergoing change as a result of diminishing availability of biodiverse resources and modernising food preferences. Many push back against 'fish commoditisation', a framing and language favoured by economists, who increasingly dominate discussions of the ‘Blue Economy’. Blue economic development models prioritise increases in fish products for all fish-as-food commercial purposes, including feed and protein or fish-oil concentrates, not food for fisherfolk at the production end of the fish-value chain (Allegretti and Hicks 2022). Such critical voices coexist alongside applied anthropologists who collaborate in interdisciplinary teams that advance aquatic and maritime economic development policies (Gupta 2003; McCormack and Forde 2020). A pertinent research and policy question is: how does prominent focus on aquatic livelihoods, or alternative framings and language like Blue Revolution or Blue Transformation and livelihoods, change the agriculture-food-nutrition conversation and incorporate culture from multiple anthropological perspectives?

Food Systems and Human Rights

Advocates for more holistic policy thinking and actions also help frame human rights perspectives on fisheries and encourage multi-levelled and systems analyses. Global findings necessarily build on the results of smaller-scale ethnographic studies, which characterise the diverse fish species harvested from local rivers and ponds, and the simple to complex ways local peoples process these fish into safe and nourishing foodstuffs. Food-system efforts call for better local-level data, combined with more detailed linkages that demonstrate the fit between higher-level policies and local-level practices, which are still largely missing in fish-focused food-system studies (Simmance et al. 2021). These ethnographies, necessarily, involve analyses of continuities and change, as local societies and their ecological and economic bases of livelihood encounter global forces and perturbations that reduce traditional biodiverse fish species and processing methods and products.

At a local community scale, ethnographers studying the cultural practices of local fisherfolk continue to analyse the cultural significance of particular fish species for particular human societies, through human-animal cosmology and ritual symbolism. Such local philosophical, symbolic and cosmological studies explore in exquisite mythological and ritual detail the complex relationships between particular fish species and the human societies that identify, manage and eat them. But the numbers of such studies are diminishing along with the cultural demise of so many small-scale fishing societies that have been displaced by political economic forces of modernisation and climate change. These reductions in fishing societies and the studies describing them are consistent with findings by nutritionists, who calculate reductions in essential fish protein, fatty acids and micronutrients in diets as local wild ('capture') fishing livelihoods atrophy in the face of climate change, exploitation by non-local forces, and diversion of livelihoods to aquaculture and diets to farmed fish.

At a global scale, multiple disciplines engage in research describing cultural, biological, environmental, livelihood and nutritional transformations associated with water-based occupational transformations. Middle-level analyses capture some of the organisational and practical dynamics of negotiations of local fisherfolk and their role in shaping, not just responding to policy initiatives. Issues at multiple levels highlight food-system, human-right-to-food and nutrition (food, health and care) perspectives and suggest the wisdom of attending to local-to-global flows in both directions. Such dual perspectives are required to understand how local fisherfolk enter global policy dialogues assessing and recommending contributions of aquatic resources to local livelihoods, food security and nutrition, while at the same time attending to place-specific cultural analyses and dynamics of biological, ecological, political-economic and sociocultural change.

Further perspectives:

Anthropology

Although the *Annual Review of Anthropology* published its last fisheries article four decades ago (Acheson 1981), recent review articles on 'Fishing' published in anthropology encyclopaedia (e.g, McCormack and Forde 2020) give significant attention to issues of ecological displacements, legal property regimes, globalised trade (food chains) in low- to high-value fish stocks, and changing division of labour associated with aquaculture and climate-forced or conflict-affected migrations. Particular areas of research explore:

> 'fishing ways of life, fishing knowledge, marine tenures and economies, the gendered nature of fishing, how people cope with danger and risk,

and the specificities of how this particular watery nature is manifested in social, political and cultural systems. …'

(McCormack and Forde 2020: 1)

Anthropological research on fisheries, in theoretical and practical policy-engaged studies, 'engages critically with neoliberalisations, the extension of privatisations, and the proliferation of industrial aquaculture, thus challenging Blue Economy attempts to reconfigure nature-culture relationships and reposition the marine environment as a locus for the enactment and perpetuation of inequality.'[9] (McCormack and Forde 2020: 1)

Artisanal fishing societies differ from artisanal agrarian (land-based farming and pastoralist) societies in their technologies, gendered division of labour, structured and informal transmission of knowledge, cultural management of nature-based risk and uncertainty, and also their evolving engagements with modern states and global food systems (see also e.g., Gupta 2003). Their watery environment is difficult to constrain or enclose within the terms of property regimes designed for terrestrial peoples, their economies and livelihoods. Authors, therefore, critique the Blue Economy (i.e. economic studies and proposals for sustainable fish-based livelihoods and environments) and its working framework of enclosures, which treat seascapes like 'giant aquariums' and fish species as commercial commodities; they tend to ignore and destroy the nature-culture relationships of traditional peoples along with their sources of sustenance. Some particular criticisms concern the extinction of traditional fish species along with the cultural and nutritional roles of these species in local diets, e.g., giant catfish (*Pangasianodon gigas*) in Southeast Asia (see van Esterik 2006) as well as roles of locally produced fish not only for home consumption, but as sources for livelihood to enable fisherfolk to trade them for other nourishment (Fabinyi et al. 2017).[10]

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[9] 'Fishing can be defined as a productive activity that takes place in a multidimensional space, depending more on natural or wild processes than manufactured processes. The idea of fishing being closer to nature is an analytical thread, giving the anthropology of fisheries a particular edge on the multispecies and more than human ethnographic turn in contemporary anthropology. Research in fisheries anthropology has long held the connections between fisher and fish to be of central concern. Significant too, however, is the thesis that the construction of commodity fisheries as a natural domain, of which fishers are atomistic extractors to be managed, is a highly politicised process involving the bioeconomic creation of fish stock and broader political economies.' (McCormack and Forde 2020: 1).

[10] In the terms of Amartya Sen's 'Entitlements' framework, fish constitute both resource endowments and exchange entitlements (1986).

Anthropologists interacting with interdisciplinary teams engaged in fisheries policy and governance, furthermore spotlight the frequent disconnects between rule-making agencies and the communities they govern, and suggest that anthropologists have important roles to play in interpreting fisheries management, property and ownership rules, including individual versus communal ownership over territories, gear and products (e.g., Gupta 2003). Yet fisherfolk join indigenous social movements demanding respect and protection of their customary rights to property. Ethnographic reports, in summary, provide primary and continuing sources for establishing systemic data points and tracing linkages (e.g., Hamada and Wilk 2019).

Fish as Food in the International Food System Research and Policy Summit Processes

Although economic-development activities favour those practising terrestrial livelihoods, media reports assert that fishing organisations have been deliberately and carefully included in the 2021 World Food System Summit process, with more integration to come. Additionally, basic and applied research in sustainable fisheries and total nutrient contributions of biodiverse fish consumption to diets appear to be hot topics.

The FAO Liaison Office in Brussels (Food and Agriculture Organization 2021), in a news release 'Towards the UN Food Systems Summit' expounded 'The vital role of fisheries and aquaculture' as part of the process, and pointed to the FAO 'Blue Transformation' initiatives, and the 'food from the sea' as vital nutrition and source of livelihoods for millions of people. New fishing economies, especially aquaculture, receive prominent attention regarding livelihoods and who benefits, and, also, ecological and economic sustainability (e.g., Belton et al. 2021; Virdin et al. 2021). These policy blogs are part of an Ocean21 series sponsored by the science and policy news source, *The Conversation.*[11] Recent literature reviews related to conceptual models of 'food fish systems' add evidence that the divides separating studies of production, provisioning and consumption and wild-capture versus aquaculture, may be breaking down or be bridged by new

[11] See for example:: https://theconversation.com/5-ways-climate-driven-ocean-change-can-threaten-human-health-162341.

evidence and emphases, especially for freshwater food-fish systems (Tezzo et al. 2021).[12]

A UN FSS brief urged three policy priorities for governments:

(1) 'bring blue foods to the centre of food-system planning and decision making;
(2) protect and develop blue food potential to end malnutrition;
(3) support small-scale actors in blue food developments.'

(Leape et al. 2021).

An intriguing finding and challenge reported in this UN FSS policy brief concerns Bangladesh small- and medium-scale fisheries developments. These developments reportedly involved public investments in infrastructure and a positive business environment for smaller-scale actors, but notably no government controls regarding size or species of fish or fishing systems (see Hernandez et al. 2018).

Dietary analyses provide an additional and growing focus on the unique nutritional contributions of fish to essential fatty acid, protein and micronutrient intakes. The significance of different species and sizes of fish in local, and especially young children's diets, has been spotlighted by Thilsted's activities, as the global lead for nutrition and public health at WorldFish, the aforementioned CGIAR research centre, headquartered in Malaysia, with regional offices in Bangladesh, Cambodia, Egypt, Myanmar, Solomon Islands and Zambia. Nutritionists, consistent with her leadership, note that fish is often an essential and irreplaceable source of accessible high-

[12] This review is particularly useful because it carefully defines 'production,' 'provisioning' and 'consumption' step-by-step, from water to plate, in broad, but detailed terms. Also, concerning 'governance' and 'policy,' the authors focus on the full range of government and non-government organisations and institutions, with special attention to science policy-based research that guides sustainability developments. For the analysis, the authors considered works by three main fish research and policy agencies from the 1970s through the 2020s. They observe that their selection criteria produced results heavily skewed toward WorldFish publications, which accounted for 78 percent of their analytical sample. The other two agencies in their review were FAO and SEAFDEC. Also, literature from Bangladesh and the Philippines, which host major fish food agencies, accounted, respectively, for 35 and 15 percent of their sampled literature. A third observation concerned conceptualisation and content. Fully 57 and 24 percent of the papers, respectively, presented 'segregated' studies, discussing exclusively aquaculture or wild-capture fisheries. Only 19 percent presented integrated models, frameworks, or findings, although the reviewers show that there is considerable overlap in practices. An additional issue was exclusive focus on production prior to the year 2000, when there was some attention to interactions connecting provisioning and consumption. Provisioning and consumption were mainly of interest for wild fisheries, where studies explored the complex connections between communities and policy makers, whose efforts to regulate and conserve fish and their habitats did not routinely emphasise fish as food, but instead environmental conservation and other management issues. One rationale for lack of focus on consumption is the 'hidden harvest' narrative promoted by major fish agencies that more than 80 percent of freshwater fish harvest goes unrecorded.

quality nutrients for those who lack access to land or income to purchase marketplace fish. As access to wild-fish resource endowments diminish, economically disadvantaged households do not necessarily have money to buy farm-raised fish or nourishing food substitutes in the marketplace. So, species, size and nutrient composition specifications of small indigenous species matter.

Across the 2021 UN FSS preparatory documentation, one finds teams of interdisciplinary scientists exploring food-systems approaches that consider ecology of production, market and economics, sociocultural distribution of food and ranked preferences, and nutrition and health implications. Human rights frameworks and analyses are also on the agenda. Climate change and climigration – Adaptation, Mitigation, Resilience – or move — are topics of ongoing conversation among climate (change) policy professionals (Kenny et al. 2021; Kleisner et al. 2021).[13]

These summit-level processes raise important questions about fishing collectivities and equity. For example:

- What kinds of social organisations and cultural groupings exist for production, processing, marketing, policy, environmental and social protection?
- Where more than half the fish food value chain jobs are filled by females, in countries where females are economically and socially disadvantaged, what kinds of organisations and infrastructure, at multiple levels, might be required and promoted to protect and improve their livelihoods and well-being?

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[13] Kleisner et al.'s (2021) abstract gives the flavour of such studies:

'Fisheries are critically important for nutrition, food security, livelihoods, and culture of hundreds of millions of people globally. As climate impacts on ocean ecosystems increase, policy-makers are asking critical questions about how to implement reforms at local and national levels to reach goals around improving performance of management systems, sustainability, equity, and resilience to climate change. These goals can be achieved by enhancing the structure, function, and biodiversity of marine ecosystems as climate change proceeds, together with adaptive, sustainable management. However, resource, technical, and governance capacities vary widely across management systems. These capacities will determine, in part, the best policy approaches to build resilience and overcome systemic challenges to equity and sustainability to stressors such as climate change. To illuminate how fisheries resilience can be improved within the constraints imposed by these capacity limits, we present case studies from Myanmar, Belize, Peru, and Iceland, which offer a spectrum of capacity conditions to explore social–ecological resilience challenges and solutions. Using a set of nine social–ecological resilience criteria, we examine each system's attributes that may confer or undermine resilience and explore interactions between them. We use this assessment to identify policy approaches that can help build resilience in each particular context.' (Kleisner et al. 2021: Abstract)

The UN FSS 2021 Blue Food Brief recommended: 'Governments should support and strengthen multi-stakeholder initiatives that have the benefits of SSFA (Small Scale Fisheries and Aquaculture) at their core, including organisations of fish workers, harvesters and producers at global, regional and national levels, such as the World Forum of Fish Harvesters and Fish Workers (WFF), the World Forum of Fisher Peoples (WFFP) and the International Collective in support of Fish Workers (ICSF)' (Leape et al. 2021: 11). But in practical terms:

- How do governments favour revenues (aqua-product trade), employment (informal *versus* formal jobs in the fish value chain), farming and fishing interests that may be at odds regarding chemical use, property rights and so on?
- How should governments promote inclusiveness for females in contexts where such integrated and inclusive gender and ethnic empowerment perspectives are not routine?

Such negotiated benefits are relevant to nutritional perspectives that favour particular nutrient concentrations and nutritional contributions of hundreds of small fish species. Can (or should?) government food and nutrition policy guidelines specify fish size and species, which potentially impact recommendations all along the food value chain, from production to consumption (Hicks et al. 2019)? Acceptability of such recommendations, of course, would be impacted by cultural food-habits and norms regarding consumption of seafood or particular species. Relevant cultural questions include: local understandings of fish classifications, processing, control over products across political, geographic, ethnic, class, gender and age groups; the salience of particular fish products in children's and everyone's nutrition as complementary to other sources of essential dietary nutrients in particular cultural diets, and affordability and accessibility of fish in local cuisines.

All these points relate to the spectrum of human right-to-food criteria that policies should RESPECT, PROTECT, FACILITATE and FULFILL, the right to adequate food of all people, in a way which considers fish-folk organisations and advocacy groups, and human rights case law describing human rights violations (e.g., Ratner et al. 2014). These cases deal with issues such as access to fishing areas, forced evictions, detention without trial, violence and personal security, exclusion from education and health programmes, and several different but related abuses of child and adult forced labour. Documenting such rights violations suggests additional roles for local anthropologists or other researchers who advocate on behalf of fisher folk.

'Recognise Fish as Food' and Nutrition Perspectives

UN FSS encouraged a number of related efforts. Bennett et al. (2021) 'Recognise Fish as Food in policy discourse and development policy' note that fish is absent from SDG Zero Hunger (SDG#2) and World Nutrition reports, targets and recommendations, and, reciprocally, 'food' is scarce in fisheries framing, which emphasise economics and environmental conservation.

SDG#14, 'Conserve and Sustainably Use the Oceans, Seas and Marine Resources for Sustainable Development', overviews marine-based livelihoods, with particular attention to small islands developing states[14] and connects to the UN General Assembly process of Ocean assessments, which include status of fishing populations, but not necessarily fish as food (Bogard et al. 2017; *The Second World Ocean Assessment* 2021).

These gaps are emphasised in Environmental Defence Fund Fish blogs that spotlight voices of ocean experts who envision ways to provide more fish, more human food and thriving fishing communities. The blog by Willow Battista, 'Engaging Small-Scale Fishers in the U.N. Food Systems Summit', as a case in point, asserts 'that the global community of NGOs, civil society organisations, development agencies and policy decision-makers have been failing to treat fish as food.' Instead, they channel millions of tons away from the people and groups sorely in need of their nutrient contributions to diet.

UN FSS dialogues exhibited a mixed picture, as fish figured in three dialogues: 'Integrating Blue Food into the UN Food Systems Summit Agenda,' 'Centering Small-Scale Fisheries in National Food and Nutrition Plans', and 'Transitioning to Nature Positive Production: Sharing Lessons Across Land and Sea.' The last drew 107 participants, 97 in middle adult (31-65) age ranges, slightly more females (59) than males (48), with just more

[14] See: https://sdgs.un.org/goals/goal14

than half identifying from the ‘fish and aquaculture’ sector. The goal of prime stakeholders – to foster ‘inclusion’ with small and marginalised farmers through Information Technology (IT) outreach and connections – was partly achieved, as the process managed to engage smaller scale fishers from eight countries, in formats (breakout rooms) where they could share experiences and ideas for moving forward. An assessment dialogue box following the summit dialogue process noted, with regard to ‘inclusion’: ‘Small-scale … farmers and fishers are not (necessarily) combing the internet for opportunities to get involved in UN-developed virtual events so if we (stakeholders) truly want to hear their voices we (the NGOs, governments and other highly-engaged agencies) need to … actively seek them out’ and ‘make the process accessible’ (Official feedback on Summit Dialogue processes).[15]

Fish are key for reducing hunger and malnutrition at multiple scales

Critics contend, furthermore, that framing fish as a commodity or environmental resource ignores or diminishes an emphasis on fish in human food and nutrition, particularly for marginalised populations. The aggregate substitution of aquaculture for wild fish may balance reductions in wild catch, but these benefits may not nutritionally compensate the poor who depend on wild fish for essential protein and micronutrients (specifics are unpacked in more technical nutrition articles) and aquaculture may not be managed in ways that sustain wild-fish habitats. Putting emphasis on end of the food chain (nutrition and health impacts), then working back, important policy questions are:

- Where do aquatic livelihoods contribute to people’s ‘food first’ or ‘food sovereignty' capacities to feed themselves?
- How are these capacities disrupted by climate change, political-economic transformations affecting production and trade rules (globalisation of food and globalised food systems)?

In the case of Bangladesh, an International Food Policy Research Institute comparative study of the situation between 1996-1997 and that between 2006-2007 indicated that the decline in capture fisheries was replaced by an increase in aquaculture sources (Belton et al. 2014). However,

[15] See: https://blogs.edf.org/edfish/2021/07/07/engaging-small-scale-fishers-in-the-u-n-food-systems-summit/ https://summitdialogues.org/ https://summitdialogues.org/overview/official-feedback-to-the-summit/

such gains relative to losses were not evenly distributed across income classes and the results suggested reductions in overall contribution of fish to protein and micronutrient contents of diets in the poorest classes (Belton et al. 2014). The specifics of these reductions were captured in a later study by Bogard et al. (2017). The policy lesson and recommendation, in both cases, indicate the need for nutrition-sensitive aquaculture to replace wild fish sources of protein, fatty acids and micronutrients in lower income groups (Belton et al. 2014; Bogard et al. 2017) and aquaculture's complementary versus replacement value for nutrition (The Second World Ocean Assessment 2021). Additional nutrition studies (Hicks et al. 2019) argue that sales of small fish to aquaculture industries, which grind them into fish feed,[16] diverts vital protein and micronutrients from fisherfolk households, especially children. Withholding just a fraction of that fish for home consumption could eliminate micronutrient deficiencies, such as iron deficiency.

In connection with UN FSS (United Nations 2021) a food-system approach articulated in a review article by Simmance et al. (2021) explored the terms fisheries, aquaculture and/or aquatic foods using the search string aqua* OR fish* OR mollusc* OR crustacean* OR 'aquatic plant*' OR seaweed* OR invertebrate* OR 'marine mammal*' OR reptile* OR seafood* OR 'blue food*' AND 'food system*'. The results eventually included 88 articles that examined aquatic foods in relation to human food and nutrition, which the authors then aligned with HLPE's (2017) coding structure. The article flagged the lack of studies spanning multiple spatial levels (it identified only eight); they indicated this research focus on a single level reflects a failure to integrate research across levels and to meet the potential advantages that food-systems concept might bring to the research. As the review points out, national and regional framings can account for external drivers of change, stakeholder priorities, and vulnerabilities that exist within food systems, but potentially obscure differences in production, processing and consumption among different subnational, ethnic, gender or occupational groups. The author joins other fisheries researchers (e.g., Béné et al. 2016) in calling for more local level assessments that disaggregate outcomes with markers of social identity (see also Béné 2020).

[16] Iain Young (personal communication 2023) observes: 'aquaculture species fed on a diet containing fish meal have a nutritional profile closer to that of the wild-capture fish than fish fed a diet with lower proportions of fishmeal or no fishmeal. While fishmeal maintains a high value, there will be a ready market for small fish from small-scale fisheries. A potential solution is to break the chain by producing a nutritionally rich substitute for fish meal. Unfortunately, these remain expensive (e.g., Black Soldier Fly larvae, algae, zooplankton, microbial proteins) (Bestion et al. 2020)'.

In other words: broaden the species resources under consideration, examine flows and trade-offs at multiple spatial scales, pay more attention to subnational populations and gender, age and other demographic criteria to better understand nutritional and environmental impacts of changing food systems involving aquatic foods. Research on this was sponsored by CGIAR Research Program on Fish Agri-Food Systems (FISH) led by WorldFish and the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH) led by the International Food Policy Research Institute. The findings and recommendations are consistent with other systemic analyses (e.g., Tezzo et al. 2021) that urge researchers and policy makers to move beyond studies of shrinking wild-catch versus burgeoning aqua-farmed resources. The key, as in Thilsted's work which serves as a model, is to reject the narrower productivist paradigm in favour of the wider systems framework for understanding fish resources, particularly freshwater species, especially in South and Southeast Asia, which account for much of the supply.

Sullivan (2022), alternatively, offers visions of future change based on large-scale data technologies that promise increased efficiency and sustainability in the context of enlarged, more diversified, 'whole fish' productivist models. More than 3 billion people get 20 percent of their protein from fish, and it is the top traded food commodity. But the future of fisheries will likely see a shift to value over volume, with help from modern technology. Wild capture species are overfished, much unreported and very much threatened by climate change, which raises surface water temperatures and reduces phytoplankton growth, thereby endangering the fish and food chains that rely on this ecosystem.

A related question is: where are the fish to feed the world going to come from? Farmed fish so far are mostly fresh-water species, although farming marine species is growing rapidly. For example, the well-managed New England marine fisheries in USA, present complex solutions for complex ecosystems, with multiple livelihood streams for fisherfolk adapting to these ever-transforming water environments.[17] An additional perspective, which

[17] The review by Sullivan (2022) focuses on New England, a well-managed fishery. It presents interesting facts, like abundant haddock but many fewer cod. The former are unregulated, but hang out with cod, which have quotas, so fisherfolk may avoid both. Lobsters are moving north in search of colder waters. Sullivan expects big fish to get smaller based on lower oxygen and gill size. These are very complex ecosystems. Some of the innovations – better surveys to protect fish recovery – involved scientists, regulators and fishermen collaborating, for example, on rotating beds for scallops. But description of regulators on board and technology that can distinguish fish species suggest that only big fish operations

will not be developed further in this review, is whether sustainable fish as food will include ever larger proportions of cell-cultivated or 'cultured', laboratory-grown alternatives to fish-meat from whole fish, which is rapidly under development.

Summary and Conclusions:

Fish as food is excluded no more. However, scholars and activists recognise that fisheries demand different concepts and metrics. They advocate distinct lines of interdisciplinary research into diverse fishing livelihoods and fish as food; these move beyond narrower, conventional economic assessments of 'big fish' increases or total harvests for all purposes.

In anthropology, numerous studies document fisherfolk transformations in response to globalisation of food in the additional context of climate change. These fish-focused social scientists contest and offer alternatives to Blue Economic models and metrics, which emphasise fish as commodities directed toward non-food as well as food issues. As scholars and activists, they champion the human rights of indigenous and other small-scale fisherfolk, and advocate their demands for sovereignty over traditional fishing areas, respect and protection of their cultural aquatic resources, of their struggles for livelihoods, and of their command over adequate nutritional food.

Food-system analysis contributes to world food system assessments emphasising diverse fish as food and livelihood. These food-system efforts, despite contentious arguments over the framing process, arguably advanced during the UN FSS, although it proved difficult to integrate fisherfolk, particularly indigenous fisherfolk, fully into the process.

Fish-as-nourishment, as well as examination of multiple small indigenous fish species as part of overall aquatic resource development, are also advancing. This significant end-of-the-food-chain and everything in between research direction has been largely championed by CGIAR Center WorldFish and its 2021 World Food Prize laureate, Thilsted, who leads their

(trawl nets, cameras and algorithms) will survive and flourish. More fish as food will likely rely more on farmed fish. Not all are polluting. Fully 70 percent of the farmed seafood products are shellfish and kelp. Shellfish are high in protein and some (e.g., mussels) do not need feed, as they clean the water and make their own protein and restore estuaries. Sullivan provides examples of wild capture fisherfolk shifting to fish farming for sustainability; e.g., one Newfoundland former cod fisherman grows oysters, scallops and kelp; even some Maine lobstermen grow kelp.

research and policy initiatives, advocating for more diverse conceptualisations and counting of fish species and contributions to critical nourishment, particularly by women for children.

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CHAPTER 2
GLOBAL VARIABILITY IN FISH (AND OTHER SEAFOOD) CONSUMPTION: WITH ANECDOTES ABOUT *SHISHAMO*, *SHIRASU* AND *HOTATE*

by Brittany Carol Rapone

As a child in the US, the only time my food had a face was when I ate a 'Goldfish', a small, cheddar-cheese flavoured cracker in the shape of a fish with eyes and a smile. Years later as an adult in Japan, when I was to eat another fish with a face, I wouldn't exactly say it was smiling, but it did have eyes and a mouth. And fins. And a tail (Figure 2.1a). As I soon found out when I took a bite out of its middle, eggs. Lots and lots of eggs. It was completely different from the vague breaded-white fish I had eaten in the form of grocery store fish sticks (called 'fish fingers' in the UK), fast-food fish fillet sandwiches or the American version of fish and chips.

Figure 2.1a: Cooked s*hishamo* (smelt); one is open showing the eggs.

Photograph © Karipoto - Stock adobe.com

This fish in Japan was nothing like the canned tuna, clam chowder or the honey-walnut shrimp I had previously eaten. Even compared to the couple of times I have had to remove skin and watch for bones while eating a fillet of salmon, this was just so much more…fish! This was shishamo, and it ended up being just one of many seafoods I had never encountered before my time in Japan, but was often offered, as exemplified in Figure 2.1b.

◀ **Figure 2.1b:** Breaded *Shishamo* as available in a student canteen in Japan for breakfast

Photograph © Brittany Carol Rapone

Introduction

Fish is food globally.

However, to what extent and how it is consumed varies from country to country. Rather unsurprisingly, according to the online database of Food Balance Sheets from the Food and Agriculture Organization of the United Nations (FAO), the top consumer countries of fish and seafood worldwide are either island or peninsula nations (Food and Agriculture Organization of the United Nations 2019). Japan, being the second most populous island nation, assuredly eats a lot of fish. Attempting to quantify this amount, or any other country's amount, for comparison's sake is, however, not straightforward. Multiple studies cover the topic of fish consumption by country with inconsistent results. Methodological differences, hard-to-find or non-existent data, ill-defined data, differing definitions of fish[18] and different ways of estimating consumption all lead to large variations. The literature shows comparisons between countries that sometimes contain over-simplified calculations, relating false equivalences or lacking in sourcing detail.

On top of these issues, complications arise when considering food loss, including waste at the consumer level and what is lost during food processing. In documentation from scientific bodies and government organisations, this loss is either unaccounted for or calculated with broad assumptions. I put forward that the variability in how fish (and other seafood) is eaten throughout the world, and thus the variability in what is lost, complicates these consumption statistics in normally unaccounted for ways. In turn, the validity of these statistics, most especially when making cross-country or cross-cultural comparisons, should be taken with a large pinch of salt. This is because the variability of fish consumption created by cultural differences exists in conjunction with other factors, such as geographic and economic ones.

[18] Statistics on fish, cephalopods, crustaceans, bivalves, etc., are often combined into a single 'fish' or 'seafood' category when reported. Aquatic mammals and plants are less often included. In the FAO's most recent publication on this subject, they have acknowledged the mis-representation of using 'fish' to mean all aquatic animals and adjusted their terminology accordingly (Food and Agriculture Organization of the United Nations 2022: 224).

How we measure fish consumption: complications of processing loss and food waste

Food consumption data are frequently estimated from what is called 'supply data' or 'availability data'; these are calculations of the total weight of food available for human consumption in a country per year. These food availability data are also commonly called 'disappearance data' because they represent 'the amount of the food supply that "disappears" from farms, net imports and storage facilities into the food marketing system and is available for consumption' (National Research Council and Institute of Medicine 2015: 3). Data on fish, however, are presented in ways that differ between the various concerned countries, governments agencies and organisations. Combined with inconsistently or vaguely defined terminology when it comes to weight given for fish, e.g., landings versus catch, edible weight versus live weight, etc., this can make comparisons between data sets particularly precarious. As an example of this, we get widely varying estimates of consumption of fish and seafood in Japan, which are anywhere between 2 to 11.5 times (whether in kilograms or pounds per capita per year) as much as the estimates for consumption in the United States (Johnson et al. 1998; Tonsor and Marsh 2007; Smil 2008; Food and Agriculture Organization of the United Nations 2019).

In an attempt at standardisation, the use of what is referred to as the '(fresh) live weight' or 'nominal weight' is encouraged, which is the weight immediately after harvesting from the water. This weight is often found by using conversion factors to convert the already processed fish's weight into its live weight. The reason for taking the processed fish and converting it back to live weight is because seafood is often partially or fully processed on boats before making it to shore, so a true live weight is never measured. There are conversion factors for different kinds of seafood in many forms (e.g., whole, viscera removed, headless, filleted, etc.), and the conversion factors used by different countries may vary, for example, because of differences in how they process fish (e.g., filleted by machine versus filleted by hand). But, even using the same 'units' for seafood weight, supply data can still be considered a weak estimate for actual consumption, as mentioned above, because of loss during processing and consumer waste.

The FAO, which appears to be the most expansive and thorough in its research on worldwide food supply data, notes that its Food Balance Sheets do not account for waste at the consumer level, and thus their calculated assumed consumption is likely to be overestimated.[19] The US's Economic Research Services' give a similar caveat to their own Food Availability data (National Research Council and Institute of Medicine 2015: 13). This would not be a significant source of error for comparison's sake, however, if consumer-level seafood waste was consistent across the globe, but there is subjectivity in what is edible and what is waste across different cultures and geographic regions

The FAO's own report on food loss and waste shows this variability in what is wasted globally, but still applies assumptions on how fish are consumed based broadly on a country's citizens' income level (Gustavsson et al. 2011). The proportion of fish consumed fresh was one of the factors taken into consideration when calculating volume of loss, as the amount of fish wasted was assumed to be different between fresh and processed products.[20] For countries considered low-income, an average of 60 percent of fish and seafood consumed was deemed to be fresh. This is in stark contrast to countries considered medium- and high-income, in which only an average of 4 percent consumed was deemed to be fresh (Gustavsson et al. 2011). These economic groupings were largely geographically grouped, with Africa, most of Asia (without China, South Korea and Japan) and Latin America being defined as low-income. All of Europe, Australia, New Zealand, the USA, Canada, Japan, China and South Korea were defined as medium- and high-income. This high percentage of fresh fish consumption in developing nations relative to developed nations was attributed to insufficient infrastructure for the long-term preservation of perishable goods along with 'well-established consumer habits' (Food and Agriculture Organization of the United Nations 2009: 43).

These calculations create an interesting situation where countries in which fish consumption levels are estimated to be, perhaps widely, different, such as Japan and the US, also assume that on average the same proportion

[19] https://www.fao.org/faostat/en/#data/FBS (see: Definitions and standards: Glossary: Per capita supply)

[20] The waste percentages used to calculate volume of loss at the retail and consumer level for fish and seafood across the globe are questionable. For 'fresh' fish and seafood, they were assumed or estimated from reports that did not necessarily just include fresh fish. For 'processed' fish and seafood, they were assumed or estimated from reports on canned fish only.

of fresh versus processed fish is eaten. But can that be assumed? Are citizens' income levels the most salient factor in how fish is consumed? In the same report on food loss, when looking at the stages in the food cycle where loss occurred, results inferred other significant factors. In the USA, Canada, Australia and New Zealand, the largest proportion of fish and seafood loss was attributed to waste at the consumer level, at about four times as much waste at the consumer level than in industrialised Asia (Japan, China and South Korea). This is important to note as it illustrates the existence of other factors besides income levels that have a substantial effect on how fish and seafood are consumed in these countries. However, as mentioned, these waste data and their potential variability and inaccuracies are not accounted for in the calculations of the FAO's data or in many other fish supply data calculations. Regardless, in terms of estimating consumption, the largest potential cause of variation likely comes from what is discarded during processing, before reaching the retail market.

As fish and seafood are often reported in live weight in an attempt at consistency, supply data do not account for the weight lost during processing. However, let us consider what is farmed or caught versus what actually ends up on the dinner plate and how this might vary across countries and cultures. The amount lost during processing is dependent upon the proportion of fish eaten fresh or not and the type of processing (e.g., freezing of the whole fish, partially gutting, filleting, canning, etc.), but it is also largely dependent upon the animal being processed. When considering all seafood, crayfish, clams and scallops, most of their weight loss is during processing for human consumption, with estimates of only between 11 to 13 percent of the animals actually considered edible (Food and Agriculture Organization of the United Nations 2016). Yet cephalopods, at the other end of the spectrum, generally have relatively little removed during processing because over three-quarters of their flesh are considered edible (Food and Agriculture Organization of the United Nations 2016).

With finned fish, there is much greater variability in their processing and thus in the edible portion sent to the consumer. A fillet of Nile tilapia (*Oreochromis niloticus*) represents 30 percent of the edible portion of the whole fish, while a Nile tilapia served with viscera removed, but with head attached, represents 81 percent of the edible portion of the whole fish (Food and Agriculture Organization of the United Nations 2016). This is where the aforementioned ‘well-established consumer habits’ (Food and Agriculture Organization of the United Nations 2009: 43) and the debate about edibility come into account. For example, in the case of the yellowback seabream (*Evynnis tumifrons*) sold in a grocery store in Japan (Figure 2.2), there is no loss during the processing and the waste will be completely at the consumer level, based on whatever they consider edible.

Figure 2.2: A packaged yellowback seabream as sold in a Japanese grocery store as *renkodai*. It has been cut in half to fit the packaging better.

Photograph © Brittany Carol Rapone

The subjectivity of edibility

What fish and what parts of fish or other seafood are considered edible varies across the globe. Take the scallop (Pectinidae) for example. Depending on the location, scallops can have between one to three ‘edible’ parts. Why is this? In the USA, for decades the adductor muscle, the meat of the scallop, has been the only commonly eaten part, with sea scallops from the northwest Atlantic Ocean thoroughly shucked of everything before reaching the shore. The rest of the animal is thrown out as waste at sea (Rudalevige 2018). This includes the scallop’s gonad, in the culinary world referred to as roe or coral.[21] The scallop's adductor muscle mostly consists of a cylindrical-shaped piece of striated, fast-acting muscle that it uses to quickly close its shell shut in order to swim by jet propulsion. On the side of this striated muscle, is a small piece of smooth, slow-acting muscle, also referred to as the catch muscle, that the scallop uses to hold its shell shut (Sun et al. 2018). While most often not even differentiated on anatomical diagrams, a few English-language culinary websites specify removing this catch muscle, so that the ultimately cooked and eaten part is an even smaller portion of the whole animal.

[21] This is because of the coral colour of the ovary in female and hermaphroditic scallops.

While the shishamo was not something I ended up eating after that first bite while I was volunteering at a children's home where the kids were required to eat everything on their plate, I did earnestly strive to set a good example by eating almost every other sea creature that came before me. This included an, at the time, unknown to me bivalve, Hotate (Figure 2.3a).

◂ **Figure 2.3a:** *Hotate* in Japan, with frill and coral still attached

Photograph © Kariphoto – stock.adobe.com

While I could tell that it had more to it than what it would have had if served in the US, I wasn't completely sure what that 'more' was. Much later after leaving Japan, I discovered that what I had eaten were scallops and the frilly part around it was the mantle, which I had vaguely recognised from past biology classes as a body part of molluscs. If I had known at the time, firstly, that the mantle is 'inedible' and, secondly, that it contained the scallop's hundreds of eyes, it might have gone the way of the shishamo and been guiltily passed off to a child sitting next to me. But in my naivety, I ate this unknown animal, known in Japan as hotate (Figures 2.3a and 2.3b), including its inedible parts.

Figure 2.3b: *Hotate* on a grill in Japan

Photograph © Brittany Carol Rapone

One reason given for the disposal of the gonad is that the levels of potentially hazardous-to-human-health biotoxins found in scallops are more of a concern in the roe, so eating only the muscle is arguably safer. This is because the scallop collects biotoxins through filter feeding, meaning that they are concentrated in the digestive tract. While the gonadal tissue itself might not be a significant source of biotoxins, the roe contains a loop of the scallop's intestines embedded in it, and consequently is more likely than the muscle to be a source of dangerous substances, such as Paralytic Shellfish Poisoning (PSP) toxin (Lamont et al. 2010; European Food Safety Authority Panel on Contaminants in the Food Chain et al. 2021). Another reason given by a chef in the New England (US) area, where both Atlantic Sea and Bay scallops are caught locally, is that their roe is less tasty than roe in the European scallop varieties. Other chefs and suppliers remarked that there 'just wasn't a demand', since Americans who saw the roe, when left attached, had no desire to eat it. European-trained chefs who wanted the gonad intact had to import scallops from France or Scotland (Miller 1979; Tager 1985; Rudalevige 2018).

This is because in Europe, scallop roe along with the muscle are often eaten. While the European Union (EU) does not define what it refers to as edible in its legislation concerning the safe consumption of scallops,[22] industry standards, as given by European Food Safety Authority (EFSA), describe 'edible parts' as both the muscle and the gonad (European Food Safety Authority Panel on Contaminants in the Food Chain et al. 2021). A London-published cookbook, *The Cook's Book of Ingredients*, when explaining how to shuck scallops, specifies cutting away 'the "frills", "skirt", or "mantle" of the scallop – [as] this contains gills and many eyes' (Jackson and Muir 2010: 78). Following this are instructions to remove the stomach sac and anything else besides the muscle and roe. Seafish, a UK-based organisation that refers to itself as 'the authority on seafood', similarly gives shucking instructions along with a warning: 'Don't use the viscera (the membrane, grey-brown frill and black thread of intestine are all discarded). These are inedible. Don't crisp it, cook it, blitz it or even feed it to your pets. Just throw it away as it is potentially dangerous if consumed' (Seafish 2010: 2). This is because the EU gives specific guidelines on the acceptable levels of various biotoxins that can be found in different scallop species and other

[22] Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. (https://www.legislation.gov.uk/eur/2004/853/annex/III/section/VII#)

bivalves, with different parameters for the whole animal versus the parts meant to be eaten. While various biotoxins from the scallop's whole body must be below a specified level, because of the industry standards in Europe, it is the potential amount of biotoxin in the muscle and roe that ultimately determines whether it can be placed on the market. Thus, the safety of eating other parts of the animal cannot be guaranteed.

As mentioned, the roe contains a loop of the scallop’s intestines embedded in it, but interestingly, no culinary recipes observed online included this information, and shucking instructions give the impression that the digestive tract is fully discarded. Whereas Seafish explicitly warns of the danger of ingesting anything but the muscle and roe, for example, the ‘frills’, instructions specifically on how to prepare and cook such parts can be easily found on various websites and blogs online,[23] because as it turns out, eating this frill is not unusual in Japan (e.g., Figures 2.3a, 2.3b and 2.4).

Hotate, as scallops are called in Japan, can be bought at a market or served at a restaurant in almost any anatomical combination. Even the mantle, known as *himo*, can be found separately as a dried snack (Figure 2.4). Whereas the muscle can be served by itself raw in sushi, pre-boiled and frozen scallop muscle with the *himo* and roe attached is available in the supermarket ready to cook. The question of edibility only comes up when shucking the whole scallop or when the (mostly) whole animal is grilled and served on a half shell at restaurants, as can be seen in Figure 2.3b above.

◂ **Figure 2.4:** A bag of ‘Grilled scallop string’ (*himo* or ‘frills’), from Hokkaido scallops being sold at the Tsukiji Fish Market in Tokyo. These are commonly eaten as a snack with drinks.

Photograph © Brittany Carol Rapone

[23] e.g., at https://www.kikkoman.com/en/cookbook/

Japanese culinary websites specify that the mantle, muscle and gonad are all edible. It is only the brown gills and the black digestive gland, the *uro*, that must be shucked away. The reason given is that the black digestive gland contains the stomach, where biotoxins accumulate. Any 'black lines' leftover is scallop dung that can be gently pushed out, as it does not taste 'good', according to one Japanese-language website explaining *hotate* preparation. Overall, the danger of eating certain parts of the animal is much less emphasised in Japan.

From this, we can see the large variability across different parts of the globe in what is considered edible as indicated by shucking instructions, culinary recipes and safety guidelines. In the US, only a single part, the muscle (and sometimes only part of the muscle), is regularly eaten. The rest, including the potentially dangerous and not so good-tasting roe, is discarded before ever reaching land. In Europe, industry standards determined the edible portions of the scallop, the roe and the muscle, giving explicit rules on what is allowed to go to market based on the presence of certain amounts of biotoxins. Finally, to Japan where frozen pre-boiled scallops come ready-to-cook, with the muscle, roe and mantle attached and only the dangerous *uro* is missing.

The unknown

The subjectivity of the edibility and subsequent palatability of fish and other seafood has been shown to be partially dependent on our knowledge of what we are eating exactly. In Brazil, a country with a relatively low level of fish consumption despite its large coastline, when research participants were shown a picture of nuggets or a burger, there was a significant difference in the words they associated with the images when they were told it was a fish nugget or fish burger compared to when they assumed it was chicken or beef. So, while the visual cues were identical, the presence of the word 'fish' elicited differences, not only in the perceived taste or smell, but in whether or not they would even try the food shown in the picture. In this case, participants were less likely to want to eat the food presented in the pictures when told it was fish (Mitterer-Daltoé et al. 2013). Whether something is or is not a fish can affect people's choice to eat it, but does the specific type or fish or other characteristics of the seafood itself affect edibility?

Scallops are unique, in that they have advanced eyes for an animal without a brain. Those from the genus *Pecten*, such as the Yesso scallop (*Mizuhopecten yessoensi)* found in the waters around Northern Japan, can have up to two hundred of them peeking out from their shells spanning about 250 degrees around the scallop. As most scallops can swim freely, unlike other bivalves such as clams, mussels or oysters, their eyes are thought to detect movement and guide their swimming when escaping from predators, such as starfish (Palmer et al. 2017). Could knowledge of its many eyes, or its unique behaviour potentially affect its edibility for some people? (As explained below, the eyes of fish can reduce its edibility for some people; Figure 2.5).

Figure 2.5:
Atlantic cod
(*Gadus mohua*)
On a fishmonger's slab, with 'angry' eye expression.

Photograph © Frédéric Duhart

Some people, even among those who are not put off by the notion of eating fish and other seafood, can be affected by a lack of knowledge and can be influenced by the accompanying vocabulary. As a result of vague umbrella terms and, sometimes intentional, mislabelling of fish seen in over 46 countries,[24] as shown by DNA barcoding identification, it is likely that fish consumers have at some point eaten some fish that they thought were from some other species of fish entirely (Galal-Khallaf et al. 2014; Khaksar et al.

[24] Countries indicated through scientific articles, including, but not necessarily limited to: Australia, Austria, Belgium, Belize, Brazil, Bulgaria, Canada, Chile, China, Colombia, Czech Republic, Denmark, Ecuador, Egypt, Estonia, France, Germany, Ghana, Greece, Hong Kong, India, Indonesia, Iran, Ireland, Italy, Malaysia, Mexico, New Zealand, Panama, Peru, Philippines, Poland, Portugal, Romania, Russia, Singapore, South Africa, South Korea, Spain, Sweden, Taiwan, Thailand, Turkey, Turks and Caicos, UK and the USA. Japan, specifically, had no English or Japanese scientific articles on the subject of fish mislabelling, but there are multiple news articles on the topic.

2015; Pardo et al. 2016; Hobbs et al. 2019; Mitchell et al. 2019; Biffi et al. 2020; Tang et al. 2022). This includes fish caught illegally, fish threatened by extinction, fish dangerously high in biotoxins and fish that are not thought worth the sale price. Notably, various species of shark meat is sold deceptively, for example in the UK and Peru, under broad commercial names without including the word 'shark' (or '*tiburon*' in Spanish), so that not only are consumers unaware of what type of shark they are eating, they also do not necessarily know they are eating shark at all (Lopez de la Lama et al. 2018; Hobbs et al. 2019). For example, Hobbs et al. (2019) explain how fish and chip shops in the UK (Figure 2.6) sell shark, often the spiny dogfish shark (*Squalus acanthias*, of which the northeast Atlantic population is on the 'Critically Endangered' list), under different names, such as 'rock salmon', 'huss' and 'flake'. The selling of shark meat under other fish names is seen globally.

Figure 2.6: A takeaway meal from a UK restaurant, described (above) as 'breaded haddock' and (below) as 'rock fish'

Photograph © Rusana – stock.adobe.com

Is this type of labelling necessary for the selling of shark meat? Is it easier to eat something if one does not know exactly what it is? Research on vague or outright incorrect labelling of fish also indicate the lack of visual clues that enable a person to discriminate between different fish as a factor behind its prevalence, especially when it is in an already processed form, such as a fillet. Whereas fish fraud is seen globally, whether it is more or less pervasive in countries that eat fish more frequently or primarily in less processed forms has not been quantified.

Additionally, for victims of fish fraud, what has not been studied is whether, if they had known beforehand what they were about to eat, would they still have eaten it or not? This is interesting to consider since, even if safe to eat, not of conservation concern and fairly priced, it is known that factors besides taste are clearly at play as regards the edibility of a fish.

At this particular children's home, traditional Japanese food was frequently served. While I had made it clear I would not eat (non-fish) meat and refused natto after trying it once, I forced myself to eat many other foods I would normally never try. I knew my displeasure with some foods was not a factor of taste. Once, I took a bite without problem into my rice, only to become deeply troubled by the idea of eating the rest when I noticed many little black dots mixed in with the grains. This time I was making eye contact with shirasu (Figure 2.7). Known elsewhere as whitebait, unlike the cooked scallop with its indiscernible eyes, these little fish were clearly looking at me.

Figure 2.7: A pile of *shirasu,* which is usually immature Japanese anchovy a couple of centimetres long, known as whitebait.

Photograph © Cocone – stock.adobe.com

Influences on fish consumption

As discussed, what is described as inedible is not always so and varies across countries. While island and peninsular countries are at the top of the list as regards fish and seafood consumption, FAO data also show that when ordering the list of countries from those that consume the most amount of fish to those that consume the least amount of fish, differences in levels of consumption do not equate 'one-to-one' with access to bodies of water. In other words, the top consumers of fish and seafood consumption are island and peninsular nations, but not all island and peninsular nations are top consumers. For example, the US consumes more fish per capita than the UK, and other island nations such as Cuba and Madagascar are towards the bottom of the list of quantity of fish consumed (Food and Agriculture Organization of the United Nations 2019). So, what else contributes to global differences in fish consumption?

Studies on factors relating to consumer food choices identify many determinants that are both personal and environmental. Personal factors include consumers' own attitudes, habits, taste preferences, convenience, health, ethics and environmental concerns. Environmental factors include cultural differences, family preferences and social norms. These personal and environmental factors can create consumer habits. However, all these determinants are not found to be significant across different cultures, and the ones present vary in degree of significance, even when looking at countries that are geographically relatively close (Prescott et al. 2002; Verbeke and Vackier 2005; Brunsø et al. 2009). While fish-as-food literature commonly focuses on the safety and health factors of consuming fish, taste preference or 'sensory appeal' is a significant determinant in the selection of food across a wide variety of regions and cultures (Glanz et al. 1998; Magnusson 2001; Park 2004; Sun 2008; Honkanen and Frewer 2009; Carrillo et al. 2011). However, humans' perception of taste is affected by both genetic and environmental factors, paving the way for these differences between different geographic regions and cultures, and affecting our perceptions of taste before food has even reached our tongues.

Genetic differences have been shown to affect perceptions of taste on the tongue of some individuals, known as 'supertasters'.[25] With more taste buds, supertasters are not only much more sensitive than other people to bitter, sour, sweet, salty and umami flavours, but also experience oral heat (e.g., from capsaicin) and tactile sensations like viscosity (e.g., from the fat in dairy) more intensely (Bartoshuk 2000). Beyond this genetic inheritance, there exist extrinsic factors, such as branding and packaging, along with intrinsic factors, such as olfactory and visual cues (Spence 2015). In food literature, these 'visual cues' often refer to colour, and preconceived ideas from past experiences and culturally established norms that may have led to certain colours being strongly associated with certain tastes or flavours. In turn, this has been shown to affect people's perception of taste.[26] Overall, these studies have shown that visual cues, as well as taste, flavour and even safety, can lead to cognitive and contextual constraints in consumption

[25] In addition to supertasters, there are medium tasters, who are less able to perceive certain tastes, and non-tasters, who are even less able to perceive certain tastes; also, some supertasters might genetically be non-tasters of some substances (e.g., phenylthiourea).

[26] For research showing how altering colours effects flavour perception and how this varies between different cultures, see experiments with dyed, flavoured beverages in DuBose et al. (1980) and in Zampini et al. (2007).

behaviour. So, how do visual factors affect the perception of fish specifically, for which one might expect taste to be a major determinant of whether it will be eaten or not?

For whole fish, people can accurately identify the relative freshness, and thus best taste, by looking at the eyes. In a study, the perceived freshness identified by consumers was significantly influenced by the brightness or glossiness of the eye, measured by its luminance distribution. In turn, both the glossiness and the perceived freshness of the fish were negatively correlated with the degradation time of the fish. Namely, the longer the fish was left to degrade, the less glossy its eyes were and the less fresh it was (accurately) seen to be (Murakoshi et al. 2013). Other intrinsic cues, such as the flesh's sponginess when poked or its smell, are also often recommended as ways to determine the freshness of whole fish. In cultural contexts where more processed fish is preferred, just the presence of certain characteristics of fresh or whole fish, such as the eyes, can influence the perception of taste and intent to buy. There has been an overall decrease in consumption of tinned tuna in the US since at least 1990 (Shamshak et al. 2019), but this product still battles for first place with salmon as the most consumed fish in the country.

Studies show how environmental factors, such as family preferences, social norms and cultural practices, can be combined with visual factors and can be at odds with 'taste' factors in determining the purchase or consumption of fish. In quotes from American tourists in Ghana trying local fish dishes, one tourist mentioned that he would never try the dried fish. Whereas he admitted that, 'It might be delicious', he also said, 'It intimidates [him]'. A different tourist remarked on being served tilapia with the head and tail on (Figure 2.7), that 'seeing the head of what you are about to eat is not nice'; then a friend cut off the head and tail before she ate it. 'And it was good', she said (Hiamey et al. 2021). In the UK as well, group discussions led by market research experts revealed the influence of the overall physical appearance of fish, especially when compared to other commonly eaten animals. Fish, and particularly eel, can be physically unattractive, and thus unappealing to eat, according to these respondents (Leek et al. 2000).[27] In

[27] Mammals such as cows and pigs having an 'inoffensive physical appearance', or even being considered cute when young, seems to make them more open to being bought to eat.

the UK the majority of fish are not served whole, but when it is ‘Many people…often imagine that the eyes are staring at them’ (Leek et al. 2000). These negative opinions on seeing the fish’s head are not mirrored everywhere, however, again for reasons related to both context and culture.

Chinese traditions based on wordplay and symbolism, as well as preferred cooking methods like braising and steaming, can make it desirable to see the whole fish on the plate. In addition to the Mandarin Chinese word for fish (鱼 yú) being pronounced similarly to the character meaning rich/abundant/plentiful (裕 yù), and thus being symbolic of wealth and prosperity, having the head and tail is symbolic of beginnings and endings (Hu et al. 2014; Laing 2017). Eating habits showing proclivities for eating whole fish are also seen in the traditional consumption of herring in the Netherlands. Symbolic of Dutch prosperity through the seventeenth century thanks to herring fishing in the North Sea and international maritime trade, consuming *Nieuwe Haring* (see Nijman Chapter 6) involves eating a mostly gutted and headless fish but with tail and skin still attached.

Of course, other factors that have nothing to do with either physical taste or culture also lead to variations in fish consumption. Distribution processes and access to cold storage, species availability and form (i.e. canned, cured, fresh, etc.) can affect the overall quantity of fish consumed. Wealthier, urbanites of coastal cities in China appear to have more access to marine fish like tuna and salmon or ‘high-value’ *sashimi*, whereas (the lack of) distribution logistics seems to contribute to folk with lower incomes in more rural inland areas consuming primarily freshwater fish (Hu et al. 2014).

The lack of cold storage and distribution processes also occurs in Peru, where fresh fish consumption is concentrated in the coastal areas, frozen fish in the coastal and adjacent areas, and only canned or cured fish is an option for the more rural inland peoples (Durand and Seminario 2009). In addition, politico-economic processes lead the majority of Peru's fish catch, the Peruvian Ancheta (*Engraulis ringens*), being exported out of the country to be made into fishmeal instead of going to the domestic fish market for human consumption (and nutrition!), even though market research shows a preference for it among those who live in Lima (Fréon et al. 2014).

Universally subjective

The distinction between what is edible and what is inedible varies from region to region, but the overall concept, that some things are and others are not acceptable to eat, can be seen globally and has been thoroughly commented on in anthropology. Mary Douglas' discussion on Ancient Hebrew dietary restrictions focuses on symbolic interpretations of what is edible. Terms such as 'pollution', 'cleanliness' and 'purity' are used to describe inedible animals because, she argues, they are 'anomalous' to acceptable categories (Douglas 1972: 74). The anomaly of scaleless and finless fish, such as the eel, is one example given as inedible.[28] As opposed to many others, Douglas rejected that ancient dietary rules such as these were created primarily for health, allegory or discipline (Douglas 2001; see also Collinson and Macbeth 2023). This is contrasted with the arguments of cultural materialist Martin Harris who analysed what was subjectively 'good to eat' in many cultures based on the practicalities of what was most feasible or beneficial to those people. Ecological and economic feasibility and nutritional considerations are argued to be significant determinants of long-held dietary taboos even when presented in contexts conventionally believed to be largely symbolic, such as religious doctrine (Harris 1985). Evidence exists for this interpretation in relation to fish as they are often one of the specifically 'pure' and acceptable foodstuffs in a variety of religion's dietary rules, and their various nutritional components have been shown to be beneficial to both human physical and mental health (Reis and Hibbeln 2006).

In terms of food, Raymond Firth's extensive ethnography of the Tikopia islanders in Oceania (Firth 1959) illustrated both the seemingly practical considerations of cultural materialist ideology and the heavily symbolic representation seen in the structuralist mind-set of anthropology. Given the high human population density on the tiny island, domesticated livestock that compete for space and food had been forgone in favour of relying almost solely on marine life for their animal-protein consumption. In contrast to pragmatic reasoning for not allowing livestock, some fish were inedible because they were associated with at least one of the island's four clans or

[28] While this is prescribed in Leviticus and Deuteronomy, freshwater eels actually do have scales, but they are small and embedded in their skin and are thus not as visually obvious as the scales seen on many other fish.

with one of their many deities (Firth 1959: 2011). The 'more repulsive fish' (Firth 2011: 26) were always taboo to eat, especially eel (Anguilliformes), such as the eel species called *rafua*, known for its savagery and associated with *Pusiuraura*, a particularly malevolent god. However, eels were often disliked just as a common fish, not a godly vessel, as revulsion to a different species of eel was described by some islanders in terms of its fatness, sliminess and writhing. Thus, we see mirrored the kindlier worded, yet also completely visual sentiments, of the 'unattractive' and 'anomalous' eel and why it is not desirable to eat. Even after Christianity had been introduced to the Tikopians and many aspects of paganism declined, such as the symbolism associated with certain animals, Firth was told, on a subsequent visit, that if someone were to eat an eel, they would die (Firth 1959). Firth described the 'repulsive' *rafua,* spoken about by the Tikopians, as a grey reef eel, which is presumed to have been a species of Gymnothorax. While different in colour, *rafua* would probably have been similar in morphology to *Gymnothorax meleagris,* referred to in an animal exhibit in an aquarium in Osaka as a Turkey moray (Figure 2.8).

Figure 2.8: A captive *Gymnothorax meleagris* marine eel on exhibit in an aquarium in Osaka.

Photograph © Brittany Carol Rapone

Overall, fish that are dangerous to humans are considered inedible. So, the Tikopian reasoning behind not eating certain fish, particularly eel, is the same as the reason why certain parts of the scallop are sometimes deemed inedible, i.e. because that food is dangerous. The subjectivity of dangerousness, namely, the fact that the inedible parts of the scallop are regularly eaten in other countries, is also mirrored in the Tikopian view of the eel. They are unique in that they are the only Polynesian peoples to have this distinct aversion to eels, whereas other Polynesian groups appear to eat them without issue. The Tikopian man, who had told Firth that he would die if he ate eel, was not even convinced of their edibility when told that the Māori ate eels regularly.

This is similar to how the ancient Greeks considered dolphins to be large fish that were taboo to eat while knowing that the close-by Thracians ate them (Mylona 2007),[29] the Tikopian determination of the (in)edibility of eel seems partly tied to social identity.

Conclusion

As shown, fish and other seafood consumption contrasts greatly around the world and not for one single reason. Quantifying this consumption is undertaken by researchers for both government and non-governmental organisations using food availability (or supply) data. Yearly tracking of this food availability data can show long-term dietary trends and details of a country's agricultural and food-related economy (National Research Council and Institute of Medicine 2015, Food and Agriculture Organization of the United Nations 2022). However, quantifying this consumption for global comparison is fraught with methodological difficulties and relies on attempts to standardise from many different sources. When estimating fish consumption, gaps in the data come from various points, but especially from the frequent lack of inclusion of food loss during processing and consumer waste. In addition, when geographic and economic factors are considered, seemingly unexpected variations in fish consumption can still be seen. Namely, not all island nations are top seafood consumers, closely located

[29] While the exact reasoning behind eating dolphin being taboo is unclear, their association with Poseidon and Aphrodite and positive anthropomorphising by the ancient Greeks is known. A structuralist interpretation points out that the dolphin is, 'anomalous since it disregards the boundaries between elements and in addition bears its young in a womb' (Hoffman and Halverson 1977: 527-528). In other words, it is constantly traversing between water and air and gives birth to live young instead of laying eggs like most creatures from the ocean.

countries can have very different fish consumption patterns and countries with similar income levels vary significantly in their per capita consumption. This, I argue, is largely based on cultural differences that influence how fish is consumed, and in turn how much is wasted, by and large because of the subjectivity of edibility.

What is consumed and wasted is directly related to the highly subjective concept of edibility. Determining edibility is sometimes based on seemingly sound logic and practicality, such as wanting to avoid potentially dangerous biotoxins found in filter feeders; these can easily be tied to the medical materialist's point of view of why some foods are taboo. Other reasons stem not from pragmatic viewpoints, but from emotional or symbolic ones, which align more with the structuralist anthropological point of view. From various cultures we see examples of fish or fish parts being inedible to a person merely because it is not eaten in their social surroundings, often because it is ugly or anomalous to what they consider to be the norm. Amazingly, this aversion brought on by their cultural environment, perhaps by folklore or by 'well-established habits', persists even when knowing of the existence of others who eat the same fish or fish parts without any negative consequence. Because cues besides taste, especially visual cues, can change the perception of a fish and its edibility, interestingly, the exact same visual cues can lead to different perceptions from people from different cultures. Whereas in one culture it may be considered taboo or inedible to see the head and tail of a fish about to be eaten, it may be specifically desired in some cultures, again, sometimes for practical reasons or sometimes for reasons that are purely symbolic.

So, in conclusion, when comparing fish as food across the world, we should note the many caveats about simply using food availability data, and instead consider that global comparisons are inherently confused, largely due to cultural factors, especially around those that determine edibility.

In the end, I cannot remember the taste of the shishamo, shirasu or hotate I ate. I just remember how they looked. My inexperience in eating fish and other seafood left me unprepared for many traditional dishes, and I worried about appearing culturally insensitive on top of my guilt in not eating something that all the children had to eat. Learning that taste is not entirely objective but is affected by genetic and contextual factors provided some relief. And whilst my future time in Japan should be more flexible in terms of diet, I have no desire to give shishamo, hotate or shirasu another chance. For now, same as many others, I will stick to what I find less anomalous, and avoid any eye contact with my fish.

As a final comment I prefer my fish to be alive and swimming! (Figure 2.9).

Figure 2.9: The 'smiling' spot-fin porcupine fish (*Diodon hystrix*) alive and swimming at the Sumida Aquarium in Tokyo.

Photograph © Brittany Carol Rapone

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CHAPTER 3
EEL CONSUMPTION IN INDONESIA: FROM INEDIBLE TO A LUXURY FOOD

by Vincent Nijman

Introduction

Eels (Anguilliformes) are a popular food in various parts of the world, including Europe, North America and East Asia. Eel meat is consumed jellied, smoked, grilled, boiled, and some people even have a taste for juvenile glass eels. With declining stocks of European, American and Japanese eels, and a subsequent increase in their protection, restrictions on their harvest and increased export regulations, significant shifts have occurred in the global eel trade.

By combining wildlife trade research methods (analysing official trade statistics, fisheries data, reviewing government policy documents and regulations, etc.) with anthropological fieldwork (visits to Indonesia, discussions with eel farmers, analyses of discussions on online forums, e.g., Facebook, Instagram, etc.), this chapter provides an overview of the harvesting, regulation and promotion of eels as food in Indonesia, and how their consumption has made the switch from an inedible to a luxury food.

Consuming eel has seen an increase in popularity in East Asia, to the extent that annually tons of eels are (or were) imported from Europe, North America and Southeast Asia. The export of eels from Indonesia to East Asia increased exponentially following the ban of export of European eels from the EU in 2010. Currently some 10 million kilograms of eels are exported from Indonesia each year. Most of these eels are caught as glass eels in the estuaries and river mouths along the south coast of Java and the west coast of Sumatra. From there they are either transported to eel farms in Java or are exported to eel farms abroad, most of which are in East Asian countries, such as China, Japan and South Korea.

Traditionally eel was not a popular food in Indonesia, and consequently, there were very few eel recipes, and few restaurants served eels. That eel was seen as inedible was partially because of ambiguities about whether it was permissible to eat them under Islamic law. At around 2013 Muslim scholars and clerks made it clear that it is permissible to eat them, thereby opening the door for eel products to obtain halal certificates and for Muslim restaurants to serve eels. On the back of the increase in exports, eel is now promoted as a luxury and healthy meat, suitable for consumption by all. This increase in popularity has implications for glass eel fishermen/women, consumers and eel stocks. Indonesia gained an interest in harvesting eels because of the protective measures that were put in place to protect the European eel, whereas the protective measures that are in place for the various species of Indonesian eel are minimal, unenforceable, and there is ample evidence of illegal or unregulated export. If Indonesia wants to continue with its new-found love for consuming eel it needs to get its affairs in order before stocks collapse.

Prelude

'Vincent, do you know about Ikan Sidat?' asked Pak Dana casually one day while driving on the toll road between Bandung and Jakarta in the west of Java, Indonesia. Pak Dana is a professional driver with his own sedan car and we had hired his services on numerous times for our trips to and from project sites, government offices, wildlife markets and the international airport. Just as he worked for us, he also worked for other researchers, NGOs, film companies and other people visiting Indonesia for business. With congested traffic being the norm and travel often taking the larger part of a day, we always had plenty of time to discuss current affairs, politics, the state of the Indonesian economy, and indeed all things to do with animals and the environment. 'Do you know about Ikan Sidat?' I did know Ikan Sidat, very well in fact. Ikan Sidat are freshwater eels, remarkable fish of the genus *Anguilla*. Some people may know Anguilla as one the northernmost Leeward Islands in the Caribbean, close to the breeding ground of both European and American eel; both the fish and the island can trace their name back to the Latin diminutive form of *anguis* or snake.

At the time of Pak Dana's question, I had just finished the first in a series of projects documenting the international trade in eels from Indonesia and published the results in the journal *Marine Policy* (Nijman 2015). It was highly unlikely that Pak Dana had read my paper (we converse in Indonesian and my paper was written in English), so I was eager to know what he knew and how he had learned about them. He told me that a few months earlier a South Korean film crew had visited western Java specifically to make a one-hour documentary on eels. He had driven them to the areas where juvenile (glass) eels were harvested, he had taken them to eel farms where the fish are grown to sellable size, and they had visited South Korean-Indonesian joint-venture companies involved in eel production and trade. Being vegetarian, he had not tasted any of the eel products himself, but, as ever, Pak Dana did see an opportunity: 'Eels are big business these days in Indonesia and it is something we both could invest in, if you are interested.'

To me the discussion with our driver marked a turning point in the story of eel in Indonesia. Here we had someone who was not a fisherman, not a marine biologist, and not a connoisseur of seafood dishes, yet he had a very good knowledge of the eel business in Indonesia. I come from the Netherlands, I was born and raised below sea level, in an area that I would consider to be prime eel real estate. While rarely seen, in the 1970s eels were present below the waterline in just about every pond, lake, ditch and canal. They shared this habitat with many eel traps as the Dutch do appreciate the taste of eel. Our family business was in restaurants and catering, and smoked eel was very much a luxury dish. We rarely specifically bought smoked eel for ourselves but there were plenty of opportunities to taste this delicious meat as we prepared it for others.

Fast forward to the 1990s and 2000s, at which time I had moved to Java, to work in biodiversity conservation. I knew from a map of the 1920s that was reproduced in *The Ecology of Java and Bali* (Delsman 1926; Whitten et al. 1996) that eels did occur in many of the Javan rivers, especially the ones that flow south into the Indian Ocean. However, I did not come across eels myself for years, not in the rivers, nor in the fish markets, nor in the restaurants. Eel was not of importance to Indonesian society. I currently hold a professorial chair in anthropology, and as part of my research programme I use a combination of wildlife trade research to gain insight into the intricacies of the harvesting, regulation and promotion of eel as food in Indonesia.

Here, I aim to give an overview of eel consumption in Indonesia and how eels (comprising a number of species) have gone from an obscure fish, not worthy to be singled out, and widely seen as inedible and not to be touched, to one that is now not only a luxury food but also one that is viewed as super-healthy, either as food or in a processed medicinal form. I will argue that eel had not been a mainstream fish eaten in Indonesia; I will show that the initial interest in Indonesian eel came from other Asian countries, in response to a change in the global landscape of the eel trade; I will briefly touch upon (changing) religious beliefs surrounding the consumption of eel both in Indonesia and in the wider Muslim world; and finally I will present data on the role that eel plays in contemporary Indonesia, as a luxury and health food, and how best to regulate the trade and export of eels. I start, however, by presenting a concise background of the biology of Indonesian eel, where they are harvested and how these fish are processed.

Eels in Indonesia

Globally, there are 19 species of *Anguilla* eel. The best known are the ones that occur in northern temperate regions, i.e. the European eel, *A. anguilla*, the American eel, *A. rostrata,* and the Japanese eel *A. japonica*. We have reasonably detailed information on their breeding biology and life cycles, their abundance in the wild in at least parts of their range, and in some cases, we have excellent data on their exploitation (Kaifu et al. 2019). In terms of life cycle, eels are born typically thousands of kilometres away from the areas where they will spend most of their life, i.e. the Sargasso Sea for the European and American eel, and the North Equatorial Current in the western North Pacific for the Japanese eel. The leptocephali larvae follow the ocean currents to be transported to more northern regions, during which they gradually transform into glass eels. Glass eels arrive in their millions in Europe, eastern North America and Japan, where they enter the rivers and estuaries. Here they transform into yellow eels and change from a saltwater fish into a freshwater one. Yellow eels have the capacity to move overland to move from one stream to the next, and they typically will spend several years in their freshwater habitats. These are the eels that I encountered in my childhood.

Triggered by reasons largely unknown, at some point, often many years later, the eels, now called silver eels, move back to the seas and oceans, and make the long way back to their breeding grounds. Here they meet up with other silver eels, spawn and die. Eels are caught as yellow eels in freshwater, and these are large enough to be prepared for consumption. While the details are largely lacking, by and large, tropical eels, including the ones we encounter in Indonesia will have a similar life cycle. Glass eels are also caught, either in the estuaries or when they have entered rivers. In the past these would have been consumed as well, but nowadays virtually all glass eels are destined for eel farms (Figure 3.1) where they are grown to commercially ideal sizes, after which they are turned into various products (smoked, grilled, jellied, etc.) intended for diverse markets. All eel trade is dependent on wild-caught eels as it has not been possible to breed them in captive settings (Okamura et al. 2014).

Figure 3.1: Eel aquaculture in Bogor, West Java

Photograph © Vincent Nijman

Indonesia is one of the richest countries when it comes to eel species. Eight species are found, with five species occurring sympatrically in the central parts (Sulawesi and eastern Borneo) and three in the west (Sugeha et al. 2008). In the rivers and estuaries of Java's south coast, the region most relevant for my research, the Indian mottled eel, *A. bengalensis*, the shortfin eel, *A. bicolor,* and the marbled eel, *A. marmorata,* can all be found entering the same river systems. At the glass eel stage, these three species are difficult to distinguish.

Currently the main catching areas for glass eels in Indonesia intended for aquaculture, are the river systems along the coast of West Sumatra and Bengkulu, Pelabuan Ratu Bay in western Java, and Banyuwangi in eastern Java (Affandi 2005; Nijman 2015). Indonesia's largest eel aquaculture facilities are based near Palabuan Ratu and Bogor in west Java and in Banyuwangi; both receive glass eels that were caught nearby, but also ones that were caught far away around islands other than Java (Figure 3.2).

Figure 3.2: Glass eel fishing in Palabuan Ratu Bay, west Java; this photograph was taken during the day, whereas most of the glass eel fishing takes place at night

Eel not to be found on the menu

As stated above, when I first arrived in Java during the 1990s, eel was not an important culinary dish. There genuinely was no tradition of eel consumption. I have not come across any specific recipes for eel in any Indonesian cookbooks, other than the ones that were written by Dutch authors prior to Indonesia gaining independence. The few times eel was mentioned, it was for this fish to be added to soups and stews, mostly as a replacement for other fish when these were not available.

In 2014 I searched for Indonesian restaurants that specialised in serving eel dishes; I only found three (Nijman 2015). Two were based in Yogyakarta and one in Bandung, both on the island of Java and both were clearly novelty restaurants. One of the oldest and that has been featured in many local news reports because of its uniqueness is Pondok Makan Ikan Sidat Bu Istiana (Mrs Istana's Eel Diner) in Sleman (Figure 3.3). She started her diner several decades ago because of her husband's hobby of fishing and because of him having met some eel collectors in Cilacap along Java's south coast. She only buys wild-caught adult eel sourced from Cilacap and serves it to locals and to tourists from Japan and South Korea.

Figure 3.3: Pondok Makan Ikan Sidat Bu Istiana in Sleman, Java, one of the few novelty eel restaurants in Indonesia

Photograph credit: KotaJogja, licensed under CC-BY

One of the reasons why eel may not have been found on the menu of traditional Indonesian restaurants is that Indonesia is the world's largest Muslim country, with 255 million Indonesians adhering to Islam. Islam has strict rules on what animals can be eaten (halal) and what cannot be eaten (haram), as well as there being those animals that are generally disliked or detested as foods (makrooh). According to Shia Islamic jurisprudence (Fiqh) it is haram to consume eel, just as any other fish that does not have scales (biologically eels do have scales, but they are small and covered in mucus). According to Sunni Islamic jurisprudence it is 'sea game' not fish, and that is haram. Yet, there is disagreement about whether eels should be on the list of prohibited fish. Some argue that for Hanafi Sunni Muslims, eel is halal.

Riaz and Chaudry (2003) added that what matters is not just whether or not sea animals have scales, but also whether they can only live in water. Species that are fish-like, live in water permanently and do not have scales but that can breathe oxygen from air rather than from water may be permissible to eat. Eels fall into this category. As such Riaz and Chaudry (2003) argue that eels are acceptable to eat for most Muslim consumers, but theirs may be a minority view.

Certainly, up until 2013 there was a debate within the Indonesian Muslim communities whether eel is haram or halal, and in the absence of a clear answer from the Ulama Council many refrained from consuming it based on their religious beliefs. Starting in 2013, in Indonesia at least, eel was declared as halal (Purwati et al. 2018). Producers of farmed eel obtained halal certificates from local interpreters of Islamic doctrine and law (e.g., the Indonesia Ulama Council of West Java) and these certificates are prominently displayed on their company's webpages. Likewise, individual products, when advertised, often have it clearly marked as halal (Figure 3.4). This opened up the domestic consumer market.

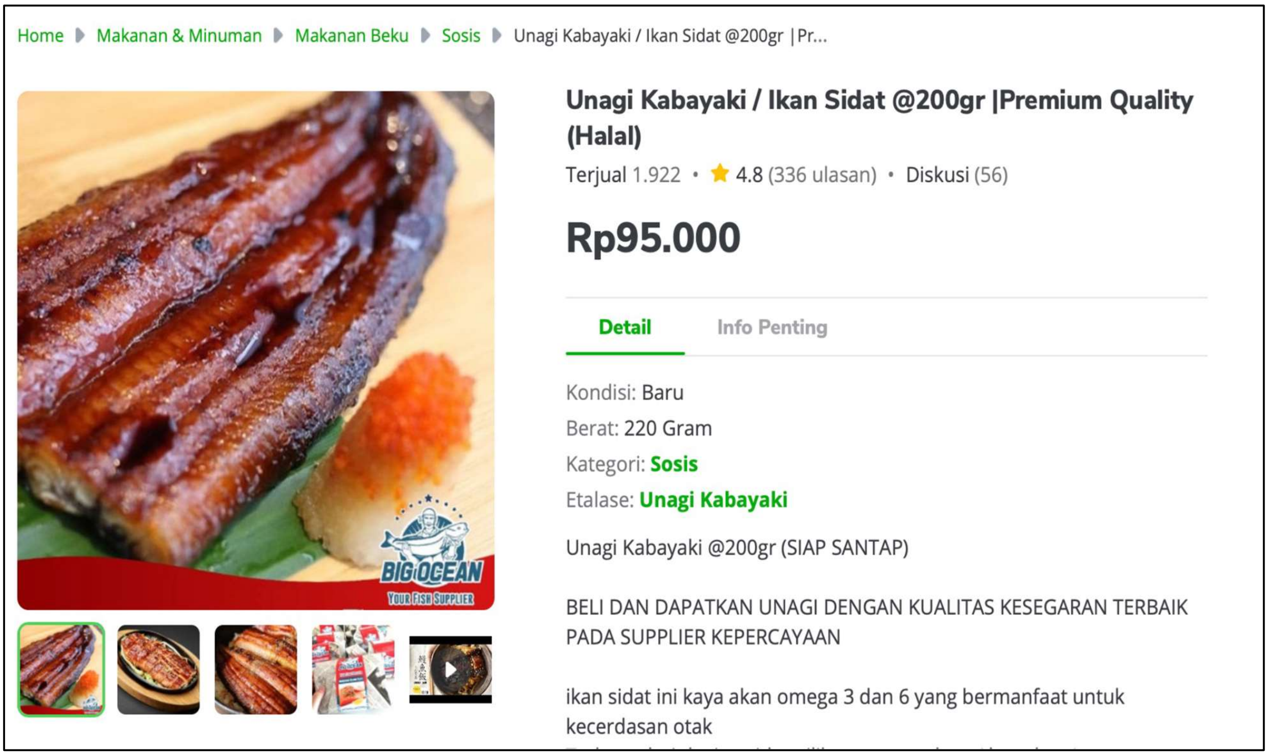

Figure 3.4: Unagi kabayaki, traditional Japanese grilled eel covered in sweet soya sauce, produced in Indonesia and labelled as halal (permissible for Muslims to eat)

Photograph credit: Big Ocean, licensed under CC-BY-SA

Interest in Indonesian eel in the context of a changing global eel landscape

Eels received protection and regulation, firstly in 1973 when Indonesia restricted the export of shortfin eels to specimens less than 5 mm in diameter. It appears that few were aware of the presence of other species of eel as it took until 1982 for the same restrictions to be put in place for four more species of eel. After a series of changes, in 2009 a simpler regulation was introduced, restricting the export of eel to those with a mass equal to or larger than 150 grams. These regulations are relevant to the export of eel and not to the harvest of them nor to local trade. In 2020 a new decree was issued that precluded the harvest of glass eels during the two darkest nights of the month, and adult shortfin and mottled eel above two kilograms, and adult marbled and Sulawesi eel, *A. celebensis,* above five kilograms are not allowed to be caught.

Despite these regulations on the export of eels having been in place since the early 1970s, it appears that very few eels were exported. For instance, in the late 1980s and early 1990s the quantity of eel exported amounted to a few tonnes a year (Nijman 2015). This changed during the 2000s largely due to an increase in regulations and export bans that were implemented in Europe with regards to European eel. In 2007, because of declining populations, the international trade in this species became regulated via the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). European eel is widely consumed in various parts of Europe, but by the mid-2000s much of the glass eels were being exported to East Asia for aquaculture.

Because of the challenges in establishing how many eels can be harvested sustainably, in 2010 the EU banned all import and export of European eels from outside its borders. Consequently, eel farmers in East Asia, primarily those in China, Japan and South Korea, had to source eels elsewhere. This led to an exponential increase in the export of eels, in terms of volume, from Indonesia and indeed other Southeast Asian countries (Crook 2014). Currently close to a million kilograms of eel with a declared value of US$19 million, is exported from Indonesia, every year, to roughly fifteen to twenty countries (Figure 3.5). Much of this is in the form of processed eel, primarily in the form of unagi kabayaki (Figure 3.4) – grilled eel covered in soya sauce – or as chilled fillets.

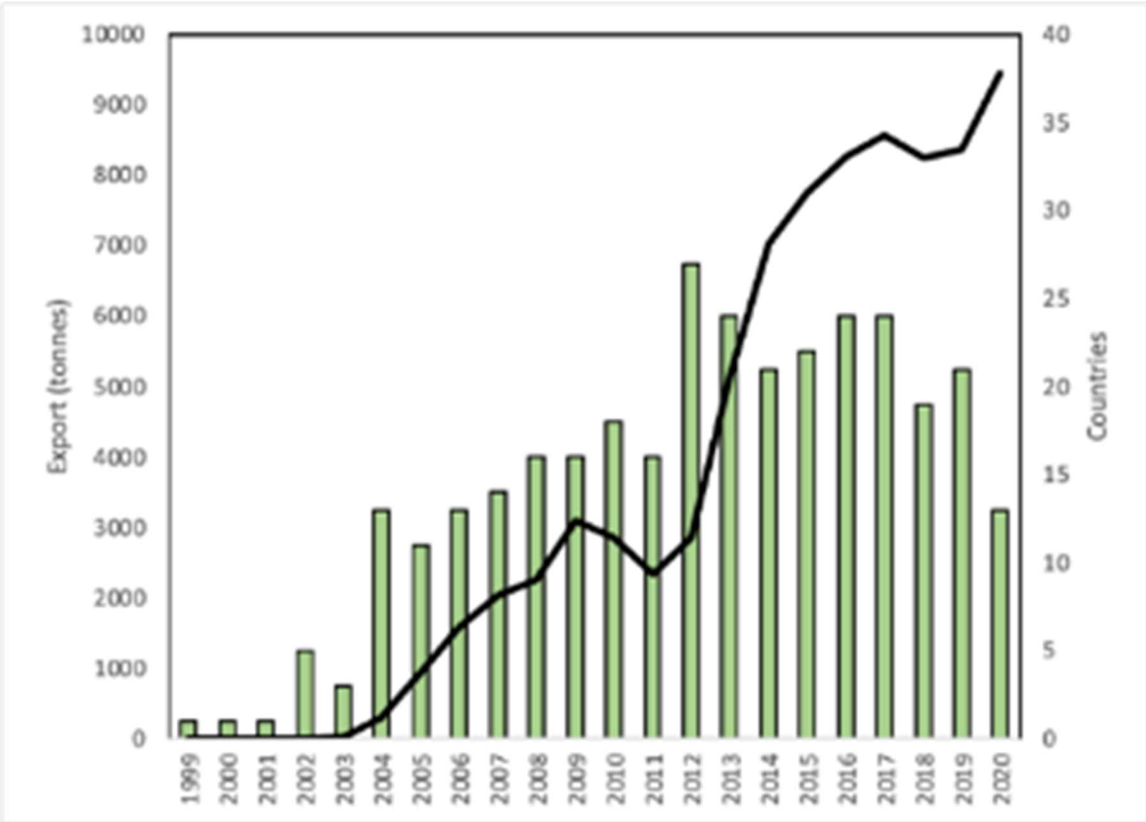

Figure 3.5: Export of eel from Indonesia with mass indicated by the solid line and the number of countries to which eel is exported in bars

(***Source:*** *UN ComTrade, downloaded in November 2021; UN Statistics Division 2021).*

On the back of this increase in demand for eel from Indonesia, local, regional and national government agencies, as well as business interest groups and chambers of commerce, started promoting eel farming and associated glass eel harvesting and eel exports (Suitha and Suhaeri 2008; Triyanto et al. 2020). Numerous articles in business magazines inform the readers of the investment opportunities there are within the eel trade, while the eel trade and eel farming are now regularly featured on major television news channels. Brochures are produced by governments providing guidance on how to operate in the eel business. Google searches for eel in Indonesia have gone up and up with most of the searches originating from the islands of Sumatra and Java (Figure 3.6). The initial focus of all this promotion was to highlight the export of eels to countries, such as Japan, but recent years have seen a shift towards promoting both export and domestic consumption.

Figure 3.6: Google search trends for 'ikan sidat' (eel) in Indonesia from 2011 to 2021, showing an interest in eel especially in Java and Sumatra.

Eel as food and economic commodity in contemporary Indonesia

While eel was traditionally not served as a dish in local Indonesian restaurants, eel has always been a popular dish in Japanese restaurants. Over the last two decades Japanese cuisine has become a truly global cuisine, and Japanese restaurants, alongside French, Italian, Thai and Chinese ones, are ubiquitous on every continent (Farrer 2015). For capitals of countries along the Indian Ocean there is a correlation between the number of Japanese restaurants per million people and the GDP per capita (Kaifu et al. 2019). The wealthier a nation is, the more Japanese restaurants are found there. Jakarta alone has over two hundred Japanese restaurants, and Surabaya, Indonesia's second largest city, has over one hundred. Most of these serve eel dishes, and much is locally sourced. Data on domestic consumption are difficult to come by, but in 2012 the demand for eel in Jakarta (mostly for Japanese restaurants) was 37 tonnes a year and a few years later, one east Javan trader supplied 50 tonnes of eel a year to restaurants in Surabaya and three other cities (Anonymous 2013). On the back of the export of eel to East

Asia and an increase in demand from domestic Japanese restaurants, eel producers increasingly started targeting domestic consumers. The World Bank (2019) graduated Indonesia to the list of upper middle-income countries in 2019, and between 2002 and 2016 the middle class tripled as a percentage of the population (with two-thirds of them living on Java).

This helped create a new middle-class consumer. By targeting middle-class families and promoting eel as a health product, the sale and consumption of eel in Indonesia has become widespread. Today, eel is promoted as a healthy food for pregnant women, with high levels of Omega 3, Vitamin A and iron, and especially important for embryonic brain development (Wijayanti and Setiyorini 2018). Whereas in the past there were very few recipes available specifically for eel dishes, now there is a wealth of information available online, including in the form of videos, blogs and vlogs (Figure 3.7).

Figure 3.7: Ikan Sidat Kemangi Saus Tiram, a local dish with eel, chillies, shallots and oyster sauce

Other than as a food, eel is now also widely promoted in Indonesia as a health supplement, with brands such as Gizidat, Nutridat and Afidat containing eel extract, honey and turmeric as their main ingredients. In 2020 Indonesia's National Agency for Drugs and Food Control approved the market leader Gizidat as a traditional medicine because it increases appetite. Eel oil purportedly also aids in lowering cholesterol levels (Sasongko et al. 2017).

Finally, it is not all about the consumption of eels. Indonesians are very entrepreneurial. The concept of Agricultural Tourism, whereby mainly domestic tourists can visit farms or orchards, has been around for a long time especially in Java (Faulkner 2003). This has now expanded to Eel Tourism. Organised groups of tourists can now visit eel aquaculture farms to see how eels are grown, they can go angling for eels and other fish in stocked ponds, they can visit fishing villages that rely on the harvest of eels and, of course, they can eat eels in dedicated on-site eel restaurants.

This increase in popularity has implications for glass-eel fisheries, consumers and eel stocks. Indonesia gained an interest in eels because of protective measures that the EU put in place to protect the European eel. The protective measures that are in place for the various species of Indonesian eel are minimal, unenforceable, and there is ample evidence of illegal or unregulated export (Nijman 2015). The Action Plan for the Conservation of Eel for 2016-2020 (Sadili et al. 2015) is a good first step but it provides mere guidance on the management of eel stocks, seeks to explore the potential for eel exploitation, and it has no authority to implement change. There is a real risk that what we are seeing in Indonesia is a boom-and-bust exploitation of eel, where ultimately the eel and the fishermen/women will lose out (c.f. Arai 2014; Honda et al. 2016). And this brings me back to Pak Dana whom I introduced at the beginning of this chapter: 'Eels are big business these days in Indonesia, and it is something we both could invest in, if you are interested' he had suggested all these years ago. I did not invest, and nor did he. The one that really should invest in the future of its eel production is the Indonesian government. If Indonesia wants to continue with its new-found love for eels it needs to get its affairs in order before stocks collapse.

Acknowledgements

I thank the International Commission on the Anthropology of Food and Nutrition for organising the Fish as Food Conference as this allowed me to bring my various interests together into a story of Indonesian eel. I also thank Florian Stein and Willem Dekker for guiding my thinking about how to best regulate the trade in all species of eel, and Iain Young, Helen Macbeth and Diana Roberts for constructive comments and suggestions.

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CHAPTER 4
ASSEMBLING A MULLET ROE MOONCAKE: SUSTAINABLE AQUACULTURE, RETURN MIGRATION AND GASTRONOMY

by Eric Siu-kei Cheng

Opening a box of Mooncake

A carton of boxes arrived at my office in Taiwan ahead of the Mooncake Festival in September 2021. I opened it and counted 10 black boxes of mullet-roe cake. As advised by Meng-fen in our LINE instant messenger conversation, I hurried to give the boxes of cake to my colleagues. They were surprised to find the mullet roe texture of the filling to be different from the ordinary salted duck egg yolk filling. 'An ecological[30] fish farm produces the mullet roe. Besides, an urban to rural return migrant bakes the pastries', I added. The gift-giving of these pastries became an occasion for me to introduce to my colleagues, as they tasted them, two social phenomena in rural Taiwan that I have studied since 2010, which celebrate both eco-friendly aquaculture and return migration (Figure 4.1).

Figure 4.1: A bite of mullet-roe cake

Photograph © Eric Siu-kei Cheng 2021

[30] In this paper, the word 'ecological' is used to mean 'conscious of environmental effects'.

This chapter focuses on the making of this mullet-roe cake since that encapsulates the life stories of two generations of urban-to-rural return migrants. Fish as food not only sustains human survival, it can also support a person's cultural tie to their hometown. In Taiwan, public attention to food safety, sustainability and gastronomy has become a driving force for return migrants' innovative practices in food production, processing and marketing. I use the case study of mullet-roe cake to exemplify processes that bring together the return migrants' visions, practices and products. Adopting the analytical lens of material-semiotics[31] (Law 2019), this chapter argues for gastronomy as a practical tool that weaves together people and materials that are partially outside of a social structure.

This chapter is organised into four parts. First, I provide the background of return migration to rural Taiwanese fishing communities. Secondly, I account for how eco-friendly practices have become connected to gastronomy. Thirdly, I explain the making of mullet-roe cake within this context. Finally, I discuss the material-semiotics of Taiwanese farmed seafood in gastronomic marketing. The cultural ecology of aquaculture continues to play a key role in production, while taste becomes more important in food processing and marketing.

Skills of return migrants

During the past six decades, Taiwan has become one of the powerhouses of East Asian development. It has experienced rapid growth and rural-urban migration. The increasing number of young adults moving to cities resulted in ageing rural communities, despite the improved living conditions and standards. The governments at different levels have implemented programmes to facilitate community building, rural regeneration and more recently, placemaking. Although these programmes enhanced infrastructure and provided funding for various kinds of community-based projects, the lack of job opportunities still deter many young adults from return migration to rural areas. More precisely, the public tends to consider rural communities as backward and stagnant; some job opportunities are related to primary production and, to a much lesser extent, industrial work. The skills acquired with high-level education fail to equip the young adults for return to their

[31] Material semiotics resists reductionism and assumes that the weaves of social life are messy ad multiple (Law 2004).

home towns, despite their wish to take care of their ageing parents (Cheng 2016).

A minority group of return migrants has acquired and has been learning various skill sets to live in rural Taiwan. These people are diverse in terms of education levels and work experiences. The media generally report those having high-level education and describe them as sacrificing their original urban jobs with a high salary to return to their home towns. The media have ignored those with low educational levels or less desired urban job experiences. In my field experiences, the return migrants share the common feature that they, at first, can stay with their parents to lower their living costs. Their rural homes become a sponge to these returnees who feel dissatisfied in cities. In other words, marginalised urban people may return to their rural homes for a sense of safety and peace. However, some people with poor rural job skill sets find it difficult even to make a living there (Cheng 2018a). In Taiwan, some return migrants have acquired skills to stay in both urban and rural areas. They have better cultural capital for geographical and social mobility. Producing one's food products for branding and marketing (in Chinese: *zichan zixiao*) as associated with one's local cultural identity has become one of their major practices for the recent decade. Such a trend is growing in Taiwan.

In fishing villages, some return migrants turn to food production as their means of earning a living. Sustainable, usually referred to as eco-friendly (*youshan huanjing*), aquaculture has become common in the past two decades, despite its various definitions and categories among fish farmers and middlemen. Broadly speaking, return migrants engaging in aquaculture use less, or even zero, pharmaceuticals compared to the older generations of fish farmers. Some return migrants also give up applying herbicide and algaecide. The major reasons for such changing practices include environmentalism, food safety and marketing. The categories of non-toxic (*wudu*; responsible usage of pharmaceuticals and chemicals) or ecological (*sheng-tai*; using none) aquaculture have added value to the products. Taiwanese organic fish farmers could not use the term 'organic' to describe their products until 2019. 'Ecological' aquaculture, which indicates sustainable practices, continues to be the major term used among the fish farmers. Noticeably, while the market for such products is growing, most consumers still want cheap commodities in Taiwan. Practising eco-friendly aquaculture often comes at the cost of sacrificing profitability. The return migrants engaging in such practices highlight the ecological and social values.

As a return migrant born in a fish farming family, Ching-yao practises ecological aquaculture and he set up his team of production, marketing and processed product development. As I reported elsewhere (Cheng 2016; 2021; 2022), Ching-yao has become a reputed fish farmer promoting sustainability, biodiversity, food safety and high-quality seafood for the past 15 years. Briefly, Ching-yao currently runs a 30-hectare fish farm including multiple brackish-water ponds and a cold storage facility for storing frozen seafood. His polyculture practice highlights a food web formed by fish and shrimp. He selects multiple fish of both herbivore and carnivore species. He cuts the grass on the pond bank instead of applying herbicide. He plants trees wherever possible. He nurtures a living-thing-friendly environment so that migrant birds come to feed (Figure 4.2).

Figure 4.2: The author recording Ching-yao's daily routine on his fish farm

Photograph © Eric Siu-kei Cheng 2010

Ching-yao and his team develop different kinds of seafood products, meeting their food quality standards and also the market demand. Ching-yao chooses to subcontract his seafood processing to plants where the plant owner or manager understands his vision and practice. Several kinds of products (e.g., fish essence) have become popular among consumers supporting sustainable agriculture and fisheries or those who seek safe and healthy food (Cheng 2022). However, a few products are hardly popular. For example, he feeds grass carp (*Ctenopharyngodon idella*) with grass along the pond bank. The grass carp is a labour fish that helps consume the excess grass to maintain a balanced ecosystem in the fish farm. Taiwanese consumers, after centuries of carp consumption (Tseng 2012), have turned to seawater fish consumption and since the 1980s, there has been less demand for carp. Whereas Ching-yao sells his frozen ecological grass carp to organic food shops and consumer co-ops that support eco-friendly practices, he finds carp consumption is lower than for his other products. Even so, Ching-yao continues to raise grass carp in his ponds.

Since his return migration in 2009, Ching-yao has acquired better aquaculture skills and practises his goals of commercial and ecological polyculture. His story has spread from his home town to other fishing communities and to cities, where ethical consumers know and support his actions. Ching-yao has received a national environmental education award, the first food producer to be recognised in this way. His experience reflects the diverse values generated from eco-friendly aquaculture in Taiwan. As a return migrant, Ching-yao has found such strategies to stay in his home town while maintaining his influence on fisheries, food consumption and environmental education.

Taste making and gastronomy while weaving in eco-friendly practices

Terroir has become a popular term in gastronomic events in Taiwan. Return migrants are the major practitioners of exploring the conditions on their farms that may deserve the term *terroir*. They brand their products with *terroir* to create market differentiation from other similar products in the market. In Taiwan, making a regional *terroir* different from that of the neighbouring counties is difficult, because the physical distance between counties is short and so the climatic and soil conditions are similar. The county governments continue to use administrative boundaries to make a distinction between local products. The construction of *terroir* across counties satisfies the politicians' goals for vote-seeking, but it hardly has any effects on the products, the features of which are closely similar in terms of gastronomy.

Taste (including texture and smell) making is different from *terroir* construction in gastronomic Taiwan. Farmers and fish farmers can apply their skills to produce food ingredients with specific features. Selection of varieties, feed, water and even soil is key to taste making. While regional differences of *terroir* are insignificant, Taiwanese food processors can choose from a rich and diverse source of food ingredients over the island, which has tropical and subtropical climates, inland and coastal landscapes, and animals and plants that differ across various altitudes. Unlike the county governments limiting their choices, the Taiwanese producers and processors have formed a more dynamic gastronomic network across county borders.

Ching-yao is one such network actor. His ecological aquaculture offers a variety of food ingredients. In the township where he stays, the local cultural association has become a social enterprise promoting local production and marketing in a way that introduces gastronomic writers and chefs to producers like Ching-yao (Cheng 2021). For example, being a visiting artist of the association in 2020, a writer A-lin wrote blog posts to introduce these producers and their food to the public. After returning to Taipei city, this writer began to develop white-leg shrimp (*Litopenaeus vannamei*) dumplings with Ching-yao's shrimp. On a Facebook post (August 26, 2021), Ching-yao's team made an advertisement as follows:

'Three flavours of dumplings are sold:
Classic: seabass, shrimp, and cabbage
Special flavour: mullet, shrimp, and basil
Savoury: mullet, shrimp, and chive.'

'The Taiwanese love dumplings… A-lin has spent more than a decade searching for 'delicious, natural, and local' dumplings. She hopes to let children enjoy nutritious and delicious dumplings at least twice a week! Ching-yao and A-lin found that no dumplings using fish and shrimp (without pork, the major ingredient) are available in the market. It would be fantastic if Ching-yao's high-quality fish and shrimp can become ingredients of the delicious dumplings to satisfy the foodies! After two years of trial-and-error development, these two picky people finally developed the dumplings without any pork or lard… They use shrimp paste to add the savoury of fish and help the ingredients to mix together as the filling… dumplings do not only make one full, they can make the eaters feel satisfied with the delicacy made by such an easily absorbed and digested protein… Please try the delicious dumplings filled by Taiwanese artisan spirit and *terroir*!'

Such a product illustrates the growing trend of Taiwanese eco-friendly food producers, some of whom are return migrants, connecting themselves to gastronomic writers and chefs who understand the market demand for safe and sustainable food. Furthermore, the food products should be delicious and healthy. In this respect, ecological seafood producers, including but not limited to Ching-yao, at the same time become gastronomic experts. They provide a balanced environment for animals and plants to grow and become local food ingredients that meet a high-quality standard. Such producers also research reactions to the taste of their produce by interacting with consumers. Such a practice draws the attention of gastronomic experts such as A-lin. They form an actor-network that leads the food ingredients, skills and marketing strategies to be assembled, filled in and projected to a potential ethical and healthy dumpling eater.

The recently formed actor network marketing dumplings weaves ecological aquaculture with gastronomy. The official website of Ching-yao's seafood brand sheds light on the vision of Ching-yao:

'Aquaculture is not difficult, but it is difficult to nurture [aquatic animals] to become delicious [seafood]! Ecological (*sheng-tai*) aquaculture allows food to return to its natural character. Consumers' trust is our motivation to insist on our good practice.'

This quotation demonstrates the current market situation; ecologically farmed seafood hardly guarantees market demand. So, seafood producers need to market their seafood with strategies that differ from those of traditional wholesalers. For example, I once suggested ‘marketing their own seafood’ as an alternative strategy. However, my informant from the local cultural association, who produces sundried salt and connects producers to gastronomic writers and chefs, asked, ‘why is it alternative?’ After years of exploration, this gastronomic network provides a better description. Rather than becoming an alternative choice for consumers, the producers and gastronomic writers are mainstreaming their products. They deploy a strategy of combining environmentalism, food safety, gastronomy and rural idyll (to a certain extent) into their food products in order to compete in the market.

From ecological mullet roe to festival Mooncake

Taiwan has a long history of seasonal mullet (Mugilidae) (Figure 4.3), catching and drying them since the Ming dynasty.

Figure 4.3: Fresh mullet (Mugilidae)

Photograph © Eric Siu-kei Cheng 2014

The Japanese market demands dried mullet roe, and the Taiwanese wild-caught mullet in winter can satisfy this demand. In winter, schools of mullet with matured roe sacs swim towards the west coast of Taiwan. Fishermen catch the mullet before they lay their eggs. The most valuable part of a mullet then is the golden tongue-like roe sac. Processors buy baskets of roe sacs (Figure 4.4) which they shape, salt and press.

Figure 4.4: Mullet roe

Photograph © Eric Siu-kei Cheng 2014

The roe sacs are then dried under the sun and chilled by the wind for weeks. The dried mullet roe is hardened and can be preserved. Nowadays, processors freeze the vacuum-packed mullet roe for the market.

The market demand for these in Taiwan and Japan as gifts is high enough to encourage fish farmers to practise mullet farming. In Taiwan, mullet flesh consumption is less popular than that of mullet roe. In night markets, one can find a stick of barbequed mullet roe with pieces of spring onion or apple. Gift shops sell boxes of higher-quality mullet roe for gift-giving or souvenirs. These boxes can even be found in Taiwan's international airports. Processors currently import mullet sacs from Brazil, the United States and other countries. In recent decades, domestically farmed mullet roe has become the major supply for the market, despite some processors insisting that wild-caught mullet roe is more delicious and valuable. The major farming and processing regions are located along the western coast. Various processors have developed their skills and discourses to create market differentiation. The wind conditions, salt usage, and the length of time drying in the sun are factors that affect the quality and hence the value of mullet roe.

Only female mullet can produce mullet roe. Fish farmers are unsure about the sex of wild-caught mullet fingerlings, which are traded and then raised in fish ponds. To harvest farmed mullet roe, a fish farmer needs to wait for the mullet's sexual maturation which takes at least two years and up to three to five years in some species of mullet. A fish farmer buys mullet fry and keeps them for a year in a nursery pond. After that, he distributes the one-year-old mullet to different grow-out ponds. In November, the fish farmer randomly samples a mullet and opens its body to check if the sac is matured and full of roe. If so, he arranges a day around the winter solstice to harvest the mullet. (Figure 4.5). Only then will he know the proportion of female mullet in the pond. If most of the mullet are male, the fish farmer will lose his investment.

Figure 4.5: Mullet being harvested for their roe

Photograph © Eric Siu-kei Cheng 2014

In 2016, a media report uncovered the 'sectoral open secret' of mullet farming concerning oestrogen hormone application in feed. Mullet are sequential hermaphrodites; their sex depends on conditions while they grow. After one year of nursery, fish farmers distribute the mullet to grow-out ponds and then change the formula of feed to facilitate their growth. The mullet are fed with feed pellets that contain oestrogen for no more than three months. After that, fish farmers change the formula again for the next eight months or more. This practice very likely results in a 90 percent female mullet harvest from a pond.

The aquaculture stakeholders, including fish farmers, feed-plant personnel, traders and government officials, know this 'open secret.' Taiwanese consumers increasingly demand safe food, but they have little information about how the sex of farmed mullet is manipulated. In 2016 and 2017, the agriculture-centred journal, *News & Market* (*shangxiayou*), published a series of news reports that uncovered this open secret. It provided quotes and perspectives from various stakeholders (e.g., Tsai 2017). Back in 2014 and 2015, I had interviewed a few mullet farmers and mullet-roe processors. Most of them reported this to be a non-toxic practice, because the mullet have digested the oestrogen long before their harvest. They agreed that such a practice supports the mullet-roe production and market. The skill of processing dried mullet roe is key to its quality. However, some pro-ecological-aquaculture scientists, traders and fish farmers expressed their concerns for the food safety of such mullet roe.

Ching-yao took action after the *News & Market*'s report about mullet-roe production. In the past, he sold one-year-old mullet to neighbouring fish farms. He did not raise mullet for roe production. In 2017 he carried out a field experiment to raise mullet without using any oestrogen. After two years, he found the normal male: female ratio to be 7:3. He currently offers the ecological mullet roe as two products to the market. First, he subcontracts a processing plant to make dried mullet roe. Secondly, he sells frozen and fresh mullet roe on his online platform. The price of his dried mullet roe is double that of others available in the market. The production of sustainable mullet roe without the use of hormones, despite the higher price, does not increase the profit margin for Ching-yao; but he does this for the other benefits of producing a sustainable product.

Ching-yao's response of mullet farming to the aquaculture sector is connected to the gastronomic network presented above. He chose to use the sun-dried salt produced by the local cultural association to make his dried mullet roe. As I have explained elsewhere (Cheng 2016; 2018b; 2021), the local cultural association plays a key role as an actor network formation connecting producers, processors, writers and chefs. The personnel of this association have developed multiple categories of salt as commodities available in the market, including a version of which seawater containing *Dunaliella* (Cheng 2021), a type of algae well-adapted to hypersaline water, to create more flavours than a complete saltiness. Ching-yao had already cooperated with the association in cooking demonstrations and in product development (such as a milkfish snack). This time, Ching-yao chose the algae salt for making dried mullet roe. The association also helped promote this product to attract urban hotel chefs to market it.

The emergence of ecological mullet roe has strengthened a network of two generations of return migrants. From 2019, a young couple Meng-fen and Ming-chang, in their late twenties, returned to the township to run a bakery. Ming-chang makes bread, while Meng-fen bakes other products. They sell affordable bread with better-quality flour and butter than the bread sold in Taiwanese night markets. They sell their bread in night markets only in and surrounding their township. The couple develop different kinds of European bread. One day, the local community association approached them in the local night market and included them in the events organised for chefs and writers in its salt pan. They thus joined the gastronomic network in their home town.

Before the Mooncake Festival of 2020, Meng-fen and Ming-chang decided to make a Taiwanese Mooncake (a pastry filled with red bean paste) incorporating some local ingredients in the town. They source German butter and Japanese flour to make a dough. While most Taiwanese Mooncakes are made from salted egg yolk wrapped in red bean paste, Meng-fen replaced the egg yolk with salted mullet roe. She added local sun-dried salt to the dough to enhance the flavour of the pastry. In 2021, she slightly brushed golden foil onto the pastry to brighten its appearance (Figure 4.6).

Figure 4.6: Golden foil brushed on the pastry

Photograph © Meng-fen 2021

On August 28, 2021, to help promote the mullet-roe Mooncake, the gastronomic writer posted on her Facebook page (Personal communication of a Facebook public entry by A-lin).

> 'It [the Mooncake] tells you [the story] of the bright and golden sunlight of this township, the crystallisation of seawater and the fish farmers' pride, and a baker's consistently improved craftsmanship … [Inside the Mooncake there is …
>
> A piece of mullet roe which makes the local community proud;
> A baker's artisanal warmth;
> A fishing village banquet brought to you.]'.

To introduce her readers to this Mooncake. on another day (September 12, 2021), the gastronomic writer posted:

> '… The couple sells their bread in night markets … they have great skills and select high-quality ingredients. The bread they make is fresh and savoury. The aftertaste is sharp and clear. [These features make] a high-quality bread indeed … The mullet roe mooncake sold this year is even better. Here are my comments:
>
> 1. [Meng-fen] brushes golden foil [on the pastry] to make it shiny rather than tacky.
>
> 2. The balance between sweetness and saltiness is wonderful. The red bean paste and mullet roe fit in well with each other; making the pastry mildly salty and sweet while the bean savoury is well-performed. The ingredients match each other to make a great duo.
>
> 3. The mullet roe is impressive as it is now moist. The fishy taste no longer exists … The roe is now fresh, chewy while its saltiness is filled with oil fragrance. That makes an elegant taste.
>
> 4. The dough has various layers, which are a bit too dry. However, the dough is crunchy … making [the pastry] tasty.'

The presence of mullet-roe cake in the Taiwanese market is rare. The ecological mullet-roe Mooncake of Meng-fen is probably the first attempt. I purchased some boxes as gifts in September 2021. From those who received and tasted the cakes there have been two major types of responses. First, while the majority felt surprised by the cake's appearance and its mullet roe, they knew nothing about the ecological mullet roe. Secondly, some people were accustomed to salted egg yolk; the mullet roe was still too fishy to them. The meaning and taste of mullet-roe cake are thus not readily accepted by mainstream consumers.

Material semiotics of sustainable aquaculture and gastronomic returnee

According to Law (2009), the empirical actor-network approach is one of a material-semiotic analytical tool that can

> '… explore and characterise the webs and the practices that carry them. Like other material-semiotic approaches, the actor network approach thus describes the enactment of materially and discursively heterogeneous relations that produce and reshuffle all kinds of actors including objects, subjects, human beings, machines, animals, "nature", ideas, organisations, inequalities, scale and sizes, and geographical arrangements.'
>
> (Law 2009: 141)

Law (ibid.: 147-148) contends that it is necessary to explore material semiotics not from the duality of human and non-human actor, structure and agency, nor from the social and the technical perspectives. Rather, he suggests that one must study the *hows* without presuming there is something fixed. In fisheries, Law (2019) looks at how a particular form of nature is created and the environmental mechanism is generated. Deconstructing the semiotic-material binary can help us explore how material experience is knotted with the semiotic part of life (Harley 2019). The examination of environment still needs the investigation of cultural consideration and attention to technology (Evans 2020). The practice of human agents is thus important in the material-semiotic approach in economic behaviours (ibid.). The semiotic ideology is thus meaningful to some people when the material things are consolidated as social objects (Keane 2003: 421).

The writer's seafood marketing, emphasising gastronomy, is embedded in the taste-making of local food ingredients. The gastronomic writers, such as A-lin, have visited the township multiple times and may even have become visiting artists. Their connection with local producers has been transformed to cooperation, including the dumplings previously documented. Therefore, their Facebook posts on the mullet-roe Mooncake (Figure 4.7) are not only an advertisement of a new product; they are also the cultural representation of a rural idyll that is established by the return migrants' efforts for sustainable food and life.

Figure 4.7:. Ingredients (including dried mullet roe, sun-dried salt, German natural butter, Japanese flour and black bean paste) of the mullet roe cake shown on Facebook

Photograph © Meng-fen 2021

In other words, marketing the Mooncake is an actor network's outcome of turning the rural life and human-environment relationships into marketable products.

The Mooncake discussed in this chapter is an assemblage of return migrants' products including salt, mullet roe and bakery craftsmanship. The two generations of return migrants, including Ching-yao, Meng-fen, Ming-chang and some members of the local cultural association, have become part of the gastronomic network because they are producers and processors. The gastronomic network and ecological aquaculture intersect with the creation of the farmed mullet roe. The mullet roe embraces the material semiotics of Taiwanese food cultures, trade and aquaculture. The marketing discourses of gastronomic writers translate and represent the eco-friendly and gastronomic practices of these returnees to ethical consumers in urban Taiwan. The nationwide network thus partially supports the gastronomic returnees' living in rural Taiwan.

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CHAPTER 5
EATING TOGETHER AND LEARNING TOGETHER: IMPROVING ADDITIONAL LANGUAGE THROUGH CULINARY EXPERIENCES WITH SEAFOOD AND ITS HISTORY IN GREECE. A CASE STUDY

by Mary Margaroni

Preface

This chapter derives its topic from the scientific fields of Anthropology of Food on one hand and of second or additional language teaching (especially of informal learning and out-of-class education) on the other. It presents and analyses the results of research that took place at the School of Modern Greek Language (SMG), at Aristotle University of Thessaloniki (AUTh, Greece) between November 2015 and February 2020. The research goal was to find ways to utilise culinary activities related to the consumption of seafood, as well as discussing in class environmental, financial and cultural issues related to seafood (e.g., Figures 5.1 and 5.2) in teaching Greek as an additional language to foreign adult students in higher education.

Figure 5.1: Grilled cuttlefish

Photograph © Stergios Gontelakis

Figure 5.2: Greek traditional seafood dishes

Photograph © Maria Kalamida

Introduction

This study deals with the contribution of culinary out-of-class activities to teaching Greek as an additional language in higher education. As Greece is a country, most of which is surrounded by the sea, these educational activities especially concern the consumption of fish and seafood.

In recent years the number of foreigners living in Greece, either permanently or temporarily, has increased by several hundred thousand, mainly during the refugee crisis that peaked in 2015. In that year, 874,735 refugees arrived in Greece from areas where their lives were precarious (UNHCR 2021). Furthermore, the ongoing war in Ukraine has resulted in the arrival of thousands of Ukrainian refugees in the country (Smith 2022). In addition to the forced arrival of refugees in Greece, many immigrants choose the country as their place of residence for professional, educational or family reasons. According to the 2011 census, 2,037,196 foreigners (that is 18.8 percent of permanent residents) settled in Greece, have come from various foreign countries (Hellenic Statistical Authority 2014: 10). The final statistics from the latest census, conducted in 2021, have not yet been published, so the exact number of foreign residents in Greece has yet to be determined.

The high number of foreigners in Greece makes teaching and learning Greek as an additional language an increasingly necessary and widespread reality. In this way, research in this field meets the requirements of pedagogical science.

Moreover, thanks to fundamental studies by such anthropologists as Mary Douglas (e.g., 1975: 61-81), Jack Goody (1982, 1998), Sidney Mintz (1985, 1996), Marvin Harris (1986) and Arjun Appadurai (1988: 3-24), the Anthropology of Food began to emerge as an important branch of Social Anthropology. These studies highlight food as a key element of culture, identity and modern social life. However, the coupling of the learning of a language with food remains, in general, unexplored both in Greece and beyond.

Observing, therefore, although quite coincidentally at the beginning, the important role of food (e.g., cooking, eating and drinking activities inside and outside the classroom) both for the enhancement of cognitive (and specifically language and cultural) skills and for the reinforcement of social, emotional, intercultural and critical skills of the students, I decided to systematically research the contribution of food activities in language courses. In addition, being aware of the importance of the sea in Greece, in teaching Greek I focused particularly on the role of seafood activities.

Theoretical Framework

The term second language (L2) is often used for learning a language other than the first (L1) (Ellis 1994: 11). Factors that are taken into account to characterise a language as L1 or L2, L3, etc., are the order in which a person learns it, their competence in it, their attitude towards this language, and therefore their identification with it, the frequency the person uses it, as well as their worldview or any automatisms they might have in this language (e.g., if someone thinks, dreams or expresses themself spontaneously in this language) (Skutnabb-Kangas 1981: 14-18). However, in the recent bibliography the term 'additional language' has begun to be used instead of the term L2 (Leung and Creese 2010). In this way, we avoid completely entrenched language definitions, which, in fact, do not correspond to the complex linguistic reality.

Modern theoretical approaches to the didactics of an additional language concern communication models which emphasise both the holistic approach to the language and the focus on meaning rather than form (Candlin 1972: 37-44; Canale and Swain 1980: 1-47; Littlewood 1981). They also concern post-communication models which emphasise – among other things – Critical Literacy, as it enhances critical learning and contributes to the reinforcement of awareness and open thinking (Morgan 1997). Informal education is education that occurs outside of a structured curriculum, and takes place in everyday-life environments, such as at home, work and community during leisure time (Colley et al. 2003).

Out-of-class education is education that occurs outside educational institutions. During this kind of education students often use all of their senses and interact directly with the environment. The roots of out-of-class education are found mainly in the works of John Amos Comenius (Lukaš and Munjiza 2014: 32-44), John Dewey (1938), Jean-Jacques Rousseau (Gianoutsos 2006: 1-23), Johann Heinrich Pestalozzi (Brühlmeier 2010) and John Locke (Anstey 2011). All these educators advocated education in which learning takes place by head, heart and hands, that is, an education that incorporates all three aspects of learning: cognitive (head), emotional (heart) and practical (hands).

The Anthropology of Food is a subdiscipline within Anthropology. It focuses on the study of food both as a system of production and consumption and as a system of performance (Barthes 1970: 307-315). The Anthropology of Food examines, among others, topics such as what, how and when people eat, how food becomes part of individual and collective identities, how the local element is intertwined with the supra-local, as well as aspects of food related to religion, cultural, social, class, psychological and gender issues.

Purpose of this research and research questions

The purpose of this research was to focus on and explore ways of utilising culinary activities related to seafood in teaching Greek as an additional language to foreign adult students in higher education; to highlight the benefits for both students and teachers; to identify any difficulties in their implementation; and to suggest indicative ways of dealing with them.

The research questions were the following:

- In which ways could out-of-class culinary activities related to seafood enhance students' cognitive (language and cultural), social, emotional and critical thinking skills?
- Which difficulties might arise before, during and after these activities and how could these difficulties be overcome?

Research methodology: sample – research tools – classification and evaluation of research data

The research data were collected at the SMG of AUTh during the period November 2015 – February 2020 from ten classes of different levels in Greek language, from B1 (intermediate) to C1 (advanced) level, according to the Common European Framework of Reference for Languages (Council of Europe 2001). About a hundred adult students from various countries of Eastern and Western Europe, North and South America, North and sub-Saharan Africa, Asia and Australia took part in these classes. All of them had completed their secondary education, while a significant number of them had completed their undergraduate and postgraduate studies, usually in their country of origin. They lived (temporarily or permanently) in Greece for professional, educational or family reasons. They were taught Greek ten or twenty hours per week for one, three, four, five or eight months.

Hosting around a thousand students per year, the SMG is one of the largest educational institutions in the world where Greek is taught as an additional language. It has been offering courses in Greek language and culture to foreigners and Greeks from abroad since 1970. It operates under the supervision of the Faculty of Philosophy.[32]

The research tools that were used for the data collection were participant observation, detailed diary and teacher notes, semi-structured interviews and free discussions. The participant observation took place outside the classroom (during the culinary activities), as well as inside the classroom (during both the preparation of the activities, concerning cultural knowledge and vocabulary acquisition, and the evaluation of the activities afterwards). The teacher's detailed diary and notes helped me by providing a systemised and detailed recording of the research data, which could be evaluated at a later stage of the research. The semi-structured interviews took place with ten students (one from every class), while free discussions took place with all the students who participated in the culinary activities during the research. I chose the semi-structured interview and the free discussion as research tools, because these allowed greater flexibility and expressiveness for the participants. In addition, these research tools gave me the opportunity to include data that emerged during the research, without these having been designed from the beginning (Patton 1990).

The research data were classified based on different criteria.

a) First, they were based on the type of data: audio recordings of interviews, videos and photos taken during the culinary activities, personal notes from field observation.

b) Secondly, they were based on two thematic criteria: criteria related to the contribution of culinary activities and their grammatical and lexical preparation for the enhancement of students' cognitive, social, emotional, intercultural and critical skills, and criteria related to the conditions that were necessary for the successful outcome of the activities, the difficulties that arose and the ways of dealing with them.

[32] See: https://smg.web.auth.gr/may2019b/en.

The collection of research data, using different research tools, has contributed to the triangulation of the research and consequently to its greater reliability and validity.

Presentation and analysis of the research results

a. Enhancement of students' cognitive (language and cultural) skills

As we were preparing the out-of-class culinary activities in different fish tavernas, we had the opportunity to deal with various environmental, financial and cultural issues concerning fish and seafood.

First, students were able to focus on environmental issues such as overfishing, bottom trawling and illegal fishing, all of which occur in the Mediterranean. According to a recent report from the Food and Agriculture Organization of the United Nations (FAO) (2020)), the Mediterranean is considered 'the world's most overfished sea, with the highest percentage of unsustainably harvested fish populations'. In addition, according to the same report, increasing human activity (shipping, aquaculture, maritime tourism, etc.) makes the Mediterranean marine ecosystem one of the most vulnerable in the world. Bottom trawling is another omnipresent problem in the Mediterranean, and it is carried out even in Fisheries Restricted Areas (FRAs) that have been designated and approved by all the countries around the Mediterranean in order to protect certain species. Particularly problematic are the large nets towed along the seafloor, causing irreversible damage to sensitive sea habitats (De Angelis et al. 2020). Bottom trawling is also an increasing activity in the Greek seas (Damalas et al. 2014: 112-121). Illegal fishing is an additional major problem in the Mediterranean (Holland 2016).

As fishing is woven into the soul of the Mediterranean, approximately 80,000 fishing boats navigate its waters and provide a livelihood for about 180,000 people. Illegal fishing supports an industry worth €4.6 billion that puts Mediterranean fish populations in critical crisis. About seventy-five percent of fish stocks are still illegally overfished in the Mediterranean and total fish populations have decreased by more than a third over the past half-century (World Wildlife Fund Mediterranean n.d.).

Next, students were able to focus on the topic of pollution of the seas, including the Mediterranean. Studying different educational videos, documentaries and informative texts from the internet, they learnt that plastic pollution and the tons of trash in the sea result in the reduction of fauna (and flora) in the Mediterranean (Figure 5.3).

Figure 5.3: ▸
Image used in the lessons as an occasion for discussion on the pollution of the seas

Photograph © Athanasios Valavanidis

According to a study by researchers from the University of Cádiz in Spain (Cózar et al. 2014), between 1,000 and 3,000 metric tons of plastic are floating in the Mediterranean Sea. This is one of the highest levels of plastic pollution in the world. Along densely populated coasts, a high influx of tourists and increasing maritime traffic seem to be responsible for most of the floating plastic. Plastic accounts for up to ninety-five percent of the trash collected on shorelines, the ocean surface and sea floor, according to the United Nations Environment Program (2016).

By focusing on topics related to financial issues, students learnt about occupations related to the fishing industry throughout the twentieth century and the first decades of the twenty-first century. They learnt, for example, that many Jews and refugees from Asia Minor in Thessaloniki had occupations related to fishing during the first half of the twentieth century. Thessaloniki housed the largest Jewish community, mostly Eastern Sephardim, in the Balkans until the middle of the Second World War. For this reason, Thessaloniki was known as ‘Jerusalem of the Balkans’ (Veinstein 1992). Despite the timeless and almost universal stereotypes about wealthy Jews (Pine 2013), more than eighty percent of the Jews in Thessaloniki were poor and had mainly three occupations: they were fishermen, fish sellers or '*touloubatzides*', i.e. fire-fighters.

After the end of the First World War, the Greco-Turkish War (1919-1922) took place. This war ended with the so-called Asia Minor Disaster in 1922. Due to the defeat of the Greeks in this war, the Greek Orthodox populations of Asia Minor had to leave their homes immediately and escape to Greece as refugees. In addition to these refugees from Asia Minor, other Greek Orthodox populations living in Turkey had to move to Greece, according to the Treaty of Lausanne (30 January 1923), which included the exchange of Greek and Turkish populations between Greece and Turkey. The first national Greek census after 1923, conducted in 1928, showed the number of Greeks of Asia Minor origin to be officially 1,164,267, but the number was in fact, probably over three million. The majority of refugees settled in large urban centres, including Thessaloniki. In Kalamaria, a coastal area of Thessaloniki, a refugee village was built by people of Asia Minor origin. It was named Nea (New) Aretsou after the town Aretsou (modern Darica) where the refugees came from in Turkey. Nea Aretsou was predominantly a fishing village. Initially, the refugees (224 families) were temporarily housed in tents near the beach or sent to refugee camps in the centre of Kalamaria. As Nea Aretsou was by the sea, the refugees initially engaged almost exclusively in fishing. At that time Nea Aretsou was more remote and desolate than it is today. In fact, as the well-known north wind in Thessaloniki, the so-called Vardaris, was always blowing and making the fishing activities of the residents difficult, the refugees built a port for their small boats. They suffered, drowning in the mud and helpless in the harsh weather. There was no transport to Thessaloniki, although the distance was only a twenty-minutes' walk away. Thus, they often used their boats for transportation to Thessaloniki, both for themselves and for the fish they caught (Oikonomidis 2009).

During the second half of the twentieth century, important economic activities, such as shellfish farming and fishing, developed in the Thermaic Gulf, also called the Gulf of Thessaloniki, proving its value as an economic resource (Famellos et al. n.d.).

In the first decades of the twenty-first century and especially during the period of the global economic crisis, many people were no longer amateur fishermen in the port of Thessaloniki. They did not choose fishing because 'time passes pleasantly' or 'to get away from the routine of everyday life'. They became people who fished to survive (Figure 5.4). So, the old hobby of mainly retired amateur fishermen became a systematic pursuit for people to try to reduce their food expenses by providing food, such as bream, horse mackerel, blotched picarel, cuttlefish, squid, cephalopod and bluefish, for their family several times a month (Konstantinidou 2019; Athens News Agency 2020).

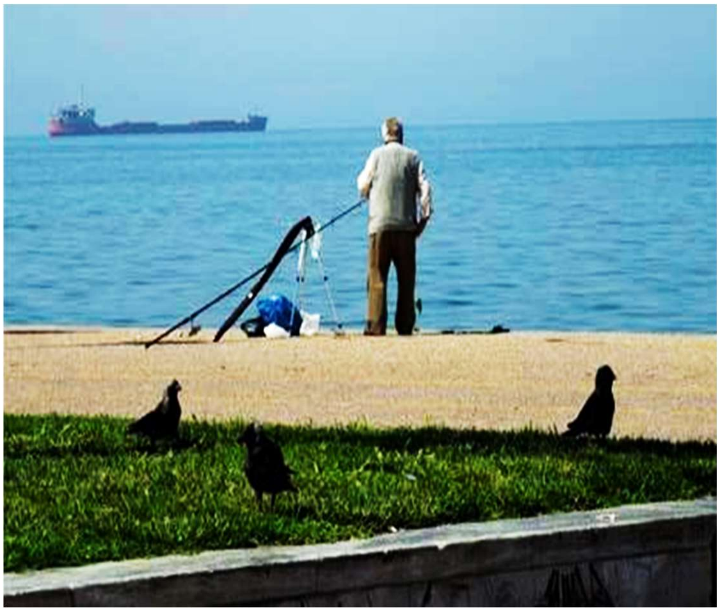

Figure 5.4: Fishing for survival in recent years at the port of Thessaloniki

Photograph © Mariana Kavroulaki

Students were also able to learn cultural aspects related to the history of eating seafood in Greece from ancient to modern times, by viewing and describing important artwork from different periods and civilisations that flourished in Greek territory.

Starting with the Cycladic civilisation (3200 BC-1100 BC), we used the Minoan fresco of a flying fish from the bronze age at Phylakopi (sixteenth century BC), one of the most important Bronze Age settlements in the Cyclades, located on the northern coast of the island of Milos. Students learnt that the people at that time were particularly familiar with fish-based dishes since fish was so readily available from the sea that surrounded them (Barber 1974: 1-53).

We continued looking at the history of seafood in Greece during the Minoan period, using a famous fresco of a fisherman. The fresco was found

at Akrotiri on Santorini (dating from the seventeenth century BC). In addition, we have used two items of Minoan pottery (1500-1450 BC), painted with seafood, showing the familiarity of the people at that time with this kind of food (Figure 5.5).

◂ **Figure 5.5:** Cookies decorated with seafood motifs that date from the Minoan period

Photograph © Mariana Kavroulaki

Using some Mycenaean palace amphora, found in the Argolis (Peloponnese), and a Mycenaean hydria dating from the twelfth century BC that shows a fishing activity, we discussed Bloedow's theory (1987: 179-185) according to which the Mycenaean fleet sailed to the Hellespont each summer, set up camp in the Troad, and from that base proceeded to catch and dry fish.

Moving to the Archaic period (800 BC-500 BC) and to the Classical period (800 BC-323 BC), we learnt about the low social status of fishing in these periods, which might be an explanation for the almost non-existent fishing scenes in the archaeological finds so far. We also saw how the consumption of fish varied, depending on the wealth and the location of the household. Whereas fresh fish and seafood (squid, octopus, cuttlefish and shellfish) were common in the Greek islands and on the coast (Figures 5.6 and 5.7), salted fish (such as especially sardines and anchovies) were more common for the citizens of Athens (Figure 5.8).

◂ **Figures 5.6 and 5.7:** Fresh fish and seafood dishes

Photographs © Koula Varydakis-Xanialakis

Figure 5.8: ▶
Anchovy fillets marinated
in lemon juice and garlic
and preserved in virgin olive oil

Photograph © Mariana Kavroulaki

As with other Mediterranean people and people that live near any water, the ancient Greeks ate a lot of fish and shellfish, octopus and squid. In addition, during the seventh century BC they started to intensively explore the Black Sea for fishing purposes. In fact, they became the first industrial fishermen. They used different kinds of fishing gear and special vessels for fishing. They were the first to use the pound net and mullet cast net, which have not changed and remain in use to this day. They were also the first to make a fish sauce in Europe and it was called *garos*. They made it by fermenting small fish with salt (Aleksandrov et al. 2021).

We particularly mentioned the art of the fish plate by the ancient Greeks. The fish plate was a Greek pottery vessel invented in the late fifth century BC in Athens and was usually decorated with seafood items. In the fourth century BC Greeks colonised southern Italy and transferred this art there, the location where most of its specimens survive today (Kunisch 1989).

Moving to the Hellenistic period (323 BC-146 AD) the students learnt about the legend of the Mermaid Thessaloniki, Alexander the Great's stepsister, from whom the city of Thessaloniki got its name. Using the two paintings of naïve art style (Figures 5.9 and 5.10), they learnt that Alexander created the Hellenistic Age and founded one of the largest empires in history, stretching from Greece to northwestern India. According to legend, Alexander found the water of immortality, but Thessaloniki threw it away by mistake or ignorance. When she realised her mistake, she begged the Gods to keep her alive so that she could return to this world and see her brother, even if he had died. Her request was heeded and so the princess Thessaloniki became a fish from her waist down; she became a mermaid.

Figures 5.9 and 5.10: The legend of the Mermaid Thessaloniki in naive art paintings

Photographs © Parallaxi

Since then, she has always swum in the sea and, as soon as she sees a boat, she asks the sailors if 'King Alexander is alive'. Having a positive answer, she swims away joyfully. But when the sailors give her a negative answer, she kills them and sinks the ship, creating a storm from her tears (Gerakiti 2020).

Using two Roman mosaics, found in Greece, as a starting point for discussion about the Roman period (146 AD-330 AD), the students were able to learn about two seafood specialties of Roman cuisine: the so-called 'salsus', i.e. fish sausages (the intestines of animals stuffed with spiced fish, instead of spiced meat; this habit was already known to the Babylonians in 1500 BC), and fish soup, cooked in huge vats. Students learnt that the Romans also ate lobster, crab, octopus, squid, cuttlefish, flathead grey mullet, sea urchins, scallops, clams, mussels, sea snails, tuna, gilt-head bream, bass, sardines and scorpion fish, which are still favourite dishes in modern Greece (Figures 5.11, 5.12 and 5.13). The Romans liked to cook fish live at the table. In fact, they loved eating fish so much that, even at that time, it is likely they were overfishing the Mediterranean Sea (Vassilopoulou and Vaiopoulou 2019; Kankeleit n.d.).

Figure 5.11:
Black bryony with octopus

Figure 5.12:
Cuttlefish with fennel

Figure 5.13:
Sardines in fig leaves

Photographs © Mariana Kavroulaki

Students also learnt about Fainos, the most famous and richest Greek fisherman of his time (second century AD), using two Roman mosaics that were found during the excavations of his villa in Bodrum (in southwestern Turkey). We discussed the various fishing techniques, as represented in these mosaics, and students made assumptions about what a fisherman's daily life might have been like as well.

For the Byzantine period (330 AD-1453 AD), students were able to learn how popular seafood was for all social classes, especially among the clergy and in the monasteries. Only the rich had the possibility of eating large and expensive fish, while seafood such as octopus (Figure 5.14), squid, cuttlefish, mackerel, sardines, shrimps (Figure 5.15), and salted fish were accessible to all. The Byzantines liked eating fish so much that they cooked them even during fasting days despite the relevant prohibitions by the Orthodox Church.

Figure 5.14: Musky octopus cooked ▸ with spinach, onions, and wild fennel

Photograph © Mariana Kavroulaki

◂ **Figure 5.15:** Fried shrimps

Photograph © Mariana Kavroulaki

At the same time students learnt about the various cooking methods for seafood used by the Byzantines. The fish were fried or boiled in water to which they added oil, dill or leeks. They also learnt preservation methods for seafood, such as smoking and pickling. The fish were preserved in salt and were consumed mainly in winter, but also throughout the year in the areas of the Byzantine Empire, which were far from the sea. At the Byzantine table, specifically in the coastal areas, seafood delicacies were served. The so-called 'pure' foods (squid, octopus, shrimp, scallops, mussels, oysters, sea urchins, etc.) (Figures 5.16 and 5.17), were cooked in various ways, while the common people ate the shellfish raw (Figures 5.18 and 5.19). Additionally, students learnt various methods of fishing by the Byzantines, such as using a fishing light (*pyrofani* in Greek), or nets in places where there were sea currents or in river mouths. Especially during the periods of fish migration, the fish were trapped in these organised fishing grounds (Angelidi et al. 2015).

◂ **Figure 5.16:** Boiled mussels

Figure 5.17: ▸ Soup with shrimps

Photographs © Mariana Kavroulaki

◂ **Figure 5.18 and 5.19:** ▸
Raw shellfish

Photographs © Mariana Kavroulaki

Finally, students learnt the symbolic meaning of the fish (Ichthus / ΙΧΘΥΣ in ancient Greek) used by Christians, including the population of orthodox Byzantium. Ichthus is an acronym which stands for 'Jesus Christ, son of God, Saviour' (in ancient Greek ''Ιησοῦς Χριστός, Θεοῦ Υἱός, Σωτήρ').

Moving to studies of the Ottoman period (1453 AD-1821 AD), students were able to learn that fish and seafood, along with bread, legumes, vegetables, meat, milk and wine, were part of the diet at that time. The people ate at the *sofra*, the small low table around which men gather (usually separately from women), a custom acquired by the Greeks from the Ottomans. Additionally, students learnt that in the travel and religious texts of that time, cuttlefish, caviar and *taramas* are depicted as standard food of Christians, while coffee and pilaf are depicted as Ottoman food. Caviar was a food consisting of salt-cured roe from wild sturgeon in the Caspian and Black Seas. As it was expensive, it was considered suitable food only for wealthy Greeks. The corresponding food for poor Greeks was *taramas* (Figure 5.20), a food consisting of salt-cured roe from cod (Alexandridou 2021).

Figure 5.20: ▸
Tarama salad (with marinated anchovy, salted cured tuna in oil, beetroot and bread, *tsiros* [dried mackerel])

Photograph © Mariana Kavroulaki

During the periods of religious fasting, the consumption of caviar, *taramas* and bloodless seafood, such as squid, octopus, cuttlefish and the like, was allowed. The consumption of fish was forbidden, as it was considered to belong to the so-called 'unclean' food, from which Christians had to abstain, not only during the long fasting periods, i.e. forty days before Christmas, forty days before Easter, and the first fourteen days of August, and during the short fasts, i.e. the fast of the Holy Apostles (25^{th}-28^{th} June), the fast of John the Baptist (29^{th} August), the fast of the Holy Cross (14^{th} September), etc., but also every Wednesday and Friday throughout the year, because of Christ's betrayal by Judas on Wednesday and his crucifixion on Friday (Papadopoulos, 1987: 51-57).

Finally, moving to the Modern Period of Greek history, i.e. from the beginning of the Greek revolution (1821) until today, we focused on three topics:

i) the long history and culture of fish tavernas in Greece
ii) the traditional fish dish that is consumed on 25^{th} March, an important national and religious holiday in Greece
iii) references to marine fauna in Greek proverbs and selective songs

(i) *The long history and culture of fish tavernas in Greece*
Preparing out-of-class culinary activities with students helped them learn the long history of food and beverage culture at the tavernas in Greece (Figures 5.21 and 5.22), the predecessors of the modern restaurant. Starting with the etymology of taverna, we pointed out that it is a word taken from the Latin *taberna* that is derived from tabula (meaning 'table'). The taverna has a history that lasts over 2,500 years, starting from Ancient Greece. The earliest Greek taverna (καπηλεῖον / *kapilion* in Greek) was found at the ancient *Agora* (meaning marketplace) of Athens during excavations conducted a half century before. Among others, large amounts of fish bones and shellfish remains were found, revealing the taverna's offerings of oysters, mussels, murex and large fish (Shear 1973: 331-374). Similar places where food and alcohol were served also existed during the Roman period (known as *taberna* or *popina*), during the Byzantine period (known as *mageriko*, i.e. kitchen) and in the Ottoman period (known as *lokanta*) (Dalby 1996).

Figures 5.21 and 5.22: Traditional seaside fish tavernas in Greece

Photographs © Mariana Kavroulaki

Concerning specific fish tavernas in Greece, there are two main types: the '*ouzeri*' (Figure 5.23) and the '*tsipouradiko*' (Figure 5.24).

Figure 5.23: ouzeri

Figure 5.24: tsipouradiko

Photographs © Mariana Kavroulaki

In both, mainly fish appetisers and fish dishes are served, such as crab salad, octopus salad, fish roe salad, grilled octopus, shrimp, fried mussels, prawns, cuttlefish, squid simple or stuffed, anchovies, sardines, cod and pasta with various seafoods (Figures 5.25, 5.26, 5.27, 5.28, 5.29 and 5.30). The fish dishes are accompanied either by *ouzo*, a dry anise-flavoured aperitif, or by *tsipouro*, a strong distilled spirit containing forty to forty-five percent alcohol that is produced from pomace (the residue of the wine press).

Figure 5.25: Mussel pilaf

Figure 5.26: Octopus salad

Figure 5.27: Fried crab claws

Photographs © Stergios Gontelakis

Figure 5.28: Grilled Sardines

Figures 5.29 and 5.30: Pasta with seafoods

Photographs © Koula Varydakis-Xanialakis

(ii) *The traditional fish dish served on the national and religious holiday of the 25th of March*

The 25th of March is a national and religious holiday in Greece. It is Greek Independence Day, the day that marks the official beginning of the Greek war for independence against the Ottoman Empire in 1821. It is also the Feast of the Annunciation or *Conceptio Christi* Day. According to Christian tradition, the day commemorates when the angel Gabriel visited the Virgin Mary to announce that she would give birth to Jesus Christ.

On this day almost all Greeks customarily eat fried cod with garlic sauce, usually accompanied by beetroot, fried zucchini (Figures 5.31 and 5.32) and, for dessert, halva, as with the Clean Monday's fasting foods (Figure 5.33).

◂ **Figures 5.31 and 5.32:** ▸ Fried cod with garlic sauce and red beetroot

Photographs © Mary Margaroni

Figure 5.33: ▸ Spring onions, lettuce leaves, oysters, octopus, shrimps, fish roe salad and *lagana* bread, are the *sine qua non* of Clean Monday's fasting foods

Photograph © Mariana Kavroulaki

The 25th of March is also in the middle of Lent, a forty-day period of strict fasting. It begins on Shrove Monday, seven weeks before Easter, and prepares Christians for the celebration of Easter, which is considered the most important Orthodox holiday. As this fast was already established in the fourth century AD, it is the oldest of the great fasts of the Orthodox Church. In fact, when Lent was first established, according to the monastic standards, *xerophagy* (i.e. 'dry eating', the practice of eating dry food, especially food cooked without oil) was provided only once a day after 15.00. It was then that the foods from which the faithful traditionally had to abstain were defined: meat, fish, eggs, dairy products, wine, oil, and even vegetable oils according to some even stricter religious traditions. However, wine and oil were allowed on Saturdays and Sundays. So, during this period of Lent, fasting is differentiated three times, thus giving the faithful an opportunity to become stronger through a more nutritious diet. The first of these differences in the Lenten fast is the 25th of March, the Feast of the Annunciation. It is a very important holiday dedicated to God's mother, according to the Christian tradition. For this reason, during the period of Lenten mourning, fish, oil and wine are allowed to be added to the Orthodox diet on that day. The second of the differences in Lent fasting is the Sunday of the Poor, which is, as it is called, a Despotic feast, dedicated to the earthly life of Jesus. On this day the faithful are allowed to consume fish, oil and wine. The third and last of the differences in Lent fasting is Holy Thursday, during which it is permissible to consume oil in remembrance of the delivery of the Sacrament of Holy Communion by Jesus Christ to his disciples (Koutsas 2001).

Regarding the link between cod with garlic sauce and the revolution of 1821, there is a legend that mentions that 'cod with garlic sauce' was an expression used by the revolutionaries of 1821. Specifically, in every battle in which the Greeks defeated the Ottomans, they used the slogan 'We ate them (meaning we completely defeated them) like cod with garlic sauce.' This expression is still used today in Greece when one refers to something that has been won very easily. So, according to this legend, the Greeks eat cod with garlic sauce on this day to honour the heroes of the revolution who liberated their country (Bosgas 2021).

Thus, we can easily understand why strict and long-lasting fasting is differentiated on this joyful day of 25th March and why fish is allowed to be eaten. The question of why the choice of this fish remains, however, as cod is a species found mainly in the Atlantic Ocean and the North Sea, both of which are in northern countries and cold climates. Although cod first appeared as a commercial product as early as the Viking Age, around 800 AD, it became known in Greece only in the fifteenth century, mainly to poor inhabitants of the hinterland and mainland Greece for whom the consumption of fresh fish was a luxury (Lee 2019; Bosgas 2021). Because cod can be pickled, it was less perishable and very cheap. Garlic sauce gave a 'more Greek character' to this dish, in addition to allowing it to maintain the blood pressure of those who ate it at normal levels, thus acting as a natural counterweight to the salted cod. The red beetroot, the fried zucchini and the halva with their sweet taste helped offset the pungent taste of garlic.

(iii) *References to marine fauna in Greek proverbs and selective songs*

Finally in class, we discussed Greek proverbs and two very well-known songs related to marine fauna. Someone who is very scared, *'trembles or sparks like a fish'*. *'If you don't wet your ass, you don't eat fish'*, means goods are only obtained with a lot of effort and is similar in meaning to the proverb *'The fish don't enter the pan on their own'*. Whoever wants to extract information from someone, *'throws an empty net into the sea to catch a full net of fish'*. The ungrateful man *'is eating the fish and is spitting on my beard'*. Of course, *'it is better eating greens and having unity, rather than eating fish and having discord'*.

'Someone cooks the fish on my lips' means that they torture me a lot. This proverb, according to legend, is based on a fact that happened in a monastery. A monk broke the Lenten fast and was found in a nearby cave frying fish. The abbot's council in sentencing him ordered his mouth to be filled with burning coals and the fish to be cooked on his lips. Of course, the monk died shortly after in horrible pain. When we say *'I want to see what fish you catch'* we mean that I want to see which skills you have. *'Fish and visitors stink after three days'* is said for long-term guests. *'Like a fish out of water'* is someone who does not feel comfortable at all. *'Large fish are caught with small bait'* means that we have great success, although we have used small means. But, in cases of failure for which we blame others, although we are responsible ourselves, we are used to the saying *'If you can't catch a fish, do not blame the sea'*. The proverb *'Big fish eat little fish'* means that the powerful people impose on and devour the weak. Talking about the impotence and especially the immorality of high authorities, we usually say that *'A rotting fish begins to stink at the head'*. In case of fraud, the proverb *'They sent him for green caviar'* is appropriate. About someone (usually a woman) who traps a person in an insidious way we use the proverb *'She wraps him in her nets'*. For the overly optimistic and particularly hurried people we say that *'The pan (is) on fire and the fish in the sea'*. It is also known that *'A hunter's and a fisherman's dish is ten times empty and twice full'*. For unfulfilled desires, the proverb *'(Your) eyes, eat fish, and (your) belly eats until you ache'* is ironically used. *'Without bait, fish isn't caught'* means that without motivation and interest nothing is achieved. When

'*Someone is fishing in murky waters'* it means that a person's actions have an uncertain outcome.[33]

The next two songs are very well known and loved by the Greeks. The first one (the folk song *Down on the Coast, on the Sand*) was used in class as an occasion to let the students learn the names of some of the most common fish in Greece. The second one (*The Baby Crabs*, is one of the most famous Greek *rembetiko* songs) was used as an occasion to discuss marital infidelity and intra-family relationships in general.

Down on the Coast, on the Sand (1970)
Music and Lyrics: Yorgos Batis

Down on the coast, on the sand,
the fish do a wedding ceremony,
they marry the pickerel
with the bonito.

The bream plays bouzouki,
the cod baglama,
the sardine guitar,
the singer is the leech,
who is a troublemaker.

The garfish plays the tambourine
and the comber has a lot of fun
and the cuttlefish do not waste time,
releasing their ink.

Down on the coast, on the sand,
the fish do a wedding ceremony,
Oh, my goodness, what a great storm
on the beach.

The Baby Crabs (1952)
Music and Lyrics: Vassilis Tsitsanis

On the little pebbles of the seacoast
two baby crabs are resting
alone, with a worried expression
and they constantly cry, poor them.

Their mom, Mrs Crab,
went out with a Bream to Rafina.
And they constantly cry, the baby crabs,
on the seaside's, on the seaside's
little pebbles.

Mr Crab came back at night.
He found their home in a mess.
He looked for his family
and pulled his hair in desperation.

He set to go, slowly-slowly to Rafina
to meet Mrs Crab.
And they constantly cry, the baby crabs,
on the seaside's, on the seaside's
little pebbles.

From the above detailed description of the thematic and lexical in-class-preparation of the culinary out-of-class activities, we can see that students were able to enhance their knowledge on topics related to everyday life, entertainment and leisure, tavernas, diet and eating habits over time, social life, social contacts and holidays, natural environment and ecology,

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[33]. See: https://www.sansimera.gr/proverbs/ categories/215.

purchase of goods (food), economic and professional activities (occupations related to seafood), traditions and arts, as indicated by the curricula of the SMG (Amvrazis et al. 2010; Kapourkatsidou and Gavriilidou 2015). More exactly and according to specific topics of the aforementioned curricula, students were able to enrich their vocabulary regarding healthy eating habits, the relation between diet and lifestyle, disease prevention, topics related to the temperate zone, the Mediterranean fauna, ecosystems and biodiversity in Greece, endangered maritime species, environmental protection, protected wetlands, environmental organisations, climate change, international agreements for environmental protection, the negative consequences of (food) overconsumption, etc.

The preparation of the culinary activities from a thematic and lexical point of view clearly had a completely cross-interdisciplinary orientation. Aspects of History of Nutrition, History of Art, Local History, Economics, Folklore, Music, Environmental Studies, and Cultural Studies were of service to examine the topic of seafood in Greece and how through it we can teach Greek as an additional language.

In addition, thanks to out-of-class culinary activities, students were able to practise various speech acts (Levinson 1980: 5-24), indicated by the above-mentioned curricula, such as to express preference, desire or dissatisfaction (e.g., comments on prices in the restaurants and fish tavernas), to accept or decline invitations, to express intention and decision, to seek help and advice, to give orders and instructions, to order food and drink, to describe pictures (e.g., artwork such as a painting, a mosaic or a vessel, a seafood plate or recipe), to read and understand advertisements (e.g., about fish tavernas, various culinary products), to ask for information, to negotiate and claim, to discuss about the Mediterranean diet, the eating habits in Greece and other places through a comparative approach (e.g., finding similarities and differences), to discuss holidays and special food traditions (e.g., the consumption of cod on a Greek national holiday), and to exchange wishes. Finally, students had the opportunity to get acquainted with various cultural aspects of the host country, such as daily habits, forms of entertainment, ways of showing politeness in the Greek language, etc. (Amvrazis et al. 2010; Kapourkatsidou and Gavriilidou 2015).

b. Enhancement of students' social, emotional, and critical thinking skills

As eating together is often associated with familiarity, the out-of-class culinary activities in restaurants and tavernas contributed to the interaction of students with each other and with their teacher in a more relaxed and less formal learning environment than in the classroom. Thus, the 'pedagogical climate' of the class was strengthened, conditions of mutual interest were created between all the participants in the educational process, a sense of security and trust was developed, and the foundations were laid for the creation of harmonious interpersonal relationships, which are the cornerstones of the learning process (Trilianos 2013: 383). According to the semi-structured interviews and the free discussions with students, it was found that around the table they felt freer to share their personal stories and experiences and to exchange their views about various topics. The change of the educational environment (e.g., from the classroom to the tavernas) contributed to students' willingness to engage in deeper and more varied discussions, which in fact required the use of a wider vocabulary, more grammar rules and more complex syntax. The approach of the Greek language took place in a completely holistic way (Goodman 1986). Active listening and therefore mutual respect and empathy was being strengthened. Thanks to shared food and drink, the students were able to relax and interact, enhancing their social skills and creating the conditions for friendships.

Some students, especially those who had not lived long in Thessaloniki, focused on the very positive effect that the common culinary experiences had on combating the loneliness they felt in the foreign city. They often maintained that these activities helped them discover beautiful aspects of everyday life in their new place of residence. In this way, they developed positive thinking and stopped worrying, as they had the opportunity to see, at first hand, that other people were also in a similar situation, and most importantly that they were not alone. The culinary activities helped students to build healthy relationships faster and more easily, and to gain awareness of what others were feeling. The more out-of-class culinary activities there were, the more systematically all the previously mentioned emotional skills were enhanced.

Critical discussions as a part of the preparation for these out-of-class activities strengthened students' critical thinking skills. The critical discussions covered a variety of topics, such as the link between financial prosperity and the quality of food in people's daily lives, the reckless destruction of the marine environment due to overfishing, bottom trawling and illegal fishing, the imposition of humans on the rest of the living beings of our planet, and the attendant moral problems that arise.

c. Potential difficulties before, during and after the seafood activities – queries and ways to overcome them

Despite the many benefits of the culinary activities, their organisation and implementation were sometimes complicated by various difficulties. Specifically, what should be done with students who were in a period of fasting, i.e. abstention from certain foods, which was mainly by those who adhered to the Orthodox Christian doctrine, or abstained altogether from food and drink, even including water, for a certain period during the day, such as from sunrise to sunset for Muslims during Ramadan? And what about those students who, also for strictly religious reasons, were reluctant to participate in culinary activities accompanied by live music, songs, dances, alcohol and smoking? And what about vegetarian and vegan students, whose eating habits prevented them from eating the usual dishes served in fish tavernas?

Apart from the religious and philosophical nutritional orientations of some students, how could the potential financial hardship of some students be addressed? Common dining out often involved significant costs. Indeed, it could not be taken for granted that all students were able to afford these costs at any time. How, then, could food be a vehicle for inclusion and not cause economic and social exclusion? And then, how to reduce student anxiety about exams, which often means limiting outings?

To the above ideological, financial and psychological difficulties were added some organisational ones. Who organised the culinary activities in terms of finding common time, especially when it came to numerically large groups? The search for information on restaurants and tavernas according to students' requirements and wishes, the reservation of a table especially for large groups and the organisation of the transport to and from the restaurant were organisational issues that had to be settled well beforehand for a smooth enjoyment afterwards.

All of the above difficulties arose during the research, although they were relatively limited, meaning that these difficulties were the exception rather than the rule. Various solutions were used to address them, such as the systematic effort to place common culinary activities outside of fasting periods and the choice of the most economical and rich in dietary diversity tavernas. In summary, there was a conscious strengthening of the belief that these kinds of activities are *not* irrelevant to students' efforts to master the target language more effectively and to improve their understanding of the host society, but, on the contrary, contribute significantly to the attainment of these aims.

Nevertheless, necessary conditions for the maximum effectiveness of the seafood activities were:

- To create a pleasant and friendly atmosphere in the classroom, thanks to which students felt comfortable and enjoyed spending time with their classmates outside the classroom;
- To link these activities to the overall curriculum and to the educational process in the classroom;
- To prepare the activities as efficiently as possible from a thematic and lexical point of view;
- To let students co-decide and co-organise the activities, depending on the wishes of all participants in the educational process.

Conclusions and suggestions

From the above we realise the notable role that culinary educational activities play in the learning process, especially when there is the preparation of an enlarged vocabulary about intertwined topics, as we have seen in detail in the present study. In the case of SMG as a multicultural educational institution, these activities contributed to the strengthening of the intercultural dialogue between students. Food and drink, principal elements of the formation of identities, of peoples' identification with places and cultures, of the formation of individual and collective memory, were an occasion for deeper interpersonal acquaintance, revelation of self-culture, acquaintance with cultural 'others', critical expansion of the way of thinking, storytelling, and creation of common experiences, aesthetic pleasures, celebration and sharing.

At the same time, the seafood activities contributed to the empowerment of various cognitive, social, emotional and critical thinking skills of students. Although manageable, difficulties that sometimes arose due to religious, ideological, economic and psychological peculiarities, as well as organisational factors, these activities reinforced a holistic approach to the target language, giving students the opportunity to practise it in authentic language environments and created the first foundations for their further involvement in the host society. Especially when the gastronomic activities took place at the beginning of an educational programme, I found that they laid a stronger foundation for a dynamic start in a less unfamiliar and more friendly learning environment, as well as for building a positive pedagogical climate and a warmer intra-group coexistence. For this reason, the conscious and more systematic integration of such culinary activities into language education is desirable. So, let's combine the fun with the useful.

Limitations of the research

This research is subject to the inherent limitations of qualitative research. Specifically, this is a case study that took place in a specific educational institution (SMG), in a specific period (2015-2020) and with a limited number of participants (ten classes with about one hundred students). Therefore, the research results cannot be generalised. As there is an almost complete lack of studies with similar topics in both Greek and foreign literature, similar research at different levels of education and in classes of different subjects could verify and reinforce the results of the present research.

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CHAPTER 6
RAW HERRING IN THE CARIBBEAN: SALT, SLAVERY AND GOODWILL AMBASSADOR

by Vincent Nijman

‘*Get your tickets for the Haring Party 2019, a fundraising event organized by Curaçao Lions!*’

Announcement on the Ginger Restaurant Facebook Page

Introduction

On 12th June 2019 it was announced by the Curaçao Press Agency that eight days later the first ‘*Hollandse Nieuwe*’ would arrive on the island.[34] It could then be tasted for the first time at the annual Curaçao Lions Club Haring Party, between 17.00-19.00 hrs at the Ginger Restaurant in Pietermaai, a UNESCO World Heritage Site (Figure 6.1A) in Willemstad, Curaçao. *Hollandse Nieuwe* represents the first catch of Atlantic herring (*Clupea harengus*) of the year, and connoisseurs rate the quality of a year’s catch by the fattiness of the herring (the more fat, the tastier). In the Netherlands it is traditional that the first barrel is sold by auction with the proceeds going to various charities. On 11th June 2019 the first barrel of that year was sold in Scheveningen, Holland, for €95,500.

The event in Pietermaai mirrors the events in Scheveningen, albeit at a smaller scale, and following a nine-day delay. Participants had to purchase a ticket (at NA*f* 125, or €62), and apart from herring there were other Dutch culinary specialities such as *HEMA-rookworst* (smoked sausage), cheese, *snert* (pea soup) and *korenwijn* (the Dutch antecedent of modern gin). Sponsored by Coca Cola, Moises de Marchena & Sons Sales and Agencies of Willemstad and Hendrick’s Gin, amongst others, all proceeds were to go to *Fundashon Duna E Mucha un Man.* The official languages of Curaçao, and neighbouring Bonaire, are Dutch and Papiamento, but in practice this can also be interspersed with English and/or Spanish words.

[34] I write this in early 2022 and, whereas there were herring parties in the Caribbean and the Netherlands in 2020 and 2021, these were all somewhat disrupted by COVID-19, lockdowns and local and international travel restrictions; hence I focus on 2019.

A few days later, on 30th June, there was a similar party in Kralendijk on Bonaire. The first (small) barrel of *Hollandse Nieuwe* was auctioned off for the equivalent of €1,690 at the 'It Rains Fishes Haring Party'. Anyone who accidentally ended up at the Curaçao Lions Club Haring Party or the It Rains Fishes Haring Party would have been excused for thinking that they had, briefly, been transported to the Netherlands, even while acknowledging that the event organisers had ensured that there was a Caribbean feel to them.

There were other herring parties as well with, for instance, Plein Café Wilhelmina in Willemstad, offering the first hundred *Hollandse Nieuwe* for free at the Punda Haring Party (Figure 6.1B) on the 13th June (and, therefore, the announcement from the Curaçao Press Agency mentioned at the start of this chapter was incorrect as theirs was not the first herring to arrive). The wine merchant, Servir Frias, had its own Haring Party, also in Willemstad, attended by some two hundred people on the 14th June. There the *Hollandse Nieuwe* was accompanied by a glass of white wine rather than gin. Café the Plaza in Oranjestad on Aruba, announced that also on the 14th June they would continue with the Dutch tradition of 'Haring Happen' when the first herrings of the season had been flown in. They added that 'Predictions about this year's catch are very favourable: the 2019 herring is fat and tasty: it just slides down your throat!' (Figure 6.1C). And then there is the *Haringkar* (herring cart) in Willemstad, a permanent presence near the Albert Heijn supermarket, where on Thursdays, Fridays and Saturdays all types of fish: raw, fried, cooked, including herring can be consumed (Figure 6.1D).

Herring, Bonaire, Curaçao – these are not words that often go together. But the three are part of a complex, intertwined trade network, that includes salt, fish and, in the past, African slaves. Without going into too much detail about the intricacies of this network or delving too much into the history of the herring trade other than at a most basic level, I here want to focus on herring consumption, herring dishes and indeed herring parties on the islands of Bonaire and Curaçao and how this is linked to the herring fisheries in the Netherlands.

Figures 6.1. A composite of pictures relevant to Haring in Curaçao

A. The official announcement of the date of the 2019 Curaçao Lions Club Haring Party. *Photograph credit Kiko Fa Pasando, licensed under CC- BY.*

B. Promotion of the Punda Haring Party at Plein Café Wilhelmina in Willemstad, Curaçao 13th June 2019. *Photograph credit: Plein Café Wilhelmina, licensed under CC-BY.*

C. Raw herring with pickled gherkin and chopped raw onions. *Photograph credit: E. Cours, licensed under CC-BY.*

D. Herring cart in front of the Albert Heijn supermarket in Willemstad, Curaçao. *Photograph credit: Haringkar Albert Heijn, licensed under CC-BY.*

E. Former slave hut at the southern end of Bonaire at the saltworks. *Photograph © Vincent Nijman.*

F. The correct way to eat *Hollandse Nieuwe* at the 'It Rains Fish Haring Party' 30th June 2019, Kralendijk, Bonaire. *Photograph credit: Caspar Douma, licensed under CC-BY.*

G. *Haring Happen*, Oranjestad, Aruba, 18th June 2021. *Photograph credit: CaféthePlaza, licensed under CC-BY.*

H. View of Willemstad, Curaçao. *Photograph credit: Terry Off, licensed under CC-BY*

I was born in Holland, in that westernmost coastal part of the Netherlands, where most of the seaports are. The arrival of *Hollandse Nieuwe* was an annual event widely covered in the news media. Growing up I was never a big fan of *Hollandse Nieuwe*, but as an adult, often to the disgust, or admiration, of foreign visitors I would show them how to eat raw herring correctly (one holds the whole herring, by now smothered in raw cut onions, by its tail and eats it upwards holding it over one's mouth) (see Figure 6.1F). I also worked in Curaçao and Bonaire, conducting research on raptors, waterbirds and freshwater fish (Nijman et al. 2005; Hulsman et al. 2008; Nijman 2010), and co-authored a book on the avifauna of these islands (Prins et al. 2009). Just like many Dutchmen and women I have enjoyed holidays on the islands. I have never eaten herring in the Caribbean, preferring local fish dishes such as *Piska ku funchi* or grilled snapper (Lutjanidae) instead. I now occupy a professorial chair in Anthropology in Oxford where we focus our research on wildlife trade; with fisheries being US$150 billion of the legal wildlife trade, this is an area not to be overlooked. As discussed below, the trade of herring in and to the Caribbean is not important in monetary terms, but it is important culturally.

Herring, one of the world's most abundant fish

Herring belong to the family Clupeidae, a group of around two hundred species that are amongst the most common fish in the oceans. The two species of *Clupea*: the Atlantic herring *C. harengus* (Figure 6.2) and the Pacific herring *C. pallasii*, occur respectively in the temperate waters of the Atlantic and North Pacific Oceans, and in spring they migrate to the shores of Europe and North America, supporting important commercial fisheries (Hay et al 2001).

Figure 6.2. Atlantic herring (*Clupea harengus)*

Photograph © Frédéric Duhart

Other species, that are related to herring, look like herring and are sometimes treated as herring, include the false herring *Harengula* spp., the dwarf herring *Jenkinsia lamprotaenia* and the bonefish *Albula vulpes* (Zanneveld 1956). These latter species do occur in the Caribbean but are not true herrings and their trade is distinctly different from that of the Atlantic and Pacific herring.

From the mid-1500s the Dutch Republic was a leading trading nation and the herring fisheries played a vital part in this, and in fact during the first one hundred and fifty years it held an absolute and dominant position in the European herring market (Poulsen 2016). This could only have happened because of the way in which herring was prepared and preserved after capture. In order to preserve herring, shortly after being netted they are gutted, leaving the liver and pancreas in but removing the guts, gills and bones (i.e. the parts that rot first). The herring are then put in barrels filled with brine for five or six days. According to the Dutch, this way of preserving herring, gibbing, was invented by Willem Beukelszoon sometime during the fourteenth century (making him a national hero in the Netherlands). It was this fish preserving technique that enabled the Dutch to become a global seafaring nation.

In 1560, the College van de Grote Visserij (College of Large Fisheries) was formed, with jurisdiction over the catching, processing, marketing and distribution of salted herring. For the next three hundred years the College managed the herring fisheries, largely by restricting the number of fishing licences (Poulsen 2008). After its dissolution in 1857, different fishing bodies in the Netherlands took over the role of regulating the Atlantic herring fisheries, which was later transferred to the level of the European Union (EU) (de Jager 1985).

Nowadays, the herring are caught over a relatively short period (at most from 1st May to 31st August) in the North Sea, or more recently, the North Atlantic, before the start of their breeding season. Each year, the Dutch Fish Bureau determines the start of the herring season, which depends on the fattiness, (which has to be above fifteen percent, and fishing cannot commence too early in the season) and the absence of roe and milt (which develop later in the season and determine the end date).

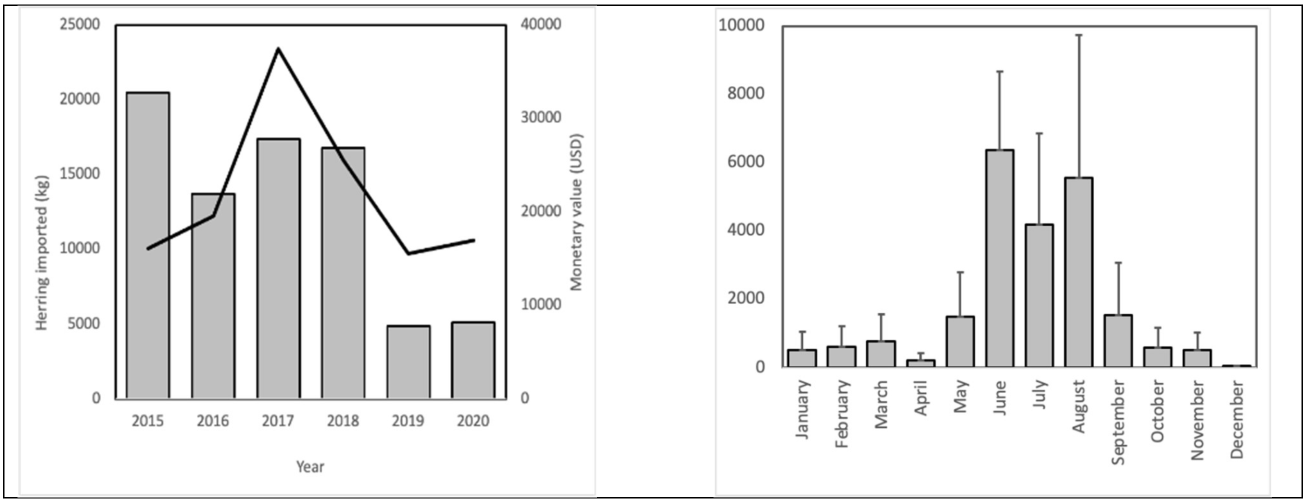
Need for salt and the Dutch presence on Curaçao and Bonaire

The massive herring industry required salt. While salt is everywhere, to harvest it at a large enough scale to make it profitable, one either must mine it (rock salt) or extract it from sea water through evaporation (saltpans). The Netherlands holds very little rock salt and it is never sunny enough for saltpans to function. Salt was thus imported, with Spain and Portugal being the largest producers of salt. The establishment of the Dutch Republic, involving the nine northern provinces, under William of Orange in 1581 started the eighty-year war with Spain. This also cut off the supply of large amounts of cheap salt (Sluiter 1948). In 1599 the first fleet set off from Holland to the Caribbean specifically for the purpose of acquiring salt. The main destination was Punta de Araya, a peninsula on the north coast of what is now Venezuela (then under Spanish rule), but after several military defeats, in 1623 the Dutch shifted their focus to the islands just off the coast of Araya, including Bonaire and Curaçao. Bonaire and Curaçao are geologically and geographically situated in exactly the right spot to provide large amounts of salt, exactly what was needed for the Dutch herring industry, as well as for European and North American cod (Gadidae) salting. The islands became one corner of a trade triangle connecting West Africa, the Caribbean and Northern Europe (Postma 1990).

Labourers in Caribbean saltpans, for around two hundred and fifty years, roughly from 1650 to 1800, were mostly, or at times exclusively, African slaves and their descendants. Salt extraction was always about export and trade, with only very small amounts of it being consumed or used on Bonaire or Curaçao. A significant proportion of the salt would be traded to the east coast of the USA and Canada. While the salt in Europe was used to make the brine to salt the herring, in the Americas it was used for salting cod. With salted cod being the cheapest or one of the cheapest forms of protein at the time, this was transported back to the Caribbean where it became the staple for many of the dishes, which we associate with the slave labourers and later with the Caribbean at large (Goucher 2014).

The import of herring from the Netherlands to Curaçao and Bonaire goes back centuries. Brito (1989) provided a list of goods that were imported into Curaçao in the eighteenth century, and the amount of import duty attached to each of these goods. Herring was grouped in the highest duty category (eight percent) showing the value people attached to importing this speciality.

At present, the value of the herring trade between the Netherlands and Bonaire and Curaçao is small when seen from the exporters' perspective, and only a little more substantial when seen from the importers' point of view. Anonymous (2020) reported that the total value of herring import (frozen and fresh) for Bonaire was the equivalent of €4,404 in 2018 and €17,938 for 2019. A similar picture emerges for Curaçao. The UN ComTrade database for the years 2011 to 2020 shows that on average 9,300 kg of herring are imported into Curaçao from the Netherlands, at a declared value of €19,171 per year. But there is a large amount of variation between years (Figure 6.3a). The values for Bonaire and Aruba are incomplete, partially, as the herring may be flown into Curaçao first but then is flown over to the other islands. There is also a clear seasonality in the import of herring into Curaçao showing a peak in June, July and August, which coincides with the herring-harvesting season in the Netherlands (Figure 6.3b). The mass of a commercially prepared clean raw herring, each weighing between 60 and 70 grammes, and, if we take a value of roughly 26,000 kg of herring being imported into Bonaire and Curaçao, this then equates to some 400,000 herrings.



Figures 6.3a and 6.3b: Herring trade (frozen, chilled, fresh) into Curacao: [**3a:** Imports of herring from the Netherlands, showing the amount in kg (bars) and the value in US$ (line) for the most recent years. **3b:** Seasonality in the importation of herring into Curacao, by value, showing a peak in June, July and August, which coincides with the herring-harvesting season in the Netherlands]

Source: UN ComTrade (accessed on 20 May 2022)

Judging from the many pictures of people attending the herring parties, and reading the comments posted online, these herring are consumed largely by Curaçaoans and Bonairans of Dutch descent, Dutch residents or tourists and other western tourists, and far less so by others on the islands. Suffice it to say that raw herring, paired with diced raw onions and gherkins is an acquired taste and this slimy treat is clearly not for everyone. Herring is used in Caribbean dishes, but mostly to enliven the taste of leftovers or otherwise to add flavour to dishes (Mackie 1998).

The story of herring and salt in Bonaire and Curaçao could be seen as a depressing one, one of hard labour, slaves and exploitation, one of a global trade in food that benefitted the few at a cost of many and one of an unequal partnership between North and South that continues to this day. Whatever one's viewpoint, and for the purpose of this chapter, it is also fair to say that without herring, the story of Bonaire and Curaçao would have been a very different one. No herring, no salt, no salt labouring by slaves. Perhaps there would have still been a much longer Spanish rather than Dutch presence in the islands, or at least a much stronger Hispanic legacy. Then, the people of Curaçao and Bonaire would be eating *Locrio de Arenque* or *Arenque Guisado*. As it is now, however, the herring parties mentioned at the beginning of this chapter fit in as a minor and recent addition to this story, with again for some, a too-nostalgic view of a western past. However, it is also worth pointing out that the proceeds of many of the herring parties do go to charities on the islands. In 2019 the Curaçao Lions Club Haring Party benefitted *Fundashon Duna E Mucha un Man*, providing over a thousand breakfasts to primary school children. Proceeds from the 'It Rains Fishes Haring Party' went to the *Fundashon Tabitha Kumi* which provides shelter for women and children in times of crisis, and the Punda Haring Party benefitted the Ahavah Bank, which provides clothing to disadvantaged Curaçaoans. Whether raw herring smothered in onions is to your taste, or you just want to support local charities, if you ever happen to be in Curaçao or Bonaire in June, I invite you (or dare you) to join the local Haring Party. Enjoy!

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CHAPTER 7
LIFEWAYS OF TRADITIONAL FISHERMEN IN DHOFAR, OMAN

by Marielle Risse

Introduction

Most work on independent, full-time fishermen concentrates on two important questions: how much money is made and what kind of fish are caught? I would like to shift the focus to two other questions: how much does it cost to catch fish and how do Dhofari fishermen in Oman use their catches to create a social and religious, as well as monetary, benefit?

Dhofar is the largest governorate (government region) of Oman (Figure 7.1), encompassing 38,300 square miles. The main city is Salalah which is located on a coastal plain; the long, straight beach of the Indian Ocean is the southern limit of the town. About one and a half hours' drive west from Salalah is the border with Yemen. To the north of Salalah is a series of low mountains, then the pure desert, the *Rub Al Khali*, also known as the Empty Quarter, bordering with Saudi Arabia to the northwest. The rest of Oman is to the east/northeast. It is a ten-hour drive across a mostly barren desert plain from Salalah to Muscat, the capital of Oman. Thus, Dhofar is quite separated from the rest of Oman.

Figure 7.1: ▸
Map of Oman, coloured cream, of which the Governate of Dhofar is highlighted in red.

In grey to the west central is the *Rub Al Khali* desert and to the southwest is Yemen

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Map copied from Wikipedia; available at: https://en.wikipedia.org/wiki/Dhofar_Governorate (accessed on 2 July 2024)

There is a line of coastal towns from the westernmost Dhalkut/Dalkut (158 km west of Salalah), Rakhyut (140 km west), Mughsayl (35 km west), Salalah (which incorporates the formerly separate coastal villages of Raysut, Awqad, Salalah, Haffah and Dahariz), Taqa (28 km east of Salalah), Mirabt (70 km east), Sudah (135 km east), Hadbeen/Hadbin (167km east), Hasik (187 km east), Shuwaymiyyah (276 km east) and Sharbithat (369 km east). All the coastal towns have Dhofari fishermen. There are also fishermen who live on Hallaniyah, one of the seven small islands that make up the Hallaniyat group[35] located 40 km off the Dhofar coast east of Hasik.

I have been looking at the theme of generosity, including sharing food, for more than ten years and the information presented in this chapter was gathered from several extensive interviews conducted in the spring and summer of 2021. I have been on over a dozen fishing trips with the Dhofari men in my research group whose first language is Jibbali (also known as Sherat, a non-written Modern South Arabian language); they also speak fluent Arabic. The men in my research group and I have also made many fishing-from-shore excursions. All words in quotation marks are from Dhofari fishermen (translated into English).

I have found no other similar research carried out on the Arabian Peninsula, but there has been work done on the types of fish caught along the Omani coast (e.g., Harrison 1980; McKoy et al. 2009; Al-Jufaili et al. 2010; Choudri et al. 2016) and on how fish are sold (e.g., Lancaster and Lancaster 1995; Omezzine et al. 1996; Omezzine 1998; Siddeek et al. 1999; Al-Marshudi and Kotagama 2006; Al Rashdi and Mclean 2014).

Overview of Fishing

The Dhofari fishing industry is divided into three sectors. The first uses wooden dhows, which are owned by Omanis, but crewed by ex-patriots, who catch sharks, tuna, grouper and other ocean fish. The second sector, my main focus, is run by individual Dhofari men who own or borrow boats and go out full or part-time to fish for sardines, lobster, abalone, squid, tuna and/or other ocean fish, depending on the season. The smallest sector is based on Dhofari men who occasionally catch fish or squid from the shore and/or set fish traps

[35] The islands are also called Khuriya Muriya.

close to the beach (Figure 7.2), and women who collect mussels and *sufela* (abalone) on rocky points in shallow water, usually at low tide.[36]

Figure 7.2: Beach near Hanu, Dhofar

Photograph © Marielle Risse

'Official' (meaning full-time) fishermen make daily decisions about whether to go out fishing and what type of fishing to do depending on the 'weather and season', meaning which types of fish are plentiful. Usually, they do not fish on Fridays, when there is communal prayer around noon. During 2020 and 2021, the mosques in Oman were closed at certain times because of the COVID-19 pandemic, so some men fished on Fridays. Most fishing occurs between September and March as the *khareef* (monsoon) season starts in April and May with the wave-height increasing and the water temperature dropping. In June, July and August, only the strongest and most skilled fishermen can take a boat out. The waves become smaller and the water temperature rises towards the end of August.

[36] There are also a few boats, mainly managed by ex-patriots and attached to hotels, which take tourists on day-fishing trips.

To give an overview of the fishing industry, the following are data from 2020, the most recent yearly statistics collected by the Omani National Centre for Statistics and Information (2022). There were 257 renewed fishing licences out of 4,678 for all of Oman and only five new boat licences.[37] In 2020, Dhofari fishermen landed 86,749 tons.[38]

The Cost of Fishing

The first and most expensive outlay is for the boat. Standard fishing boats are made of fibreglass, painted white with blue or green painted trim around the gunwales. They vary in length from 18 to 28 feet; the 18-, 19- and 20-foot boats are for fishing close to shore,[39] while the 23-, 25- and 28-foot boats are for fishing out of sight of land. If they are well cared for, a boat can last up to fifteen years.

There are two basic types of boats: Yamaha and locally made (Figure 7.3).[40] Yamaha boats need government permission before they can be ordered, take longer to make (3-6 months), must be paid off more quickly and are more expensive. For example, a 23-foot Yamaha boat is 2,000 Omani Riyal (OR) compared with 1,200 OR for a locally made boat.[41] Every boat needs a *malkiy*a (registration card) which is 5 OR.

[37] This is much lower than 2019, when there were 2,424 renewed fishing licences in Dhofar, amounting to 33 percent of 7,266 for all of Oman. There were 324 new fishing licences, 20 percent of 1,607 for all of Oman. There were 998 renewed boat licences, 1 percent of 8,847 for all of Oman and 57 new boat licences, 10 percent of 547 for all of Oman. The low numbers for 2020 are due to government offices being closed or short-staffed during the pandemic.

[38] Please note that there is wide seasonal variation. The Omani National Centre for Statistics and Information has monthly catch data until spring 2021. For example, 7,794 tons were landed in October 2020, 10,653 tons in December 2020 and 5,447 tons in February 2021 (Fisheries 2022).

[39] Oman generally uses the metric system, but different measuring systems are used in fishing. Boats are ordered by 'feet', petrol is measured by 'drum' (8 Omani Riyal for a standard 30-litre petrol can), engine power is by 'horsepower', and the radius of circular sardine nets is by *dhirae* ('arm' in Arabic, from the inside, centre point of right elbow to tip of middle finger on right hand). The depth of water, the size of fish boxes (traps) and the height of a curtain nets is by *ba'* (from furthest edge of left shoulder to tip of middle finger on right hand).

[40] There are three main methods for buying a boat: (1) cash: which could mean loans/gifts from family members and friends that might or might not have to be paid back, and might be paid back in a non-monetary method; (2) private arrangement between buyer and seller: the fisherman takes the boat or engine and promises to pay for it in agreed-upon instalments; (3) bank or 'company': the buyer gives signed cheques with the amount filled in and the bank or company will cash one cheque every month on the agreed-upon date. All types of payment avoid any interest, which is not allowed in Islam. In general, money is required up-front to buy from large companies. For example, Yamaha and Honda ask for two or four cheques, i.e. the buyer pays the total cost within two or four months. Local companies ask for twelve or twenty-four cheques, meaning the cost is carried over one or two years.

[41] One Omani Riyal (OR) is approximately 2.6 US dollars, 1.8 BP pounds or 2.2 Euros. Each riyal has 100 *baisa*.

Figure 7.3: ▸
Locally-made boat set up for net fishing as there are no winch or freezer compartments

Photograph © Marielle Risse

The second expense is the engine which can vary from 15 to 350 horsepower (hp). Engines of 15, 25, 30 and 40 hp are suitable for fishing close to the shore; 60 and 75 hp engines are powerful enough for boats staying within sight of land. However, to go ‘inside the ocean,’ i.e. out of sight of land, the engine should be at least 100 hp or the boat should have two engines, with one at least 60 hp and the other at least 40 hp.

There are two types of engines: 2-stroke, which has a carburettor, needs oil as well as petrol and produces smoke, and 4-stroke, which uses only petrol and is ‘better for the environment’. The cost depends on the size and manufacturer. For example, the price of a Yamaha 25 hp is 700 OR, while a Honda 100 hp is 4,000 OR. Engines are taken off the boat when it is pulled up on shore for repairs or the owner does not plan to go fishing soon; if the boat is used daily, it will be tied up in the water with the engine attached (see Figures 7.4 and 7.5).

Figure 7.4: A variety of boats drawn up on shore with the engines removed as the owners do not plan to use them in the near future

Photograph © Marielle Risse

Figure 7.5: Boats in small bay, ready for fishing trips

Photograph © Marielle Risse

Thus, the price of a boat and engine can vary widely. An 18-foot boat, with a 40 hp engine, set up for throwing nets could cost 3,000 OR, while a 25-foot boat, with a 100 hp engine, set up for throwing boxes could cost 8,500 OR.

With a boat and engine, a fisherman now needs to pay a nominal fee for a fishing licence, which allows the government to keep track of approximate numbers of fishermen. With the licence comes a free safety jacket 'to see from far'.

Approximate Yearly Costs

Basic Costs
There are four basic types of fishing in Dhofar: throwing nets, throwing 'boxes' (fish traps), using live bait and fishing for tuna. One fisherman estimated that a 'good day' of net or live-bait fishing would yield about 700 OR, checking boxes might yield about 150 OR and tuna could be 700-800 OR. For all of these, the basic yearly outlay is about 650 OR. This includes the cost of a GPS satellite navigator, called a 'Magellan' in Dhofar, and a satellite phone. All boats need a pump with battery (bought new almost every year), five or six round cast nets in different sizes for sardines, small nets with wooden handles to scoop fish near the boat, an anchor and rope. Each fisherman needs sunglasses, pants, long-sleeved shirts and knives.

Throwing Nets
Curtain nets are buoyed at the top with empty plastic containers such as laundry jugs and fall straight down towards the ocean floor. Usually, two to four people are needed to drop and haul them back up. Nets are either thrown in the late afternoon/evening and taken up after a few hours or thrown just before sundown, left all night and taken up before sunrise. The total cost approximates 35 OR per day plus 300 OR per year for the season from September until March/April.

Daily costs are 5 OR for petrol for the car to get to the boat and back, 3-5 OR for food and around 20 OR for two or three drums of petrol for the boat. Although the fishermen do not go far from shore, the boat is heavy because of the weight of the waterlogged net, so the engine burns more fuel.

Fishermen usually pay ex-patriot labourers 5 OR per day to check and clean the net on shore.

The yearly costs for the 200-meter-wide nets with a height of 8-12 *ba'* (see footnote 39 above) are 70-100 OR with floats and weights included. Full-time fishermen usually own six or seven nets and buy one or two every year. They also need to buy lights for the boats and themselves (headlamps) as they are often working after sunset.

Throwing Boxes (i.e. Fish Traps)
A full-time fisherman usually has twenty to a hundred 'boxes' (the Dhofari equivalent of fish traps), with fifty being most common, and maximum of a hundred and fifty. They are put in the ocean in September or October and taken out before storms and the *khareef*. If the ocean is calm, it can take about five hours for two people to check fifty boxes. A person working alone can check twenty to thirty boxes in one day (Figure 7.6).

Figure 7.6: 'Boxes', aka fish traps, on a boat

Photograph © Marielle Risse

Using fish traps costs approximately 40 OR per day and 1,200 OR per year. Plus, the boat needs to be set up with a freezer section (*thalaja*), that can cost 100-200 OR depending on its size, and a winch to pull the boxes out of the water, which cost approximately 370-420 OR new and 220-300 OR used.

The daily costs are 5 OR for petrol for the car, 3-5 OR for food and around 24 OR for three drums of petrol for the boat; bait for the traps can cost around 12 OR every day for fresh fish and 5 OR every three or four days for dried sardines.

The yearly costs are for winch batteries, about 50 OR every year, and the boxes. Boxes come in two sizes: 2 1/2 and 3 *ba'*. A new large one is around 30 OR; the smaller size is around 20 OR. The curved, metal mesh top of each box needs to be replaced yearly, but the flat bottom is iron and can be reused. The cost to replace the mesh top for a large box is 16 OR and 13 OR for a small; for both there is an additional cost of 2 OR for the rope and labour to tie the two pieces together.

Live Bait

Depending on the size of the boat, fishermen can go out alone or with several others during the season from September to March/April. Fishermen leave about *fajr* (the first prayer at sunrise), spend two to three hours catching bait (i.e. throwing circular cast nets to catch sardines), spend one or more hours to get to the fishing location, then fish until evening, *maghreb* (the sunset prayer). Using live bait costs approximately 40-75 OR per day, with a set-up cost of 350 OR for two *thalaja* (one for fish, one for bait) which can cost 100-200 OR each depending on size. As the boat will need to go far from shore, the engine must be at least 100 hp.

The daily cost is high and varies widely. In general, the equipment is:

- Line – 10 OR
- Hooks – 2 OR
- Thin sheets of lead to weight the line – 6 OR for 5 kg
- Gloves – 1 OR[42]

[42] Fishermen try to reuse equipment but, for example, knives rust quickly and if the line is pulled against the side of the boat, it must be replaced as it will no longer sink into the deep water smoothly. The equipment is carried in plastic, lattice-sided crates or thick canvas bags.

- Ice is usually provided free the night before by the person who buys the fish;[43] if bought, the cost is nominal, 1 big bag (15 kg) costs 700 *baisa*
- Other costs are about 10 OR per person for food as this type of fishing usually takes all day so breakfast, lunch and cartons of water are needed
- The amount spent on petrol is high, for example 40 OR or more (five drums) as the boat will be heavy from the ice, bait and caught fish
- Some fishermen buy the bait to save time; bait can cost 5 to 50 OR per day depending on the availability of sardines[44]

Tuna

Fishermen will rarely, if ever, go out for tuna alone as they often end up far from land; either there are two or three men in the boat, or a man fishing alone will join several other boats. Men leave at *fajr* to find dolphins.[45] Depending on where the pods are and when they are found, fishermen might return as early as 5 pm or as late as midnight. The tuna fishing season is from the end of January/beginning of February until the end of May. The daily cost is approximately 90 OR per day. A strong engine, at least 100 hp, and a satellite phone are necessary. The main daily expense is for at least nine drums of petrol which usually costs at least 70 OR, sometimes as much as 145 OR if going far into the ocean. The other costs are a heavy line with hooks – 10 OR, heavy gloves – 2 OR, water and food – 10 OR.

Abalone, Lobster and Other Seafood

Only two fishing products are regulated by the government to ensure sustainability: abalone and lobsters. The abalone season changes from year to year; it is usually a week to ten days in November or December but the government will only open the season if the abalone are plentiful. Lobster season is from the beginning of March to the end of April. There are 'ocean police' in boats and on land with binoculars occasionally checking to make sure these are not harvested out of season.

[43] Fishermen have long-term relationships with one buyer as explained below.

[44] Sardines for bait come in bags of three or four kg, which are approximately 1 OR when they are plentiful. A large plastic 'pan' (bowl) is 5 OR in season, 25-30 OR out of season.

[45] As tuna are found by locating feeding dolphin pods, men will tell each other where they see dolphins. There is never an attempt to hide information about where fish are in order to maximize personal benefit.

Abalone season costs about 300 OR for accommodation and food near the abalone beds and 10-15 OR daily for petrol and food. Lobster season costs about 150 OR for special lobster nets which have thicker rope than fish nets and cost about 55 OR each. The daily costs of approximately 25 OR for petrol, food and net repair.[46]

Squid can be caught at any time but are most plentiful in the *khareef*. They can be caught from shore or by boat with hooked lures. Octopus are sometimes caught in traps or speared while diving but they are not commonly eaten. Sometimes small ones are sold ad hoc to restaurants.

Results of fishing: how fish are distributed

As explained in *Foodways in Southern Oman* (Risse 2021), there has been long-term food trading/bartering and gifting for centuries between friends, families and tribes who inhabit the different geographic areas of Dhofar. These exchanges have continued up to the present day as many families in the main city of Salalah have relatives who live in the mountain, coastal or desert areas and engage in regular, often very uneven, exchanges of foodstuffs and prepared food.

For example, a fisherman might distribute fish free of charge to relatives and neighbours for years, without any attempt to figure out the worth of what is given or expecting any kind of repayment. The people who receive the fish might unsystematically give back a bottle of local honey or some frankincense or some meat from a slaughtered goat, cow or camel; or they might give some prepared food, such as goat, cow or camel milk or clarified butter; or, they might give some fruit, such as bananas or limes and/or some vegetables such as sweet potatoes.

There are commonly held traditions and norms that underlie how a catch is divided and fish are given away. Firstly, the fishermen take some fish for individual use, then sell the rest. With the money, they initially pay costs and then divide the remainder equally among whomever is on the boat. For example, if four men caught 120 kg of fish from throwing nets, each man would keep about 5 kg for 'the house' (meaning for their family or to give

[46] As lobster nets touch the ocean floor, they are often caught and torn on rocks meaning there are high repair costs.

away) and sell the remaining 100 kg. From the cash for the 100 kg, they would first pay for all their expenses, such as fuel and food, then divide the rest equally between them.

Secondly, fishermen make decisions based on price which can vary widely depending on scarcity and demand. As one interviewee told me: ‘it depends on the price, if the price is very low, I won’t sell, I will give away. If a fish is 800 *baisa* a kilogram, I sell it; but if it is 400 *baisa*, I give it away’. Having a low price is not seen as a problem as ‘sometimes it's better to have a low price and not sell, you might remember someone you have not seen for a long time and help them’. Fishermen also make decisions based on size; for example, ‘if you get 150 kg of fish, the bigger ones are sold and the small ones are kept for the house, because the smaller taste better’.

Lastly, fishermen make decisions based on social norms of generosity. As one informant told me: ‘never give a little’, for example, ‘not one lobster, give a *kees*’. A *kees* is a plastic bag, so this means a fisherman should give a bag full of lobsters, not a single lobster. Also, the norm is that if a person approaches a fisherman while he is unloading his boat and asks to buy fish, the person should be given enough for a dinner for a few people for free, but if he asks for a large amount (more than 3 kg), then it is acceptable for the fisherman to ask for payment.

The result is that, for example, if a man has ten fish, he might sell five, give one to an ex-patriot worker who cleans his boat, one to a neighbour, one to a cousin and keep two for ‘the house’. Thus fishermen, like most Dhofaris, continually make choices about whether to use a foodstuff for themselves, sell it for cash or give it away, which results in social credit, not only for the fisherman himself, but for his entire family. The generosity has an economic component by attaching his family to interlocking kinship and friendship networks of exchange in foodstuff.

In giving away fish circumspectly, the fisherman is also performing *sudaka*, a voluntary charity which is given to people who are in need, usually poorer members of one’s extended family.[47] *Sudaka* creates *hasanat*, an undetermined/undeterminable religious benefit that accrues to the giver

[47] This is different from *zakat*, which is the mandatory giving away of a portion of one’s possessions and savings.

when they are charitable without telling anyone about the donation and/or asking for recognition from the receiver.

The ubiquity of practising *sudaka* is part of the reason that it is impossible to tell how much a fisherman earns. For example, one of the Dhofari men in my research group might tell me that he made 100 OR from that day's fishing, but I know that that does not reflect the total value of the catch. It reflects his profit (total revenue minus costs), not counting the worth of the fish he has given away. To get the actual value of a catch is nearly impossible as the fish that are saved for the family or given away are never weighed, so there is no accurate assessment of the total cash value. One fisherman estimated that the actual landings of fish are twice as high as the official count because so many fish are given away before being sold, hence never weighed or counted.

Cultural Perceptions of Fishing

One fisherman told me: 'there is no daily system' in Dhofar. A man (X) might have a boat set up for throwing boxes and go out often with one friend (Y) who has his own set of boxes but does not own a boat. But X might sometimes go in a brother's boat to throw his brother's nets, and with another friend (Z) to catch tuna in Z's boat. These sorts of decisions are often made the night before, either by calls or a man joining friends and relatives 'on the beach', meaning sitting on mats near the ocean in the evening after dinner. The fishermen gather in groups to drink tea, discuss the day's catch, compare fish prices[48] and make plans for the next day.

The fishermen understand that in other parts of Oman, the boat owner will automatically be given two shares, i.e. when the profit is divided the boat's owner is treated as if he is two men. In Dhofar, if there are four men with a profit of 100 OR, each will take 25 OR. However, if the boat needs repairs, that cost will be taken out of the daily profit before the money is split.

Another example of this pattern is that in the abalone season, brothers and friends will go together in one boat. If the boat owner does well in diving

[48] Fish buyers are usually middle-men, consolidating the catch from many fishermen and selling on to wholesale companies. As they work independently, fish buyers can sometimes give slightly different (100-200 *baisa*) price-per-kilogram to fishermen.

(i.e. finds many abalone), he will refuse to accept any payment for the petrol and food. But if the owner does not have a good catch, the men will collectively swear that he will accept their help to cover those expenses.

Similarly, older men will pay for the accommodation during the abalone season when men rent apartments or camp near the good diving areas. It is accepted that young men who are learning to dive do not pay anything. The compensation of paying is sometimes *sudaka*, as explained above, as well as the social recognition as an established, experienced, older man who takes care of younger generations.[49]

Given that boat owners and older men willingly pay the daily costs and give advice, there are no barriers to entry into fishing. Although fulltime fishermen see that ocean fish stocks are declining, if a young man would like to start, he will be allowed to join in fishing trips, given guidance, etc. One issue that arose during interviews was a desire for a type of guild (my term, not theirs) to improve self-regulation. For example, setting yearly dates to start and end throwing nets and setting boxes because many fish are needlessly killed in nets and boxes that were left in the water and taken away by storms or the *khareef*. There was also the suggestion to regulate the number of boxes each fisherman could have (for example, a maximum of forty) and that dhows should not be allowed to throw nets near the beach in *khareef*. Lastly, there was a desire for a set price for each type of fish so that there were not large fluctuations; for example, fishermen can be paid between 700 baisa to 1,200 OR per kilogram of tuna. The suggestion is that the government would invest in large freezer storage containers and look for external markets. Thus, over-supply would not drive the price down as the excess would be frozen and sold abroad.

Men usually begin by joining one or more groups of fishermen on the beach as explained above, asking questions and going with experienced men. This informal apprenticeship usually lasts about a year so that the beginner can see all the seasons and learn about all the types of fish, then he might consider buying his own boat.

[49] Another example of the ad hoc, non-formalised conventions of fishing, is that most men do not have a written contract with their fish buyer even if they work together for years. Each fisherman and buyer set up the relationship as they see fit. For example, some settle up daily, some weekly and sometimes the fishermen will sell without taking the payment so that the buyer will hold onto the money like a bank. Or he might take a non-interest loan from the buyer in order to buy a boat or engine.

Men I have interviewed see no drawbacks to fishing. A man who is fishing will be out of the house early in the morning, might not return until sunset or later and will not be available to help with daily tasks such as buying supplies and taking female relatives to make visits. But, as they explained to me, 'brothers will help'. Given that married brothers often live in the same house as their parents, each member of the household contributes in different ways. The fishermen give food and cash to pay for supplies; other brothers will do the work of bringing food, gas canisters, jugs of water, etc., to the house.

The fishermen perceive the benefits as the cash they accrue to cover personal and household expenses and repay loans, as well as being able to supply their houses, neighbours, relatives and friends with food. This last benefit extends to the family. For example, a man who gives away fish will be perceived as generous, thus having social capital from an etic point-of-view. They also mention that fishing is healthy, with lots of exercise and fresh air, and that they 'always have new experiences' in travelling to new places and seeing different vistas every day.

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CHAPTER 8
PLENTY OF FISH IN THE SEA? WHY VARIETY MAY BE THE SECRET INGREDIENT TO SUSTAINABLE SEAFOOD

by Christina O'Sullivan, Lia ní Aodha and Lucy Antal [50]

Introduction

Consumption of food from the sea is on the rise (Figure 8.1). On the one hand, eating seafood – rich in essential micronutrients difficult to obtain elsewhere in our diets – is good for our health and is posited as key to ensuring future global food security.

Figure 8.1: Atlantic cod (*Gadus morua)*

Photograph © Frédéric Duhart

On the other hand, climate change, as well as decades of mismanagement and overfishing mean that many wild-fish populations are under stress. Moreover, the complexity of fisheries policies, alongside the rapidly shifting status of different fish stocks and the opacity of fish supply chains, means that assessing sustainability is challenging for the average shopper looking for their fish dinner. Research suggests many may even be unaware that much of the fish they buy today is, in fact, farmed.

[50] All authors contributed equally to this chapter.

In this chapter, we first discuss the increasing role of aquaculture (i.e. the farming of aquatic animals) in terms of providing us with the fish that we eat. Secondly, we highlight some of the challenges surrounding the farming of our most frequently consumed species. More specifically, we detail some of the stark socio-ecological inefficiencies surrounding the intensive production of farmed salmon, using Scottish salmon and its diet of wild fish as an example. In turn, we make the case for a different – more extensive, diverse, community-based form of aquaculture – which we argue, if coupled with some changes to the wild fish species that we eat, could provide the key to a more sustainable diet.

The rise of farmed fish

Globally, fish provide more than 3.3 billion people with 20 percent of their average per capita intake of animal protein, with this figure reaching 50 percent or more in several coastal and island states in the Global South (Food and Agriculture Organization 2022). Reflecting this and policy initiatives geared at increasing fish consumption over the past six decades, global fish consumption has increased at an average annual rate of 3 percent – a full percentage point higher than that of all other animal protein (meat, dairy, milk, etc.) over the same period (Food and Agriculture Organization 2022). Not just an important source of protein, seafood also contains several vitamins, minerals and essential fatty acids not easily obtained in land-based foods. In this respect, narrowing in from the global level, in the UK the National Health Service (NHS) tells us that a healthy balanced diet should include at least two portions of fish per week, including one of oily fish. Mirroring global trends, fish consumption has risen in the UK since the 1980s. Since 2007, however, this has reversed and today UK consumers, eating an average of 152.8g of fish per person per week, only consume around half of the amount of seafood currently recommended by health professionals (Seafish 2020).

Not just a question of quantity, in line with the NHS's recommendation, the type of fish we eat matters too. In this regard, the past decades have also seen a change in the types of seafood eaten by UK consumers – in terms of a shift away from traditional wild-caught, whitefish species such as cod and haddock towards farmed species like salmon and warm-water prawns

(Seafish 2020). Today farmed seafood dominates seafood retail sales in the UK, currently making up 55.4 percent by value and 38.2 percent by volume of the UK's top five best-selling seafood species (Seafish 2020). The choice of species most commonly eaten by UK consumers remains narrow, however, and centres on five main species – cod, haddock, tuna, salmon and prawns, all of which (apart from prawns) are 'high trophic' species (i.e. high up in the food chain) (Seafish 2020).

That salmon and prawns are farmed will likely come as a surprise to many consumers, the packaging of salmon often includes images of pristine lochs with no farms in sight. A survey carried out by Fidra, published in March 2022, revealed that only 6 percent of UK consumers are aware that the Scottish salmon sold in the UK's supermarkets is farmed (Fidra 2022) (Figure 8.2). Today, 99 percent of all Atlantic salmon on sale is farmed (Jacquet et al. 2017). Aquaculture, generally, accounts for more than half of all fish and seafood consumed globally (Cottrell et al. 2021; Food and Agriculture Organization 2022). And with an average annual growth of 5.8 percent between 2000-2010, and 4.5 percent between 2011-2018 (Food and Agriculture Organization 2022) the sector is now the world's fastest-growing food production system. Current predictions indicate that by 2030, 60 percent of the fish consumed by humans will be provided by aquaculture (Ghamkhar and Hicks 2020).

Figure 8.2: Farmed salmon on sale in Tesco July 2023

Photograph © Helen Macbeth

What does a farmed salmon eat?

Consumers might be even more surprised to learn that farmed salmon are fed on hundreds of thousands of tonnes of wild fish, harvested and turned into fish meal and oil[51] Most of these fish are food-grade species that could be eaten directly by humans instead and are frequently caught off the coasts of food-insecure countries in the Global South. Diaba Diop, President of the Réseau des Femmes de la Pêche Artisanale du Sénégal (REFEPAS), an organisation that represents women fish processors and traders, warned 'our survival depends on our ocean' (Feedback 2022) (Figure 8.3).

Figure 8.3: Women fish processors in Senegal warn about the negative impact on their coastal communities:of producing fishmeal and fish oil

Photograph © Feedback, reproduced here with permission.

Fuelled by the aquaculture industry's rapid growth over the past two decades and consequent demand for raw materials, fish for feed are increasingly caught off the coast of West Africa, where there is also evidence that the impact that this is having both on livelihoods and on food security is rising in a region where these fish are an irreplaceable and affordable source of protein and nutrients (Tacon et al. 2013).

[51] Fidra's (2021) survey also revealed UK consumers are lacking knowledge of the environmental impacts of Scottish salmon farming (Fidra 2022).

Marketed to high-end consumers in the Global North as a rich source of important vitamins, minerals and fatty acids, which it is, Scottish farmed salmon is especially dependent on wild-caught fish for feed. In 2014, the production of 179,000 tonnes of Scottish Atlantic salmon required fish oil derived from 460,000 tonnes of wild-caught fish, 76 percent of which were species that are edible by humans (Willer et al. 2022: 3). An important point to note is that according to Willer et al. (2022), many of the small wild fish (herrings, sprats, sardines, anchovies, etc.) fed to farmed salmon have even higher concentrations of key micronutrients than the salmon they feed; on examining 'micronutrient flows (the transfer of micronutrients from feed to fish) in Scotland's farmed salmon industry, which is particularly reliant on marine feeds' they found that only '1– 49% of essential dietary minerals and fatty acids available in wild fish are retained in farmed salmon' (Willer et al. 2022: Abstract).

This begs the question, from a nutritional perspective: what if we were to eat these small fish instead? A study recently published by Feedback, alongside scientists from Cambridge, Lancaster and Liverpool Universities (Willer et al. 2022) indicates that allocating 'feed' fish for human consumption could reduce pressure on wild-fish stocks and at the same time increase seafood production.

Focusing on Scotland's salmon industry specifically, the third largest worldwide and the UK's largest food export by value, this research looked at the transfer of micronutrients from the wild fish fed to farmed salmon and found that more than half of these, in some cases up to 99 percent, are lost when eaten by salmon (Willer et al. 2022). In other words, farming salmon, from a nutritional perspective, is an inefficient way of delivering required micronutrients to human diets.

To 'imagine otherwise' the researchers (Willer et al. 2022) developed alternative production scenarios whereby farmed salmon were only fed using fish by-products (i.e. heads, bones and other trimmings) and then more wild-caught fish, mussels or carp were added to the study for human consumption. According to the analysis, all alternative production scenarios compared to the current status quo produced more seafood, that was more nutritious than farmed salmon and left 66-82 percent of feed fish in the sea. These alternative scenarios for Scotland were next applied on a global scale. One scenario showed that farming more carp and less salmon, using only feed from fish by-products (Figure 8.4), could leave 3.7 million tonnes of wild fish in the sea while producing 39 percent more seafood overall. These findings show that salmon farming, in its current form as an example of fed aquaculture, is not only an inefficient way of producing food, but also irrational from a social and ecological standpoint – in terms of human nutrition and food security, placing unnecessary pressure on fish stocks, and overall fish production.

◂ **Figure 8.4:** Fish heads, which along with other bones and trimmings can be used to create feed for fed aquaculture.

Photograph © Frédéric Duhart

Go Big or Go Home: Transitioning to community-owned aquaculture

Going beyond health advice, and in line with the research discussed above, in terms of sustainability the NHS (2018) states: 'To ensure there are enough fish to eat now and in the future, we should try to eat a wide variety of fish and to buy fish from sustainable sources'. Those sources will undoubtedly include farmed species. Thus, here we make the case for the expansion of a different form of aquaculture, which we argue, if coupled with changes to the wild-fish species we eat, could indeed provide the key to a more sustainable, equitable diet.

Although the farming of aquatic species has been around for thousands of years, historically the practice has been dominated by extensive systems sometimes supplemented with agricultural by-products. In more recent decades, however, there has been a trend toward intensification – it was only in the 1980s that shrimp and salmon became the first mass-produced and widely traded farmed aquatic foods (Henriksson et al. 2021). Our example of Atlantic salmon farming, for instance, constitutes one of the most homogeneous and intensive aquaculture practices (Henriksson et al. 2021). Since the 1980s, and despite repeated calls for aquaculture to focus on lower trophic species (i.e. species further down the food web) requiring little feed (e.g., carp, mussels, seaweeds), fed aquaculture (that requires inputs such as wild fish for feed), for instance salmon farming, has outpaced non-fed aquaculture (Jacquet et al. 2017; Henriksson et al. 2021; Food and Agriculture Organization 2022).

Every year around 20 percent of capture fisheries in marine waters (in 2020 this equated to 16 million tonnes of fish) is used to make fishmeal and oil (Food and Agriculture Organization 2022), the bulk of which goes to producing feed for the aquaculture industry. While the proportion of fish meal and oil in aquafeed has been decreasing, total use in volume terms has continued to grow due to the overall increase in global aquaculture production (Ghamkhar and Hicks 2020). Given the rapid expansion of aquaculture and the fish farming industry's growth ambitions, there is little to suggest that the world's seas will be able to keep up with this demand for wild fish for feed. Some authors have gone so far as to argue that, with aquaculture, we are currently witnessing the fastest and most poorly thought-out expansion of domesticated animals ever to occur (Jacquet et al. 2017).

But what if we shifted our focus beyond the quantity and types of seafood we eat and looked at the way it is produced? Similar in more ways than one, our industrial food system is increasingly controlled by a small number of food corporations. Aquaculture food systems are no different. To return to our example, after years of consolidation, the Scottish farmed salmon industry is dominated by six companies. Scottish in name only, five of those are foreign-owned. In our current framework of progress, measured as growth and maximising profit, the answer often resides in the phrase: '*Go Big or Go Home*.' As others have argued before us, driven by this imperative, industrial aquaculture poses many of the same socio-environmental risks as land-based food systems, yet because the expansion of aquaculture, though rapid, is still in its infancy, there is a chance of doing things differently, to avoid these risks (Jacquet et al. 2017).

Merseyside Mussels?

What then if instead, we went small, local and community-focused? To investigate this here we suggest a (still imaginary) pilot project called: Merseyside Mussels (Figure 8.5).

Figure 8.5: ▸ Cornish Mussels – we are proposing Merseyside Mussels

Photograph reproduced under Creative Commons license

It has been highlighted elsewhere that a key goal of aquaculture development should be to create species- and nutrient-diverse food sources that are accessible to and appropriate for people across regions and economies (Cottrell et al. 2021). Existing research indicates that one of the strongest potentials in terms of sustainable aquaculture lies in the cultivation of bivalves (e.g., mussels, oysters, etc.). According to researchers, bivalves may contribute substantially to food security by providing a relatively low-cost and thus accessible food source, on account of their high production, and low-cost potential compared to finfish (e.g., salmon) production (Costello et al. 2020). Today, despite the promise that production of bivalves might achieve, they make up increasingly less of total aquaculture production. In the 1980s, they accounted for almost half of global aquaculture, whereas now the proportion is closer to 30 percent because of the rapid expansion of finfish farming (Jacquet et al. 2017).

Originally a fishing village, the Liverpool city region is a coastal city that has always been defined by its relationship with the sea (Wessex Archaeology Society 2006). Yet, today there is no fishing industry and no thriving seafood culture in Liverpool. The coasts were once brimming with oysters, mussels, cockles (Anon. 1777: 97-100)[52] and even salmon. However, the significant pollution of Liverpool's waterways from industrial sources during the nineteenth and twentieth centuries halted production of marine resources in two ways: it destroyed the native oyster beds while also preventing the surrounding culture and knowledge from being passed down through the generations. While the pollution has since been cleaned up, that part of Liverpool city region's culture and knowledge tragically remains lost at sea. Exporting food production also means exporting jobs and expertise.

Imagine, however, a future in which Liverpool's oyster beds are community-owned assets, with carefully cultivated mussel and seaweed farms providing vital micronutrients (e.g., Vitamin D, Omega-3, Zinc, Iodine etc.) (Feedback 2020). We need to start revitalising the city's lost seafood heritage, restoring the native oyster beds, and exploring the feasibility of small-scale mussel, oyster and algae farming which researchers of 'future foods' have shown will be critical in ensuring that nutritional needs are met within environmental and climate limits (Parodi et al. 2018).[53] Surely, we wish to revive and update our seafood culture for the twenty-first century and beyond, not just in Liverpool, but in maritime cities elsewhere where similar opportunities exist.

We draw inspiration for our vision from existing examples such as Billion Oyster Project which is restoring New York Harbour's oyster reefs in collaboration with the city's communities. Since 2014, that project has

[52] Reports suggest that there were several species produced, but these may be poorly defined; *Mytilus edulis* would be the most prevalent mussel species. There are two species of oyster usually mentioned, the native *Ostrea edulis* (you might have guessed that edulis just means edible) and the pacific *Crassostrea gigas*. In UK there are today a lot of species of clams farmed and 'natural'; our native species is *Tapes decussatus*. If we are talking about molluscs, Liverpool Bay is famous for its cockles, *Cerastoderma edule* (there's that root again), but there are at least two other species 'common' in the UK, the prickly cockle, *Acanthocardia echinate* and the Lagoon Cockle, *Cerastoderma glaucum*.

[53] According to Cefas (2019) the waters off Liverpool would be suited to such cultivation.

supported the restoration of 75 million live oysters, collected 1.9 million pounds of shell (diverting these from landfill to be used to grow new oysters on) and engaged more than 8,000 New York students in the project. Closer to home, the Essex Native Oyster Restoration Initiative (ENORI) with its aim of restoring living oyster reefs to Essex waters, is a collaboration between oystermen, policymakers, conservationists and academia. They list the creation of a 2 km^2 Restoration Box for that specific purpose as part of their achievements. Alongside this, the initiative has helped in the establishment of the first UK network for the restoration of native oysters. Similarly, the Wales Native Oyster Restoration Project, a four-year project being led by Natural Resources Wales and administered by the Welsh Government is looking into the feasibility of restoring native oysters in the Milford Haven waterway. These are just a few examples of the initiatives that such a pilot for Liverpool and elsewhere might look to for inspiration.

For Liverpool, we have a vision of hundreds of food-related enterprises forming a network across the region, connecting sea and land – growing, processing, repurposing and selling food, as well as creating thousands of opportunities for local people to reconnect with their food; where it comes from and how we use it. Such a network would form the deep roots of a regional food economy for the Liverpool city region, one that stretches from the peri-urban and rural hinterland through the heart of the city, to the docks and the sea beyond. It would draw on old and new technologies to grow the food that is good for people in ways that are also good for nature: small-scale, mixed agriculture, agro-ecology and innovative new approaches, such as the multi-trophic aquaculture of 'future foods' such as mussels and seaweed. Our ambition is great!

Conclusion

As we have discussed in this chapter, seafood consumption is increasing. It is good for our health while having the potential to provide a more sustainable source of food for a growing population. However, relying on the sea for food for the future is not without challenges. Climate change and heavily exploited fish populations mean that how we go about obtaining and producing food from the sea will matter a great deal – both to the fish and to people. Much of the seafood we eat today is farmed. And while aquaculture is not a new way of producing food – far from it – the sector's ongoing expansion, though rapid, means there is a chance here to get things right, to learn from mistakes on land and past mistakes at sea and to learn from our existing industrial food model.

Here we have highlighted some of the social and environmental consequences of farming carnivorous fish, using salmon farming as an example. As an alternative, we have proposed an early outline of our vision for a more sustainable form of aquaculture that does not increase pressure on wild fish populations and is grounded in a locale, in a community and in a wider, more networked food system that works for people and nature. The important point is that out there in the sea there are still plenty of fish if we use them wisely.

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CHAPTER 9
SUSTAINABLE FISH FOR FOOD

by Kieran Magee and Iain Young

Food security

The world faces the grand challenge of producing sufficient food for a rapidly growing population estimated to reach nine billion by 2050 (Sanyal 2011). It is generally accepted that food security comprises four main issues: availability, access, utilisation (the body's ability to metabolise food) and stability (Lawrence and McMichael 2014). In this chapter we consider whether the production of fish for human consumption can address these issues to improve food security. Aquaculture is more sustainable than production of conventional agricultural species: fish are very efficient protein converters (Austreng 1994; Tolkamp et al. 2010). However, as we will explain, aquaculture does rely heavily on feed ingredients from capture fisheries.

Animal protein in the human diet

Meat has been an important part of human diet for at least 1.5 million years (Domínguez-Rodrigo et al. 2012). The livestock sector (Figures 9.1 and 9.2) uses a huge land area: up to 30 percent of the ice-free land surface of the

Figure 9.1: Beef cattle in their winter barn feeding on a mixture of (grass) silage and grains grown on the farm

Photograph © Helen Macbeth

earth, and uses one-third of the global cropland as a feed source (Figure 9.2) and one-third of the planet's freshwater supply (Herrero et al. 2013). In 2014 the estimated global livestock population was 1.43 billion cattle, 1.87 billion sheep and goats, 0.98 billion pigs and 19.60 billion chickens (Robinson et al. 2014). In 2021 the total agricultural area in the UK was approximately 18.4 million hectares of which 17.2 million hectares (93 percent) was utilised, termed the Utilised Agricultural Area (UAA) (Department for Environment 2023).

Figure 9.2: Cattle feeding on grassland in Oxfordshire

Photograph © Helen Macbeth

The UAA consists of arable crops, horticultural crops, uncropped arable land, common rough grazing, temporary and permanent grassland and land used to raise outdoor pigs. Woodland and other non-agricultural land is not included. Of the UAA, the total cropable area was 6.1 million hectares, just over a third of the UAA with almost two thirds grassland or grazing: 10 million hectares (58 percent) permanent grassland and 1.2 million hectares (7 percent) rough grazing. The livestock maintained on the UAA is made up of cattle (9.6 million), sheep and lambs (33 million), pigs (5.3 million) and poultry (190 million) (Department for Environment et al. 2014; Department for Environment 2023). It has been estimated that global food production must increase by up to 70 percent to meet demand by 2050; an extra one billion tons of cereal and 200 million tons of meat (Food and Agriculture Organization 2009). With 93 percent of the total land area in the UK already utilised, it is difficult to conceive where these additional crops will be grown, and livestock will be raised.

Fish are a highly nutritious source of biologically high-value protein which also provides vitamins: A and B3 (nicotinamide), B6 (pyridoxine), B12 (cobalamin), E (d-tocopherol) and D, and minerals including calcium, iodine, zinc, iron and selenium. Oily fish like the European anchovy (*Engraulis encrasicolus)*, Atlantic mackerel (*Scomber scombrus*) (Figure 9.3) and Rainbow trout (*Oncorhynchus mykiss*) are a rich source of omega-3 polyunsaturated fatty acids linked to many health benefits in humans (Food and Agriculture Organization 2014).

Figure 9.3: Helford Mackerel (*Scomber scombrus*)

Photograph credit: Podknox, licensed under CC BY 2.0.

Global fish consumption is increasing. In just over 50 years, from 1960 to 2012, consumption almost doubled from 9.9 kg per capita to more than 19 kg per capita (Food and Agriculture Organization 2014). Fish consumption is dependent on many factors: availability and cost, variety of alternatives, income of the consumer, taste preference, health choices and knowledge; and it varies drastically between cultures and countries, from less than 1 kg per capita per year in landlocked countries such as Afghanistan, Tajikistan and Ethiopia to over 80 kg in Iceland, Faroe Islands and the Maldives (Food and Agriculture Organization 2022). The world total consumption of fish and seafood was 158 million tonnes with a per capita average consumption of 20.5 kg/capita/year (Food and Agriculture Organization 2022). Figure 9.4, FAOSTAT (2015) and Food and Agriculture Organization (2017), from which sources consumption data were collected, provide data for total fish and seafood. These consist of figures for freshwater fish, demersal fish, pelagic fish, marine fish as well as cephalopods, crustaceans, molluscs and other invertebrates.

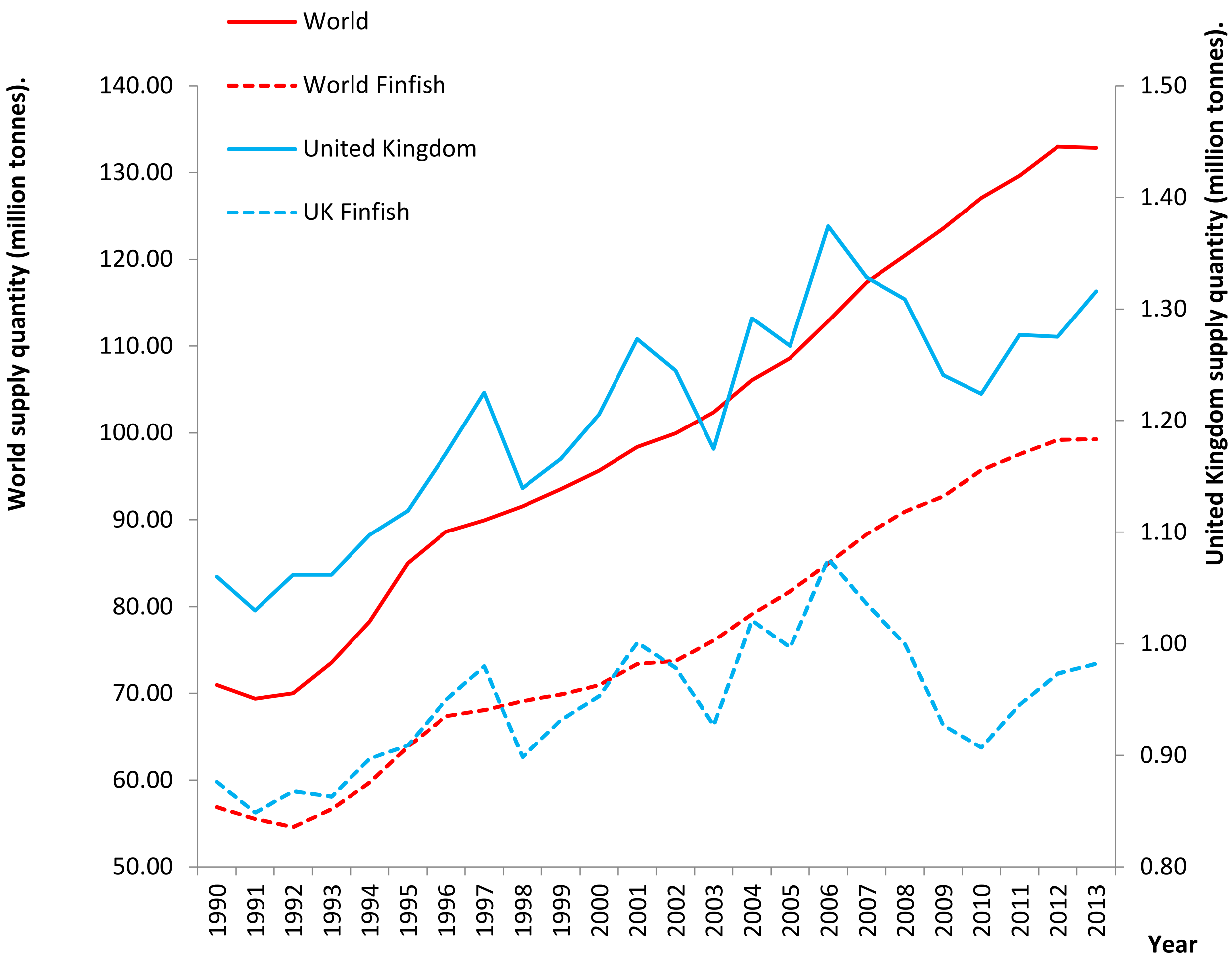

Figure 9.4: United Kingdom and World total quantity (million tonnes) of fish and sea food supplied annually for consumption between 1990 – 2013

Data collected from FAOSTAT (2017)

In the UK fish and seafood are consumed in lower quantities than terrestrial animal protein sources. Figure 9.5 (FAOSTAT 2017) shows the average annual increases in world consumption of traditional terrestrial animal protein sources between 1990-2013: bovine meat (0.81 ± 1.26 percent per annum), pig meat (2.18 ± 1.49 percent per annum) and poultry meat (4.28

± 1.4 percent per annum) compared to the consumption of fish and other seafood products, which has increased at an average rate of 2.78 ± 2.13 percent per annum. Over the same time period, finfish[54] consumption increased by 2.47 ± 2.2 percent per annum. Global fish and seafood consumption has now reached 158 million tonnes (Food and Agriculture Organization 2022) a little less than half the terrestrial animal protein consumption of 357 million tonnes (Ritchie et al. 2017).

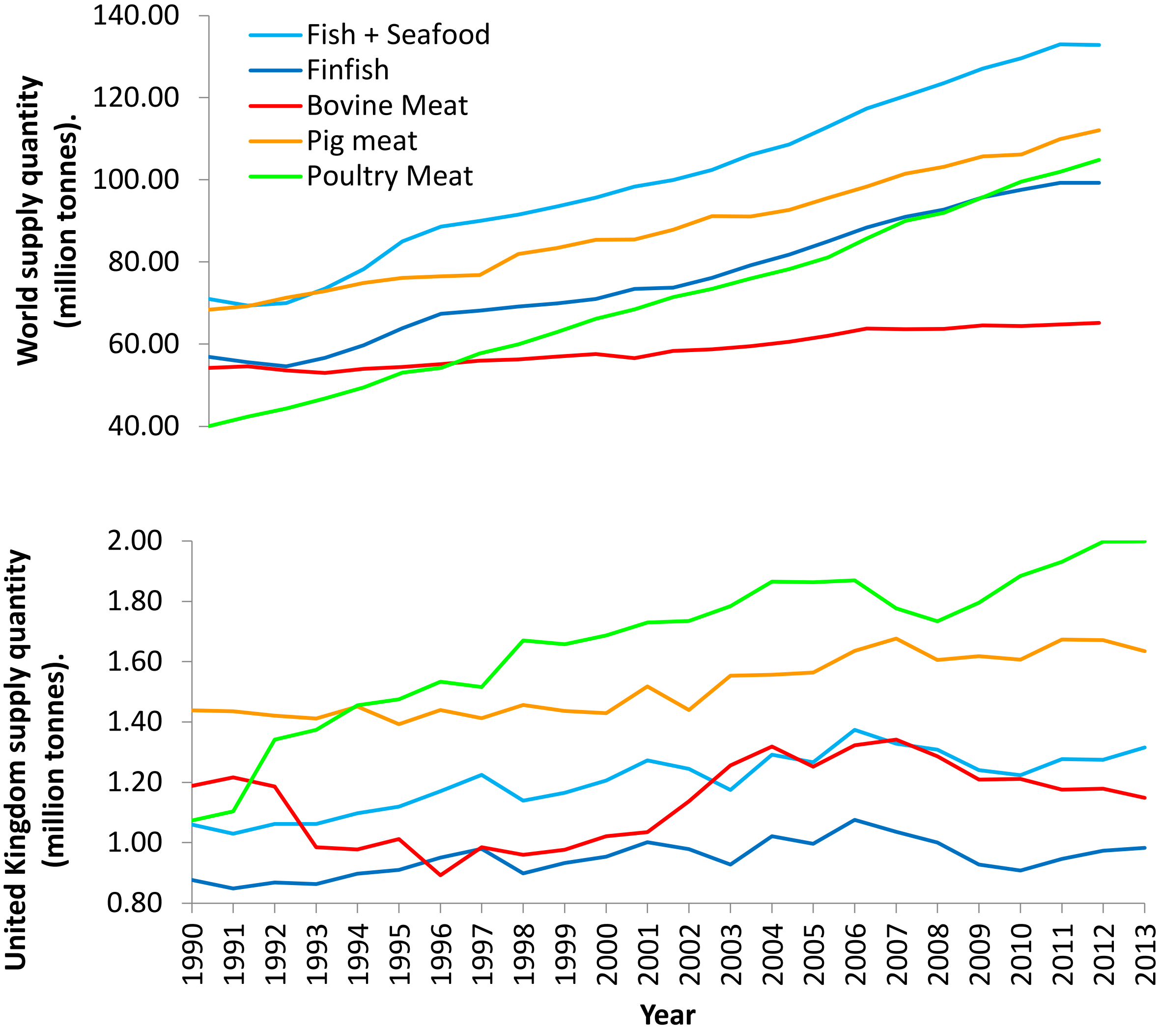

Figure 9.5: Annual world (top) and United Kingdom (bottom) consumption quantity (million tonnes) of traditional terrestrial animal protein food sources compared with fish and sea food including finfish since 1990.

Data collected from FAOSTAT (2017)

[54] Finfish meaning true fish and not other seafood such as shellfish.

In China, over the last 25 years, there has been a dramatic increase in meat production, almost doubling from 45 million tonnes in 1995 to 78 million tonnes and 91 million tonnes in 2020 and 2021 respectively (with the impact of the COVID-19 pandemic possibly precipitating a dip in the rate of increase of production in 2020). China produced close to 60 million tonnes of seafood from capture fisheries and aquaculture.

Animal protein conversion

The feed conversion ratio (FCR) indicates the efficiency that an animal converts feed into meat or other desired product. An FCR of 1.0 indicates that 1 kg of feed is required to obtain 1 kg of product (e.g., meat) – the lower the value, the higher the efficiency. For animal protein production the aim is usually to optimise muscle growth. The FCR of an individual animal is limited by both physiology and feed quality. Fish generally have low FCRs, below 1.0 in some species – this is likely because FCR is calculated using the dry weight of the feed and feed usually contains around 10 percent moisture, whereas the 'product' in fish is 75 percent moisture (Boyd et al. 2007).

The average FCR for beef cattle is very high at about 7.5, for pigs the value is about 2.5 and for poultry (broiler chickens) about 1.7 (Tolkamp et al. 2010). The fact that fish are 'cold-blooded' and do not consume energy to maintain their body temperature as mammals do reduces their energy consumption and lowers their FCR (Pillay and Kutty 2005). Fish are generally, therefore, more efficient at converting protein with FCRs of approximately 1.2 for farm raised Atlantic salmon (*Salmo salar*) (Austreng 1994) and some studies reporting even lower values: 1.04 (Mørkøre and Rørvik 2001), 0.88 (Einen and Roem 1997) and 0.76 (Hevrøy et al. 2004). FCRs of around 0.9 have been reported for Rainbow trout (*Oncorhynchus mykiss*) fed on high quality feed (Kheyrabadi et al. 2014). Rainbow trout raised at 9.10 ± 0.85^{o} C have a lower FCR (1.51 ± 0.19) than those raised at 15.00 ± 0.50^{o} C (1.85 ± 0.11). The proportion of protein in the diet and how much of it can be utilised by the animal (availability) can cause even greater differences in FCR (Karabulut et al. 2010). FCRs for carnivorous species of fish are generally lower than those recorded for omnivorous or herbivorous fish ranging from 4.76 (Kiaalvandi et al. 2011), 1.46 (Cremer et al. 2002) to

1.43 ± 0.03 (Przybyl and Mazurkiewicz 2004) for Common carp (*Cyprinus carpio*) (Figure 9.6).

Figure 9.6: Common carp (*Cyprinus carpio*)
in an aquaculture setting showing a strong feeding response

Photograph © Iain Young

Environmental Impact

Animal production can be assessed in terms of environmental impact during the life cycle of an animal or in terms of the final product. Life cycle assessment (LCA) is a standardised, internationally recognised method of evaluating environmental impact (International Organization for Standards 2006). We have used 'attributional LCA', which calculates current environmental impacts based on past averages to compare the efficiency of animal protein production processes (Samuel-Fitwi et al. 2013a). LCA is commonly conducted 'from cradle to farm gate' but should ideally extend to the final product and include waste disposal ('from cradle to grave') evaluating all inputs, outputs and other impact factors. Product inputs include all resources used for rearing the animal, including growing food crops, land, water and energy use. Outputs are formally considered as emissions or pollutants (Bruijn et al. 2004).

Table 9.1 and Table 9.2 compare the environmental impacts from the production of different animals. Terrestrial livestock production releases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). As each gas contributes to global warming to different degrees it is useful to convert emissions into 'carbon dioxide-equivalents' (CO_2-e) which represent the amount of CO_2 in kilograms that would contribute an equal effect to global warming as the gas under consideration. For example, 1 kg CH_4 has the effect of 28-36 kg CO_2, and 1 kg of N_2O has the effect of 265-298 kg CO_2 (Environmental Protection Agency 2017). CO_2-e is used in the calculation of Global Warming Potential (GWP) expressed as CO_2-e/kg of product (Vries and Boer 2010). The acidification potential (AP) of water is the reduction in pH resulting from absorption of atmospheric CO_2 (The Royal Society 2005) and is expressed as sulphur dioxide (SO_2) equivalents per kilogram (SO_2-e/kg) and Eutrophication Potential (EP) of soil or water is expressed as phosphate (PO_4^3) equivalents per kilogram (PO_4^3-e/kg) (Vries and Boer 2010). Other measures are also considered in LCA (Bruijn et al. 2004; Mekonnen and Hoekstra 2010; Vries and Boer 2010; Gerbens-Leenes et al. 2013). Beef has the highest overall environmental impact in terms of resource use and GWP, then pork and then poultry (Table 9.1).

Table 9.1. Life Cycle Assessment impact factors; resource use (land, water and energy), GWP, AP and EP for production of bovine, pig and poultry

Animal protein source	Resource use			Output		
	Land (m^2/kg of product)[1]	Fossil energy (MJ/kg of product)[1]	Water footprint (L/kg of product)[2]	AP (kg SO_2-e/kg of product)[1]	EP (kg PO43--e/kg of product)[1]	GWP (CO_2-e kg/kg of product)[1]
Beef	27–49	34–52	15400	0.008–0.055	0.009–0.025	14–32
Pork	8.9–12.1	18–45	6000	0.004–0.062	0.008–0.019	3.9–10
Poultry meat	8.1–9.9	15–29	4300	0.005–0.022	0.006–0.011	3.7–6.9

[1] *data from Vries and Boer (2010).*
[2] *data from Mekonnen and Hoekstra (2010).*

Fish and seafood can be caught in the wild from ‘capture fisheries’ or farmed as ‘aquaculture’ (Figure 9.7). If we consider the numbers reared, their value and the number of species, aquaculture is dominated by finfish production (Food and Agriculture Organization 2014), but it also includes crustaceans, molluscs, and other invertebrates as well as algae and aquatic plants.

Figure 9.7: Aquaculture – fish farming off the coast of Skye

Photograph credit MikePeel (www.mikepeel.net)

Comparison of LCAs for aquaculture is hindered by differences in production methods. For example, not all the LCA criteria available for aquaculture are applicable to capture fisheries, as resource use for capture fisheries does not include land or water use and the impact of wild stock removal is extremely difficult to quantify. However, we *can* compare AP, EP, GWP, land use and water dependence for aquaculture with terrestrial livestock production (Henriksson et al. 2012). Yet, water use (for terrestrial livestock production) is not calculated in the same way as water dependence (for aquaculture). Water dependence encompasses total water volume input and includes water that is lost during production and the water that remains available (unpolluted and of adequate quality) to be reused (Bosma et al. 2011) (Table 9.2).

Table 9.2. Summary of Life Cycle Assessment, impacts factors, resource use and environmental impact for production of Fish through capture fisheries and aquaculture. The reference and the kind of life cycle assessment carried out are described below the main table.

Production Methods	**Resource use**			**Output**		
	Land (m^2/kg of product)	**Fossil energy (MJ/kg of product)**	**Water dependence (L/kg of product)**	**AP (kg SO_2-e/kg of product)**	**EP (kg $PO_4$3--e/kg of product)**	**GWP (CO_2-e kg/kg of product)**
Pelagic fish species						
Capture fisheries [1]	N/A	37	N/A	0.017	0.004	2.14
Atlantic salmon (*Salmo salar*)						
Conventional marine net-pen[2]	*No Data*	26.9	*No Data*	0.018	0.035	2.073
Marine floating bag [2]	*No Data*	32.8	*No Data*	0.015	0.031	1.9
Saltwater flow-through [2]	*No Data*	97.9	*No Data*	0.016	0.029	2.77
Arctic char (*Salvelinus alpinus*)						
Freshwater recirculation [2]	*No Data*	353	*No Data*	0.255	0.02	28.2
Sea bass (*Dicentrarchus labrax*)						
Marine cages [3]	*No Data*	54.656	48782.2	0.025	0.108	3.601
Turbot (*Scophtalmus maximus*)						
Marine recirculation [3]	*No Data*	290.986	4.8	0.048	0.076	6.017
Rainbow trout (*Oncorhynchus mykiss*)						
Freshwater flow-through [3]	*No Data*	78.229	52.6	0.019	0.065	2.753
Extensive freshwater flow through [4]	1.279	*No Data*	473040	0.011	0.06	2.239
Intensive freshwater flow through [4]	1.008	9.194	4380	0.011	0.06	3.561
Freshwater recirculation [4]	1.474	70.639	10	0.041	0.004	13.622
Brook trout (*Salvelinus fontinalis*), **Brown trout** (*Salmo trutta fario*), **Rainbow Trout** (*Oncorhynchus mykiss*) and **Arctic char** (*Salvelinus alpinus*) combined production.						
Flow through [5]	2.737	34.869	98804	0.013	0.029	2.015
Hypothetic recirculation 5	2.097	57.659	6634	0.011	0.018	1.602

Striped catfish (*Pangasianodon hypophthalmus*)						
Intensive freshwater pond culture [6]	*No Data*	13.2	6125	0.048	0.065	8.93
Common carp (*Cyprinus carpio*)						
High stocking density in freshwater lake cage [7]	1.624	29.68	899	0.014	0.1	1.747
Low stocking density in freshwater lake cage [7]	1.876	33.61	1144	0.016	0.15	2.065
Tilapia (*Oreochromis niloticus*)						
High stocking density in freshwater lake cage [7]	1.138	20.785	629	0.009	0.07	1.253
Low stocking density in freshwater lake cage[7]	1.312	23.501	800	0.011	0.105	1.444

1 (E. A. M. Schau 2012). LCA end point of study is the retail store; the product is frozen fish fillet.
2 (Ayer and Tyedmers 2009). LCA end point of study is farm gate; the product is live weight of fish.
3 (Aubin et al. 2009). LCA end of study is farm gate / shore; the product is live weight of fish. Hatchery of fish was excluded from analyses due to lack of available data.
4 (Samuel-Fitwi et al. 2013a). LCA end point of the study is farm gate; the product is live weight of fish. Figures given for energy use exclude transport of product and materials such as feed.
5 (d'Orbcastel et al. 2009). LCA end point is farm gate; the product is weight of fish. For this LCA study land use and water use fail to account for feed growing and production, only land occupation by the infrastructure and water used in the systems is included. Data for the hypothetic recirculation system, based on a two-year pilot system, was presented for an FCR of 0.8 and 1.1; data presented here is for an FCR 0.8 to represent the most efficient system.
6 (Bosma et al. 2011). LCA end point of study is farm gate; the product is weight of fresh fish ready for delivery. This study excludes fish hatching and nursing in its assessment.
7 (Mungkung et al. 2013). LCA end point of study is market; the product is fresh fish delivered. The aquaculture system investigated is a twin net system containing Common carp (*Cyprinus Carpio*) as the primary product in the top nets with Nile Tilapia (*Oreochromis Niloticus*) produced as a by-product underneath in secondary nets.

These data highlight the differences in environmental impact between production methods: as fish production intensifies and stocking densities increase, there are improvements in land use, water dependence (although data are sparse) and EP per kg of product. Recirculation systems with advanced filtration and reuse of water require less water because they concentrate and remove solid/particular waste preventing its release as effluent. In addition, AP and GWP increase as the intensity of production increases as a direct consequence of the increased energy consumption by the filtration equipment and continuous pumping of water. Further, total feed input increases with increasing stocking density (intensity), which also means that water and land use for growing feed increases. However, land use for recirculation aquaculture is less compared to extensive aquaculture methods. Determining which aquaculture method is most environmentally sustainable depends on which factor is thought to be the most important.

Comparing the data above, we can see that fish production by aquaculture requires less land and, generally has lower GWP than terrestrial livestock production. Yet intensive aquaculture methods consume amounts of energy per kg of product that are similar to or higher than terrestrial animal production, with recirculation systems in aquaculture consuming the most energy. Aquaculture can, therefore, offer a sustainable alternative to terrestrial livestock for animal protein, but only in the case of some species or approaches.

FCR can significantly affect the efficiency of fish production. A lower FCR means that less feed per kg of product is required; subsequently land and water use for growing the feed is reduced and waste (feed and faecal waste) is also reduced. Feed use has the biggest effect on most environmental impact factors across all of the current production methods (Aubin et al. 2009; Ayer and Tyedmers 2009; Bosma et al. 2011; Mungkung et al. 2013), whereas energy use has a relatively small effect in recirculation aquaculture systems (RASs) (Samuel-Fitwi et al. 2013b). The environmental impact of aquaculture can be reduced by use of renewable energy (Samuel-Fitwi et al. 2013b), but the biggest gains are made by optimising feed and feeding to reduce FCR (d'Orbcastel et al. 2009; Bosma et al. 2011; Mungkung et al. 2013).

Fish production – capture and aquaculture

Traditionally most fish were derived from capture fisheries, including freshwater and marine species (Greenfacts 2015). The total global capture fishery increased year-on-year between 1950 until approximately 1990, then slowed to peak in 1996 at 95.16 million tonnes (Figure 9.8). The capture fishery for finfish follows a very similar same trend. However, the capture fisheries have now reached a limit due to the increasingly high-risk population status of wild fish stocks with insufficient numbers of fish at breeding age remaining to sustain population growth (Food and Agriculture Organization 2016).

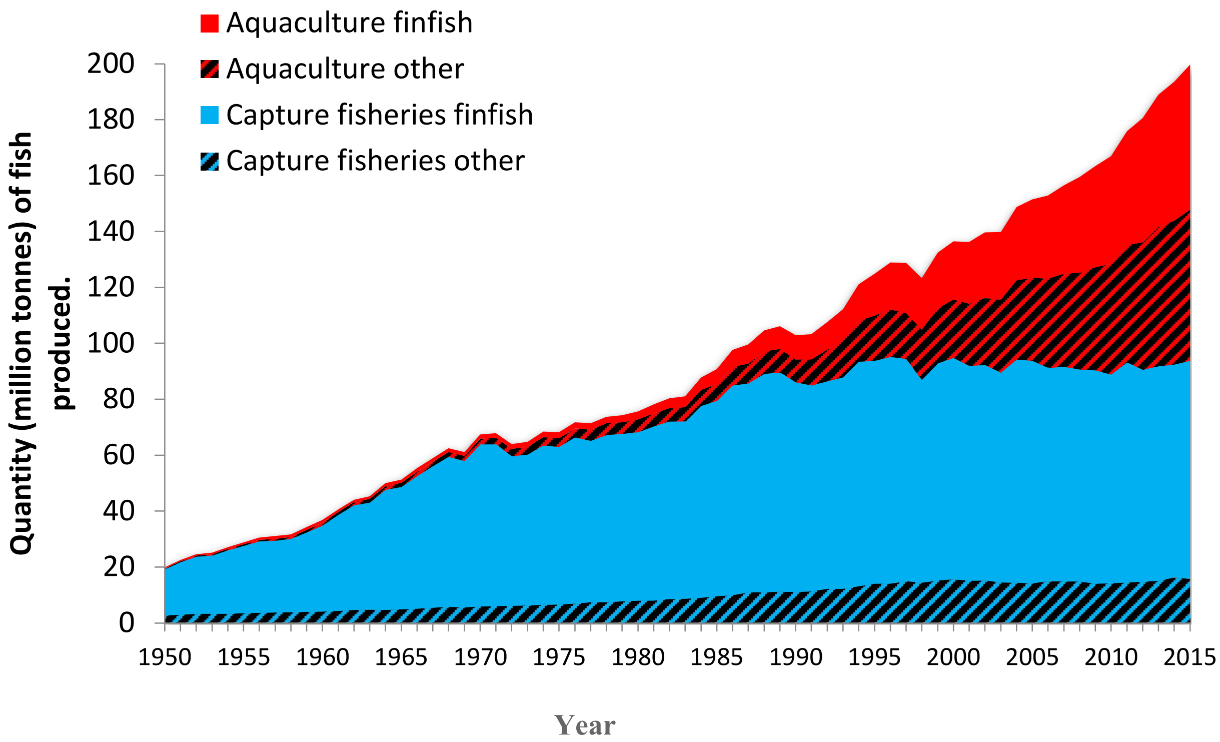

Figure 9.8: Total quantity (million tonnes) of fish and sea food (divided into finfish and other) produced annually by capture fisheries and aquaculture between 1950 – 2015

(Food and Agriculture Organization 2017)

Each year the health of fish stocks is estimated from the proportion of the fish population taken each year, the state of the spawning stock the survival rate of juvenile fish to adulthood and the quantity of fish landed annually. The health of the fish stock, together with the natural history of the species and other environmental and anthropogenic effects, is used to make a stock assessment and this is used to set annual fishing quotas to prevent overfishing. Stock assessments for the North Sea are conducted by the International Council for the Exploration of the Sea (ICES), and the European Commission sets the fishing quotas (Scottish Government Policy 2020). In 2013, 69 percent of the assessed fish stocks were considered to be fished within biologically sustainable levels, however, out of this, 58 percent were considered fully fished (i.e. fished to the maximum sustainable level). The remaining 31 percent of stocks were considered to be overfished (Food and Agriculture Organization 2016).

While capture fisheries have remained static since 1990, there has been a substantial increase in aquaculture production. Half of the production of seafood around the world comes from aquaculture (peaking at 53.1 percent in 2015 compared to just 16.4 percent in 1990). The proportion of finfish from aquaculture also increased from 10.4 percent in 1990 to 40.0 percent in 2015 (Food and Agriculture Organization 2017) – see Figure 9.8. In 2020 aquaculture counted for 49 percent of total fisheries production.

Fish are understood to have been cultivated as a food source since as early as 5000 BC in China. This was dominated by carp species (*Cyprinus sp.*) but cultivation of other species such as Nile Tilapia (*Oreochromis niloticus*) was widespread by 1500 BC, notably in Egypt (Aquaculture Association of Nova Scotia 2015). It is speculated that fish farming started with the utilisation of fish trapped in lakes left after flood waters subsided. Fish farming may have evolved when fish were captured, transferred to lakes then reared on insects and by-products of the silk industry, namely nymphs and silkworm faeces (Durgappa 2006). There are several approaches now used in aquaculture. Modern aquaculture farms can be characterised as:

- ‘open systems’, e.g., floating cages in lakes or at sea, ‘semi-closed systems’ with raceways or ponds with a nearby river diverted to provide a flow-through to maintain water quality, or

- ‘closed systems’ such as recirculation aquaculture systems (RAS) (see also Chapters 11 and 12 this volume).

These methods can be applied to fresh, brackish and marine water aquaculture.

Each method of aquaculture faces different environmental challenges, including nutrient discharge, accumulation of waste, disease management, upkeep of infrastructure, stock escapes and wild seed stock collection (National Oceans Office 2001). Disease management and impact from farm infrastructure are generally lower in closed and semi-open systems and can be minimised through strict operating procedures and careful management. In contrast, the risk of stock escapes from open and semi-open systems is increased during severe weather and is difficult to prevent. The need for collection of wild seed stock can be eliminated almost entirely through breeding of stock, although correct breeding programmes are necessary to ensure genetic diversity amongst brood stock and occasional low levels of wild collection may be required to maintain healthy brood stock.

Nutrient discharge into the nearby river, sea or surrounding body of water (cage culture) comes from excess uneaten feed, faeces and fish processing effluent. Waste can accumulate on the riverbed, lakebed or seabed beneath cages or downstream from a semi-closed farm, particularly if there is slow water flow (National Oceans Office 2001). The major waste components released are organic matter, nitrogen and phosphorous (Lin et al. 2002). The increased nitrogen and phosphorous load on the ecosystem can cause eutrophication (Nixon 1995) leading to excessive plant or algal growth and may precipitate algal blooms (Anderson et al. 2002; O'Neil et al. 2012). These reduce light penetration and cause vegetation die-offs. Once the blue-green algae that cause algal blooms die, their decomposition creates hypoxic conditions (Chislock et al. 2013) and introduces toxins (e.g., microcystin and geosmin) to the environment which can cause stunted growth or even kill the fish. (Boyd and Tucker 1998; Chislock et al. 2013). Cyanobacteria are also responsible for 'off-flavour' compounds (e.g., methylisoborneal and geosmin) (Crews and Chappell 2007), often making contaminated fish inedible.

Waste accumulation can also change the sediment chemistry including reduction in sediment oxygen levels and, ultimately, increased levels of methane and toxic hydrogen sulphide (Pearson and Rosenberg 1978). This usually only impacts small areas near to the cages (Brown et al. 1987) and water flow is usually sufficient to prevent buildup. The potential adverse effects can also be reduced by fallowing: leaving cages empty of fish, for up to 20 weeks after harvesting fish. This management method is employed by the Scottish salmon industry to reduce environmental impact (Pearson and Rosenberg 1978; Brown et al. 1987; Ellis et al. 2016). Feed composition, feeding methods and FCR also influence nutrient discharge. Optimising fish feeds and management can not only benefit operators financially, but can also reduce waste and reduce the environmental impact (Scottish Finfish Aquaculture 2015).

Conclusion

It is generally thought that fish have a lower environmental impact than other livestock. However, natural fish stocks are becoming depleted with around 70 percent exploited at, or close to, their maximum capacity. Aquaculture has started to fill the demand for fish and seafood with around 50 percent of the total seafood consumed around the world now coming from aquaculture (see Figure 9.8).

When one compares farmed fish with other livestock, the story is not quite so clear. Fish are efficient protein converters with feed conversion rates (FCR) close to one (1 kg of feed produces 1 kg of fish), up to eight times as efficient as beef. However, chickens are also efficient protein converters with FCRs of around 1.5. The energy used to grow 1 kg of fish is similar to that used to grow 1 kg of chicken with more desirable fish such as salmon (*Salmo sp.*) potentially requiring more energy (see Table 9.2). Carp (*Cyprinus sp.*) and Nile Tilapia (*Oreochromis niloticus*) are more efficient than Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) in terms of FCR and energy use but are less popular in many countries including the UK. Aquaculture can also have other impacts on the environment. Uneaten food and fish waste leads to eutrophication of areas around fish farms and also causes algal blooms, and stock escape due to flooding, cage damage in severe weather or poor management introduces non-native and genetically modified (GM) species into the environment. There has been a great deal of research into GM aquaculture species over the last 25 years (Abdelrahman et al. 2017) and, as the technology develops and pressures on food production increase, the use of GM species seems closer. The potential impact of release of genetically modified fish species into the environment is a hotly-debated topic (e.g., Dunham and Su 2020).

Fish are very nutritious, and aquaculture can be highly sustainable while also sparing natural stocks, but there are still challenges that need to be addressed in terms of increasing the efficiency of production, persuading the public to accept more sustainable species and increasing the sustainability of feed.

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CHAPTER 10
SUSTAINABLE FOOD FOR FISH

by Kieran Magee and Iain Young

The sustainability of feed for aquaculture

Farmed fish can be either 'fed' or 'non-fed', with 'non-fed' fish usually raised at low stocking densities (extensive farming) in 'pond culture' and feeding on natural sources of food such as algae, zooplankton and insects. Usually, it is herbivorous or omnivorous species, such as common carp (*Cyprinus carpio*) and catfish (*Clarias spp*), that are reared in this way. 'Fed' fish usually receive daily rations of commercially manufactured aquaculture feeds that have been specifically formulated for the species and designed to maximise growth. These fish are usually cultured at high stocking densities (intensive farming) and grow much faster than non-fed species (Boyd et al. 2022).

Commercially manufactured feeds traditionally contain fishmeal and fish oil, which create an environmental challenge as the majority of fishmeal comes from marine capture fish (wild fish caught at sea). Only around 25-30 percent of fishmeal comes from aquaculture by-products (Food and Agriculture Organization 2014), but there is a move to increase this (Food and Agriculture Organization 2016). Fillets of fish are generally the most desired for human consumption, leaving heads, tails, and entrails for reprocessing (Figure 10.1). These fish by-products yield around 5 percent oil and 22.5 percent fishmeal (Shepherd 2005; Tacon and Metian 2008).

Figure 10.1: Heads and entrails 'waste' used in reprocessing for fishmeal and oil.

Photograph © Frédéric Duhart

Marine capture fish used for fishmeal and oil production include small oily pelagic species that are generally too small or too bony to fetch a high-enough price for human consumption. These include anchoveta (*Engraulis ringens*), Chilean jack mackerel (*Trachurus murphyi*), Atlantic herring (*Clupea harengus*), chub mackerel (*Scomber japonicus*), Japanese anchovy (*Engraulis japonicus*), round sardinella (*Sardinella aurita*), Atlantic mackerel (*Scomber scombrus*) and European anchovy (*Engraulis encrasicolus*) (Naylor et al. 2000). Fishmeal contains high quality protein, vitamins and minerals, which, being derived from fish, the amino acid profile matches the profile required for aquaculture species. Diets for carnivorous fish such as Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) usually contain higher amounts of fishmeal. Fish oil is a source of long chain highly unsaturated fatty acids (HUFAs), notably the desirable 'Omega 3' fatty acids EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) (Food and Agriculture Organization 1986). The agriculture and aquaculture feed markets consume most of the fishmeal and fish oil, but there is a well-established market for fish oil as a human nutraceutical or supplement because of its perceived health benefits. It is understood that 1 in 5 'over 60s' in the USA take fish oil supplements but there is much debate in the scientific literature about the health benefits claimed for these supplements (Assadourian et al. 2023).

Annual production of both fishmeal and fish oil is highly dependent on the catch of small, bony pelagic species. During El Niño years the warmer ocean leads to lower productivity (National Oceanic and Atmospheric Administration 2015) and capture fishery is reduced. El Niño is a climatic phenomenon where the thermocline across the Pacific Ocean is interrupted, in turn, causing disruption to the ocean-atmosphere in the Tropical Pacific. It is characterised by unusually warm ocean surface temperatures, which prevent the upwelling of nutrient rich cold water. The eastern Pacific, particularly Peru and Chile are most affected. These dominate global production of fishmeal and oil, accounting for around 40 percent of global production (Naylor et al. 2009; Food and Agriculture Organization 2014, 2016). Fishmeal production peaked in 1994 at 30.1 million tonnes (live weight equivalent). Since then, production has declined overall, with production in 2022 being around 15 million tonnes, half the 1994 level (Food and Agriculture Organization 2022).

Prices of fishmeal and fish oil fluctuate with availability although they have steadily increased since January 2000 (Figure 10.2). This increase has helped to drive reduction of inclusion levels and the search for alternative ingredients. In parallel, there has been a push to improve the feed conversion ratio of aquaculture diets, in turn reducing the ‘fish in to fish out’ (FIFO) ratio of modern aquaculture feeds (FIFO is the mass of fish required in feed compared to the mass of fish produced). This figure is affected by the inclusion levels of both fishmeal and oil and, because of the low yield of oil from source fish material compared to fishmeal, the inclusion of fish oil in a diet has a bigger impact on the FIFO figure than fishmeal.

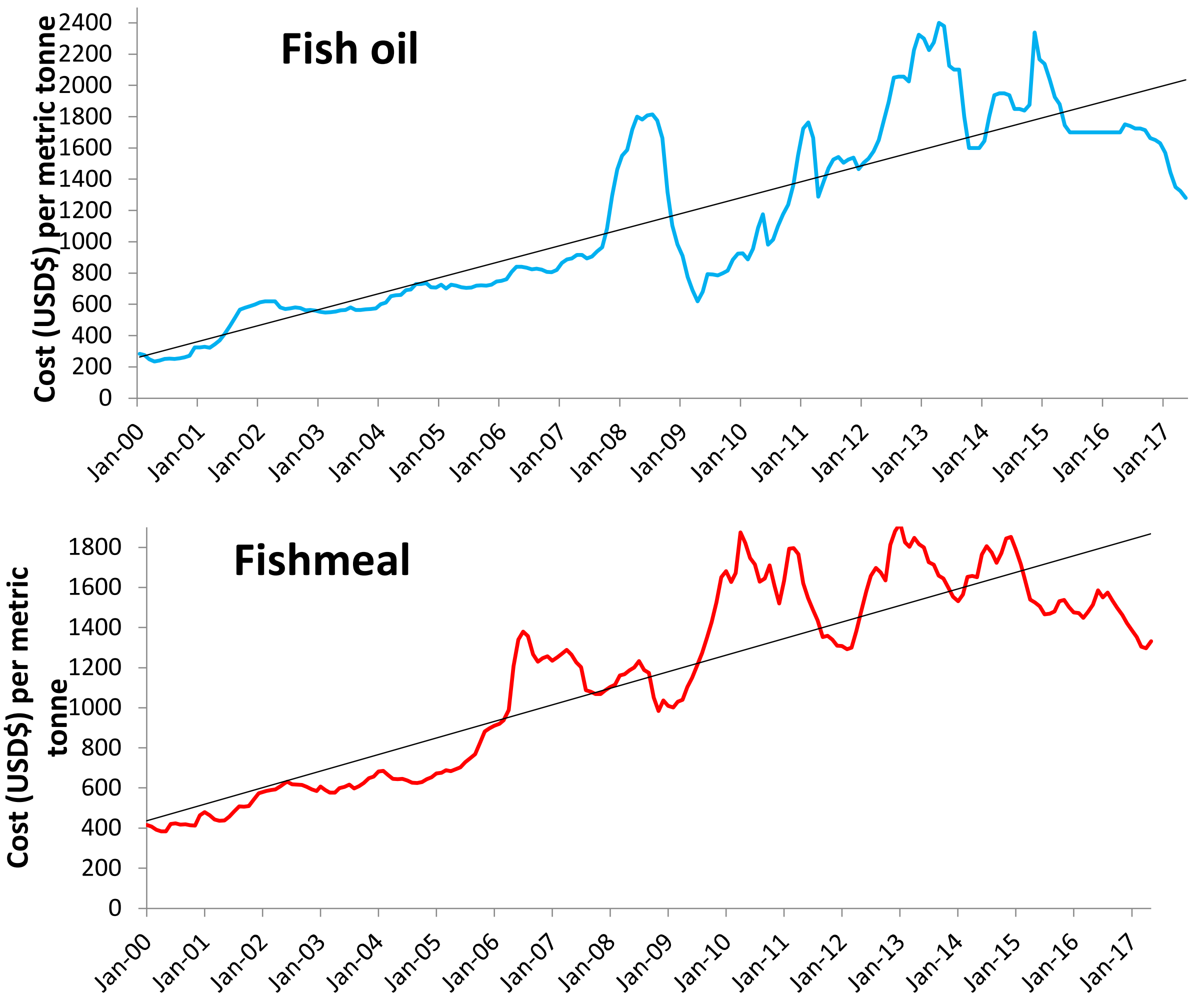

Figure 10.2: Price (US$) of fish oil per metric tonne (blue line), and fishmeal (65 percent protein) per metric tonne (red line) January 2000 to May 2017

(Food and Agriculture Organization 2017a)

Salmon feed has the highest ratio of fishmeal to oil with a ratio 1.68:1 (Jackson 2009). These high inclusion rates were thought to be key to production of high-quality salmon. However, there is a continuing and significant effort to reduce the fishmeal and fish oil inclusion rates by replacing them with other protein sources, for example krill (*Euphausiacea*) (Mørkøre et al. 2020), microalgae (phytoplankton) (Yangyang et al. 2019) and plant proteins (Egerton et al. 2020).

Farmed species and species of interest

There are now many species farmed. In 2014 580 fish species and/or species groups were registered in Food and Agriculture Organization aquaculture statistics; including 362 species of finfish, 104 species of molluscs, 62 species of crustaceans, 6 species of amphibians and reptiles, 9 species of other aquatic invertebrates and 37 species of aquatic plants (freshwater and marine). Finfish are clearly the most prevalent (62.45 percent) (Food and Agriculture Organization 2016). Of the top 10 most produced aquaculture species in 2015 (Table 10.1), 8 were finfish, including 6 carp species.

Table 10.1
Top ten most produced aquaculture species worldwide in 2015

Species	Common name	Production (million tonnes)
Ctenopharyngodon idellus	Grass carp	5.82
Hypophthalmichthys molitrix	Silver carp	5.13
Cyprinus carpio	Common carp	4.33
Ruditapes philippinarum	Japanese carpet shell	4.05
Oreochromis niloticus	Nile tilapia	3.93
Penaeus vannamei	White leg shrimp	3.88
Hypophthalmichthys nobilis	Bighead carp	3.40
Carassius carassius	Crucian carp	2.91
Catla catla	Indian carp	2.76
Salmo salar	Atlantic salmon	2.38

Data from FAO Fisheries and Aquaculture Circular FIAA/C1140 (Food and Agriculture Organization, 2017b).

Proteins and amino acids

Protein is primarily required for growth so long as sufficient carbohydrates and lipids are available (Craig and Helfrich 2009). They are made up of amino acids of which twenty are commonplace. Of these, ten are 'essential amino acids' (EAA) across all fish species because they cannot be synthesised by the fish so must be obtained from the diet. These are: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. The most commonly deficient EAAs in feed are lysine and methionine (Craig and Helfrich 2009). This is important when we are considering alternative protein sources (or considering a vegan diet) as some EAAs may be present in low concentrations in plant-based diets. Supplementation of plant-based diets with amino acids can promote growth in carnivorous fish such as rainbow trout (*Oncorhynchus mykiss*) (Gaylord et al. 2007) but not common carp (*Cyprinus carpio*) (Kim et al. 2008), which is an omnivorous species.

The EAA requirements of a species can be calculated by measuring the growth of fish fed on a test diet containing different levels of each amino acid (Wilson 1985). The ideal dietary inclusion level is determined as the level that yields the best growth. Alternatively, the EAA requirement can be determined by measuring the amount of each EAA incorporated into the fish's tissues daily. This has the advantage that all ten EAAs can be assessed simultaneously (Tacon 1987). The closer the EAA content of a diet matches the EAA composition of the flesh of the fish, the higher the quality of the diet and the more efficient its utilisation (Tacon 1987). However, if an EAA is present in very low levels, this will limit the utilisation of all amino acids, growth will be impaired and the remainder of the amino acids will be excreted as waste.

This is represented in Figure 10.3 (called Liebig's barrel or Liebig's law of the minimum). The length of each stave of the barrel represents the level of the amino acid. The maximum water level in the barrel (protein utilisation and growth) is restricted by the height of the lowest stave. Not only does this mean that more feed is needed to achieve the same rate of growth (using more resources and consuming more fishmeal and fish oil), but also more nitrogenous waste is produced. Where Lysine is deficient (left) the rest of the amino acids cannot be used and so they are excreted. When lysine is added (right) more amino acids can be utilised, less nitrogenous waste is excreted and product yield increases.

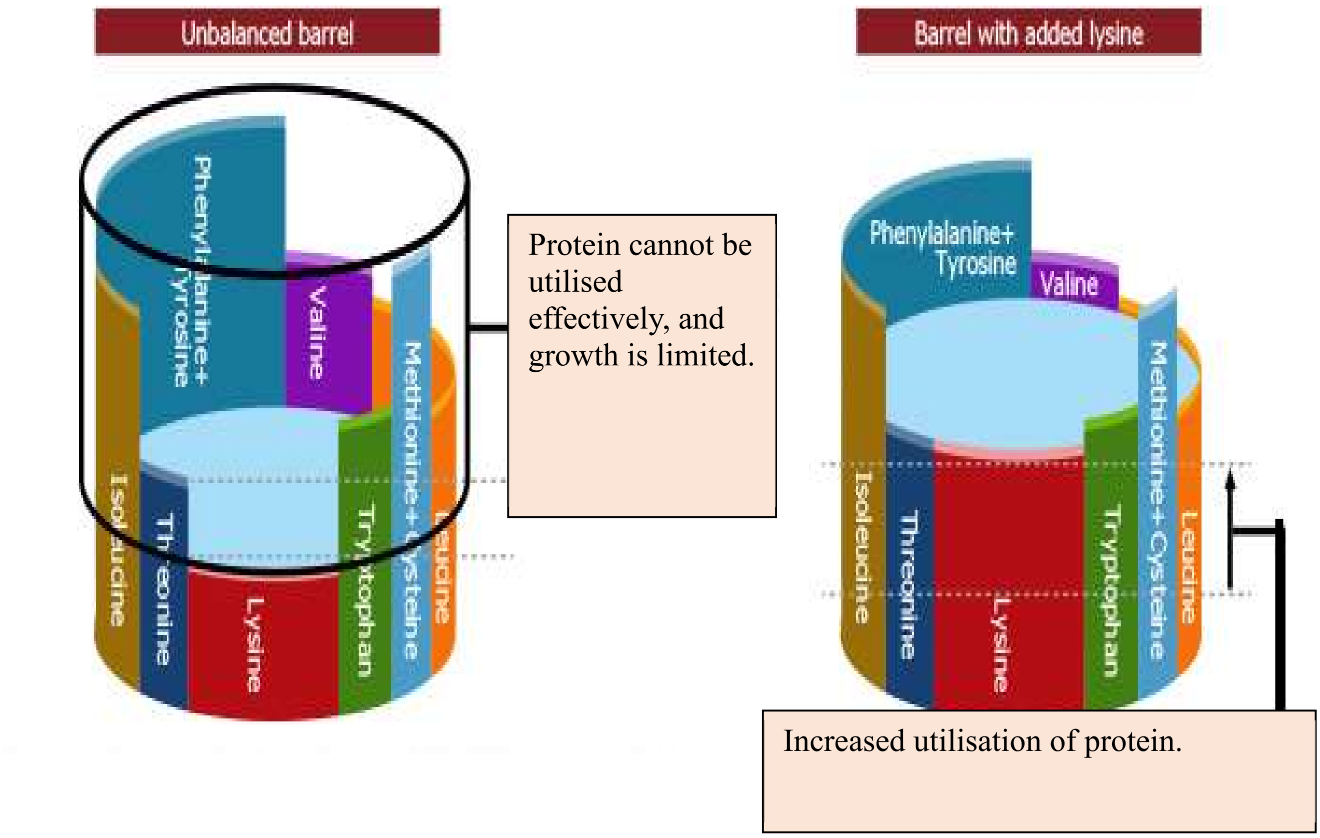

Figure 10.3: Liebig's barrel

Lipids and fatty acids

Naturally occurring fats and oils within foodstuffs and body deposits of most species of animals take the form of triglycerides: esters of fatty acids and glycerol. Over forty fatty acids occur in nature. Unbranched fatty acids with no double bonds between the carbon atoms are referred to as saturated fatty acids (SFAs), those with a single double bond are mono-unsaturated fatty acids and those with more than one double bond are poly-unsaturated fatty acids (PUFAs). The PUFAs include two groups with which most people are familiar: linolenic (omega-3 fatty acid, n-3) and linoleic (omega-6 fatty acid, n-6) (Tacon 1987).

Fish are widely recognised as a valuable source of fatty acids in the human diet. The fatty acid profile of fish tissue is strongly influenced by the lipid profile of their diet. The most common PUFA in the tissue of both freshwater and marine fish is the linolenic (omega-3) series with linoleic (omega-6) levels being much lower. Fish lack the enzymes to completely synthesise omega-3 or omega-6 fatty acids *de novo* (Henderson 1996), so they must be obtained from the diet, and they are referred to as 'essential fatty acids'.

Carbohydrates and fibre

Carbohydrates include glucose, fructose, sucrose, lactose, starch, glycogen, chitin and cellulose and are a crucial source of metabolic energy for most terrestrial animals but their importance in fish is unclear. Fish can synthesise carbohydrates (glucose) from protein and lipid sources (gluconeogenesis) and can satisfy their energy requirements from protein and lipid catabolism. However, carbohydrates are an inexpensive source of energy in manufactured diets (Tacon 1987). Certain fish species also exhibit reduced growth when fed low carbohydrate diets (Wilson 1994).

Alternative Ingredients for Aquafeeds

Fishmeal and fish oil have been staple ingredients within the aquaculture industry because their nutritional profiles match what is required by most farmed species (National Research Council 2011; Tacon and Metian 2015). Research into alternative protein and lipid sources for use in aquaculture feeds has been happening for many years, testing animal derived materials: meat meals, bone meals, feather meals, blood meals (Millamena 2002; Nogueira et al. 2012), poultry by-products (Saadiah et al. 2010; Parés-Sierra et al. 2014) and, proteins and oils from algae (Kiron et al. 2012; Patterson and Gatlin 2013). Alternative marine sources have been explored, such as krill (*Euphausiacea*) (Naylor et al. 2009). However, the majority of attention has been given to plant materials, including: soy protein and soymeal (Sevgili et al. 2015), wheat gluten (Bonaldo et al. 2015), corn gluten (Güroy et al. 2013a), copra and palm kernels (Obirikorang et al. 2015), pistachio and almond nuts (Barrows and Frost 2014), lupin seeds (Borquez et al. 2011), duckweed (El-Shafai et al. 2004), pea, canola and rapeseed meals (Hernández et al. 2013; Obirikorang et al. 2015; Ranjan and Athithan 2015). There has also been a shift towards the use of protein concentrates rather than raw materials, which improves nutrient content but increases cost. Vegetable protein concentrates have been manufactured from soy (Zhao et al. 2010; Li et al. 2015), potato (Tusche et al. 2011a; Tusche et al. 2011b), rice (Güroy et al. 2013b), canola (Thiessen et al. 2004), pea and lupin (Carter and Hauler 2000), and rapeseed (Slawski et al. 2012).

Animal derived materials commonly have higher protein levels and a more complete essential amino acid profile (Naylor et al. 2009). However, animal derived materials include Processed Animal Proteins (e.g., blood meal, feathers, bone), which were banned for use in animal feed in the EU, except for fishmeal for use in fish and non-ruminant feeds (Commission Regulation (EC) No 999/2001 European Commission 2001) following outbreaks of bovine spongiform encephalopathy (BSE). BSE is transmitted via BSE-contaminated meat and bone meal (Wilesmith et al. 1988). This ban was eased in 2013 permitting the use of non-ruminant materials in aquaculture (Commission Regulation (EU) No 56/2013 European Commission 2013). However, consumer acceptance remains a barrier to more extensive use (Ghosh et al. 2016). There has been an increasing trend in recent years for the use of insects and other invertebrates for agriculture diets (Cosgrove 2017). There are now many companies around the world producing insect-derived protein products (see also Sierra et al. this volume).

Algal species can provide high quality feed ingredients with a protein content of 30-40 percent, carbohydrates (5-15 percent) and lipids (10-20 percent) (Fujii et al. 2010). Inclusion of these products into fish feeds is of particular interest as high levels of omega-3 fatty acids (Eicosapentaenoic acid [EPA] and Docosahexaenoic acid [DHA]) can be obtained (Lane et al. 2014) enabling fish oil to be replaced (Miller et al. 2007). However, the cost of producing suitable algal species on a commercial scale are high (Ochsenreither et al. 2016).

Plant derived meals possess comparable protein levels as fishmeal, but they are often deficient in EAAs, particularly methionine and lysine (Nunes et al. 2014). They can also include high levels of fibre and starch (non-soluble carbohydrates), which reduce overall digestibility and they may contain anti-nutritional factors (ANFs) which interfere with the utilisation of their nutrients (Kumar 1991).

Insects and other invertebrates form part of a natural diet for many species of fish (Howe et al. 2014; Whitley and Bollens 2014) and they usually have nutritional profiles rich in amino acids, lipids, vitamins and minerals (van Huis 2013). Protein levels of between 50-82 percent (dry matter) (Rumpold and Schluter 2013a, 2013b) make them comparable to fishmeal. In addition, commercial production has already been established for several species. Insects are a sustainable food source as they can be grown in large quantities using little land area, water and energy resulting in a small ecological footprint (Oonincx and deBoer 2012) and can even be grown on organic waste materials (van Huis 2013).

Silkworms (*Bombyx mori*) and mealworms (*Tenebrio molitor*) (Hossain et al. 1997; Barker et al. 1998; Finke 2002, 2007; Longvah et al. 2011; Rumpold and Schluter 2013b; Yi et al. 2013; Barroso et al. 2014;) are considered very promising alternatives for fishmeal (Henry et al. 2015). Furthermore, mass production of silkworms is long established through the silk industry, while mealworms have been routinely produced for fishing bait and as pet food (Schabel 2010; Kroeckel et al. 2012; Veldkamp et al. 2012; Ji et al. 2013; Rumpold and Schluter 2013b; van Huis 2013).

The silk moth (*Bombyx mori*) was domesticated to produce silk from the wild silk moth (*Bombyx mandarina*). Its caterpillar, referred to as the mulberry silkworm (so, also *Bombyx mori*), was successfully domesticated to produce the raw silk used for weaving by Chinese farmers about 5,200 years ago (Chou 1980; Goldsmith et al. 2004). Ninety percent of global silk produced today is from *Bombyx mori* (Heuzé et al. 2015). The silkworm (caterpillar) spins a cocoon from a single strand of silk approximately 300-900 meters in length, in which to pupate. Under normal conditions, the pupa will develop into a moth after three weeks and emerge, creating a hole in the cocoon (Datta and Nanavaty 2007; Jintasataporn 2012). However, this damages the silk strand. Therefore, in silk production, the cocoons are harvested and boiled killing the pupae (Datta and Nanavaty 2007; Jintasataporn 2012) allowing extraction of the intact silk strand. These pupae are a by-product (Swarts 2011). For every 1 kg of silk, 2 kg of dry pupae (8 kg wet) are produced (Patil et al. 2013).

China now accounts for roughly 80 percent of global silk production and produces 200,000 tonnes of dry silkworm pupae (Dong and Wu 2010), which are usually discarded or used as fertiliser (Wei et al. 2009). A potential barrier to their wider use in animal feeds is that the larvae contain flavonoids and terpenoids from the mulberry leaves they eat. These seem to affect their palatability (Rao 1994; Finke 2002). Nonetheless, silkworm pupae are eaten by humans in many of the Asian silk producing countries: China (Zhi-Yi 1997), Japan (Mitsuhashi 1997), Thailand (Yhoung-Aree et al. 1997), India (Longvah et al. 2011). In Korea they are a popular snack called 'Beondegi' (Figure 10.4).

Figure 10.4: A popular snack in South Korea:
'Beondegi' silkworm pupae are sold tinned in shops.

(Available at https://www.atlasobscura.com/foods/beondegi-silkworm-pupae-korea)

Photograph credit: Rob Cruickshank 21/4/13

They are also a suitable feed ingredient for livestock because of their nutritional profile (Trivedy et al. 2008). Silkworm meal and oil have tested positive by up to 100 percent as a replacement for fishmeal and oil (i.e. total replacement of the fishmeal and oil) in the diets formulated for several fish species, yielding growth rates comparable to fishmeal diets. For example: common carp (*Cyprinus carpio*) and other species of Cyprinids (Kim 1974; Jeyachandran and Raj 1976; Jayaram et al. 1980; Nandeesha et al. 1990; Rahman et al. 1996; Rangacharyulu et al. 2003); rainbow trout (*Oncorhynchus mykiss*) (Dheke and Gubhaju 2013) and chum salmon (*Oncorhynchus keta*) (Akiyama et al. 1984). Silkworm pupae have a high-quality nutritional profile, are relatively abundant, are a cheap commodity and have shown promising results in previous fish dietary trials across multiple species.

Yellow mealworms are the larvae of the darkling beetle (*Tenebrio molitor*) (Tran et al. 2015). This is a pest affecting mainly grains and flour (Ramos-Elorduy et al. 2002), which makes them easy to feed and rear artificially. While adult beetles contain quinones rendering them unusable as a feed source, the larvae are high in protein, high in lipids and low in minerals making them a high-quality feed item (Makkar et al. 2014). They are produced on an industrial scale as feed (Veldkamp et al. 2012) for birds, reptiles and fish (Tran et al. 2015). They are highly palatable to fish (Henry et al. 2015) and yield good results for growth at modest dietary inclusion rates. For example, 60 percent fishmeal replacement yielded equal or improved growth in African catfish (*Clarias gariepinus*), but there was reduced growth at higher rates of inclusion (80-100 percent fishmeal replacement) (Ng et al. 2001). Mealworms have also been used in feed for carnivorous fish species, at 50 percent dietary inclusion for rainbow trout (*Oncorhynchus mykiss*) and at 25 percent inclusion for gilthead seabream (*Sparus aurata*) and European sea bass, (*Dicentrarchus labrax*) (Gasco et al. 2014a, 2014b; Piccolo et al. 2014). As with silkworm pupae, mealworms are readily available, relatively cheap and have a high-quality nutritional profile.

Earthworms (Lumbricina) are traditionally used as fishing bait. Commercial production of many bait species, including earthworms, has developed to meet the high demand. The most common species of large earthworm living in gardens is the common earthworm (*Lumbricus* *terrestris*). However, these create deep vertical burrows in the soil and commercial culture is not feasible. The two species that are commercially produced are composting red wrigglers (*Eisenia fetida*) and European night crawlers (*Eisenia hortensis* or *Dendrobaena veneta*). The European night crawlers grow larger, but the red wriggler reproduces faster and being a composting species, can be reared on a wide variety of feed items including waste. *Eisenia fetida* have a high protein content, between 54.6-71 percent, with an amino acid balance close to that of fishmeal (Zhenjun et al. 1997; Dynes 2003) and seem to produce good growth when included at modest levels in the diet of rainbow trout (*Oncorhynchus mykiss*) (Stafford and Tacon 1985).

More recently a great deal of attention has been given to black soldier fly (*Hermetia illucens*) larvae (BSFL) (Mohan et al. 2022). These yield high quality protein and have great potential to convert waste food and even manure into insect protein (Sheppard et al. 1994). The nutritional profile of the larvae depends on the profile of the material that it was raised on (Nguyen et al. 2015) but crude protein content of over 60 percent has been reported (Rachmawati et al. 2015). Overall, the use of BSFL in aquaculture diets has had a positive impact on fish health (Bruni et al. 2020; Jahan et al. 2021; Melenchón et al. 2021). Mohan et al. (2022) provides a comprehensive summary of the use of BSFL in aquafeeds. (see also chapter 12.)

Conclusion

The sustainability of feed in aquaculture is a critical concern, as it directly impacts the industry's environmental and economic aspects.

Traditionally, aquaculture feeds contained fishmeal and fish oil, which pose environmental challenges due to their dependence on marine, wild-caught fish. Sustainability efforts have helped to reduce the reliance on fishmeal and fish oil, focusing on improving the feed conversion ratio (‘fish in to fish out’ – FIFO) and exploring alternative ingredients. Substitutes like krill (*Euphausiacea*), microalgae (phytoplankton) and plant proteins are being considered to reduce reliance on fish-derived ingredients. Development of aquafeeds using alternative ingredients requires close consideration of the nutritional requirements for the fish species farmed:

proteins are needed for growth and the quality of the protein is crucial with essential amino acids (EAAs), such as lysine and methionine, required in balanced amounts. A deficiency in an EAA will restrict the utilisation of other amino acids, having a direct impact on growth rate and feed efficiency and, consequently, waste production.

Lipids include essential fatty acids (EFAs) like omega-3 and omega-6. These are regarded as important in aquafeeds. This is driven by consumer demand for omega-3 and omega-6 in foods because they are perceived as promoting good health. These EFAs must be obtained through the diet, making consideration of lipid sources critical in the design of aquaculture feeds. The need for carbohydrates in fish diets is unclear, but they are a source of metabolic energy in aquaculture diets and some fish species exhibit reduced growth on low-carbohydrate diets.

Alternative protein and lipid sources are being explored to reduce reliance on fishmeal and fish oil. Plant-based materials show promise but are often limited in EAAs and EFAs. Some animal products, notably from ruminants, cannot be used in fish diets because of the risk of transmission of diseases such as BSE. However, there is great interest in insect-derived products like silkworm pupae and mealworms. Silkworm pupae and mealworms are already produced in huge volumes for the silk industry and pet feed/fishing bait industries respectively. These have good nutritional profiles and show promise in replacing fishmeal. More recently, black soldier fly larvae (BSFL) have attracted a great deal of attention. In addition to an excellent nutritional profile, they are able to convert waste and even manure into high-quality insect protein.

The sustainability of aquaculture feed is a complex issue, with a growing focus on reducing reliance on fishmeal and fish oil. However, the exploration for alternative ingredients which match the nutritional requirements of different fish species is helping move the industry towards more environmentally and economically sustainable aquaculture practices.

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CHAPTER 11
AQUAPONICS AND HYDROPONICS: AN ECONOMIC CONSIDERATION OF A CIRCULAR AGRONOMY

by Laurence Anderson and Iain Young

Introduction

An increasing global human population together with environmental degradation resulting in climate change, soil degradation, water scarcity, biodiversity loss, including declining ocean fish stocks, a shrinking supply of fossil fuels and scarcity of mineral fertilisers are only a few of the issues we shall need to overcome to secure human food production for the future (Goddek et al. 2015).

Aquaculture, rearing fish or other aquatic animals (e.g., Figure 11.1) is the fastest growing sector of agriculture (8.8 percent annual worldwide growth) and may help compensate for declining fish and shellfish harvests (Troell et al. 2004; Boxman et al. 2017). Recirculating aquaculture systems (RAS – Figure 11.2) involve filtering and recirculating effluent around the fish tanks. RAS are becoming increasingly popular constituting 55 percent of fish farming in the USA, where there are the most data available for its application (Vilsack and Reilly 2012).

Figure 11.1: ▸ A sustainable fish farm in the Buikwe District, Uganda

Photograph credit: *Mohsen Taha 4th March 2021, Creative Commons Attribution-ShareAlike 4.0 International CC-BY-SA-4.0*

◂ **Figure 11.2:**

A large land-based RAS fish farm in the UK.

Photograph courtesy of David Fletcher

RAS have advantages over other types of aquaculture, by maximising production in a limited space and reducing water use. It offers close environmental control to help maximise fish production regardless of climate and it allows production to be located close to markets. RAS also facilitate harvesting, reduce pollution, and can help with disease control (Holliman et al. 2008). However, RAS have high capital costs, high electricity demands and need trained staff to operate these complex systems. RAS can also accumulate solid and dissolved nitrogen and phosphorous waste that must be disposed of in a sympathetic and sustainable way (Adler et al. 2000). This waste can be treated by exposure to artificial wetlands (phytoremediation), which can remove up to 86-98 percent of nitrogen waste (Tyson et al. 2011). However, artificial wetlands are expensive and use a large amount of land and they are not well suited for growing commercial crops (Endut et al. 2009).

Aquaponics is a culture system linking aquaculture with hydroponics (production of plants in water and nutrients). This offers a possible solution for future food production (Blidariu and Grozea 2011). The integration of RAS with hydroponic plant production (aquaponics) utilises the nitrogen and phosphate produced in effluent, reducing nutrient discharge into the environment and offsetting waste-water treatment costs, in turn generating

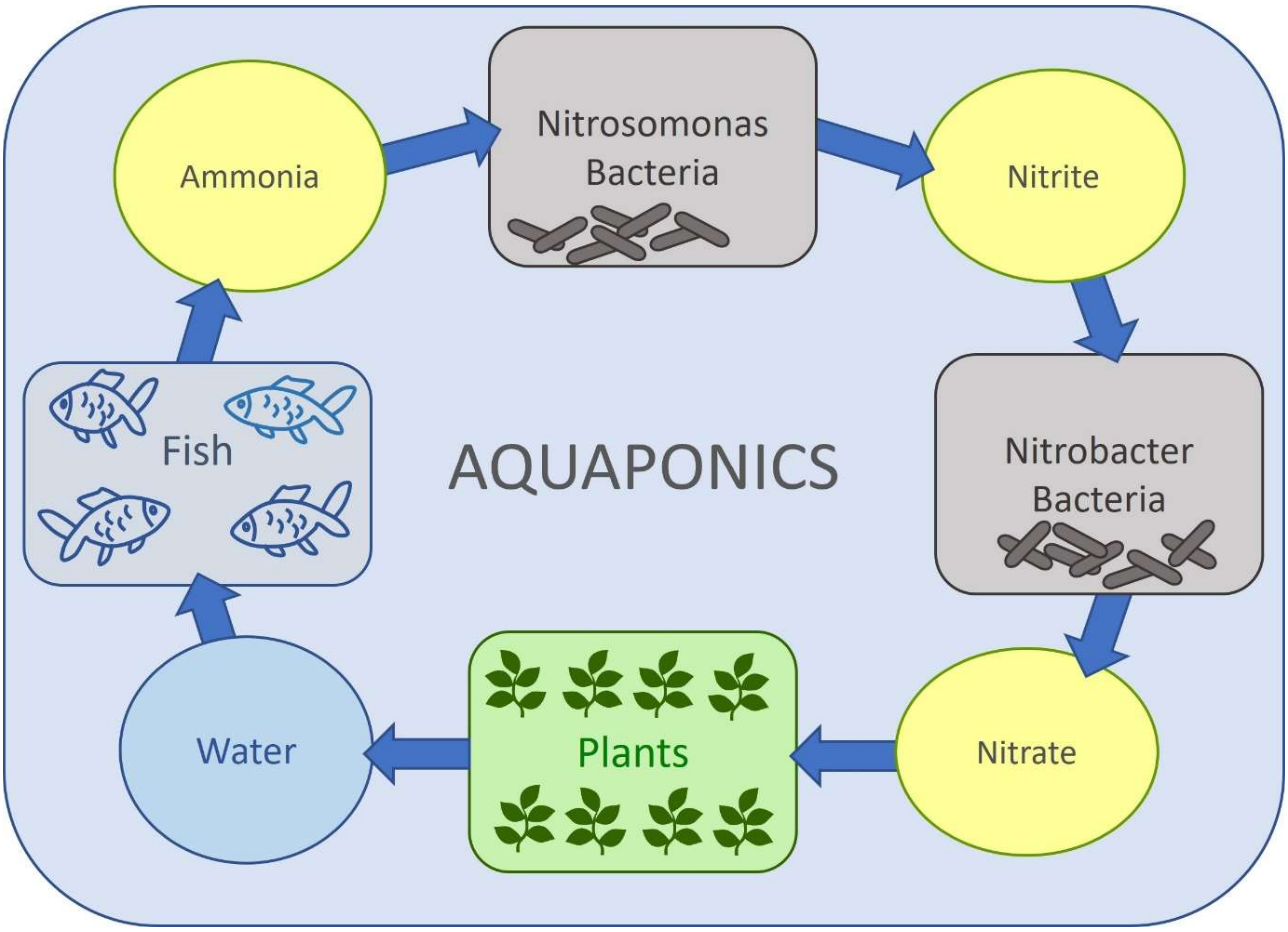

Figure 11.3: Aquaponics cycle

Diagram © Iain Young

additional revenue by producing commercially valuable plants (Adler et al. 2000). This is shown in Figure 11.3 where the ammonia waste from fish is broken down first by nitrosomonas bacteria into nitrite and then by nitrobacter bacteria into nitrate, which is used as a nutrient for the plants. These plants in turn then clean the water supplied back into the fish tanks.

The interest in aquaponics is gaining momentum with over 80 percent of papers on the topic published in the last ten years [*Citation report function* (Clarivate™, Web of Science™)]. However, most work focuses on the technical aspects of aquaponics with little information about economics, possibly because data are held by commercial entities (Goddek et al. 2015). Here, we examine the economic and technical factors that impact the viability of aquaponics as a sustainable agricultural technology.

Size and Scale of the Aquaponics Industry

The current literature on commercial aquaponics tends to focus on the USA (Love et al. 2015a). In 2012 the United States Department of Agriculture carried out the first survey of commercial aquaponics (Vilsack and Reilly 2012). There were 71 active aquaponic farms operating in 22 states compared to 360 RAS, 1,479 pond and 391 flow-through raceway operations. Of the aquaponics operators, 74 percent had sales of less than $25,000 per annum, which compares with 43 percent RAS, 40 percent pond and 30 percent flow-through operations (Vilsack and Reilly 2012). Only 1 percent of aquaponic producers had sales over $500,000 per annum, compared to 17 percent, 17 percent and 13 percent RAS, pond and flow-through (Vilsack and Reilly 2012). So, in 2012 aquaponics remained a small emerging industry representing less than 2 percent of the USA's aquaculture producers, with most operations consisting of small-scale operations (Vilsack and Reilly 2012). Examples are shown in Figures 11.4 and 11.5.

Figure 11.4: A large scale commercial floating raft aquaponics system farming fish and lettuce

Credit: Kurt Kaiser November 2019, Creative Commons CC0 1.0 Universal Public Domain Dedication.

Figure 11.5: Very small scale 'backyard' home aquaponics system growing fish, vegetables and salad crops in an adapted intermediate bulk container (also known as a pallet tank)

Love et al. (2015a) reviewed the current commercial landscape of aquaponics, with 81 percent of respondents based in the USA. Most of the remaining respondents were in English-speaking countries, with only one in China (although China is a large contributor to the scientific literature on aquaponics). They showed a doubling of the number of aquaponics operations in the USA over two years (72 in 2012 versus 145 in 2014) with less than 10 percent of respondents established for more than ten years. The mean size of operating aquaponic farms increased from 4,891 litres in 2012 to 10,300 litres in 2014 – comparable to the average RAS farm (9,611 litres) and larger than the average pond farm (6,378 litres) in the USA.

However, this was not reflected in production, with 90 percent of farms producing less than 453kg of fish/year compared to a typical catfish (Ictaluride) pond farm in the USA producing on average 5,053kg/year

(Boxman et al. 2017). This could be due to a focus in aquaponics on crop production as the primary enterprise with fish production a secondary enterprise and, in some cases, the fish are not sold but act as standing biomass to provide nutrient 'fertiliser' (Tokunaga et al. 2015).

Love et al. (2015a) also ranked the most common approaches to hydroponics in aquaponic systems: floating rafts/deep water culture (77 percent); media beds (76 percent); nutrient film technique (29 percent); vertical towers (29 percent); wicking beds (6 percent); Dutch buckets (5 percent), with most operations using more than one approach. The most employed approaches for aquaponics are not the most used in hydroponics, indeed they are almost reversed. Perlite in Dutch buckets or drip irrigation systems are the most common (56 percent); media-filled nursery pots or upright bags (20 percent); raised beds or sand floor (10 percent). The nutrient film technique was only used in 6 percent of hydroponics operations (versus 29 percent of aquaponics). Other techniques amounted to 4 percent, rarely seen were floating raft systems (2 percent) and vertical systems (1 percent) despite both being common in aquaponics. Rockwool and drip irrigation were used in 1 percent of hydroponics systems (Tyson et al. 2009). This is most likely because aquaponics systems recirculate water whereas most hydroponic methods 'run to waste' so aquaponics will utilise approaches that have the least impact on water quality. Love et al. (2015a) note aquaponic systems are commonly located in greenhouses (31 percent) with only a few systems located inside a building (7 percent). However, 43 percent of commercial aquaponic farms used supplemental lighting to produce crops.

Key Considerations and Constraints when Comparing Aquaponic Systems

There is no optimal system for aquaponics and most (71 percent) of farms design their own systems (Love et al. 2015a). There are many factors to consider when designing an aquaponic system (Palm et al. 2014; Goddek et al. 2015). These include:

- The method of hydroponic production.
- The ratio of fish to plant production surface area. This is known as the component ratio.
- The species of fish, and species and cultivar of plants.

- Climatic and geographic conditions, including seasonal daylight, temperature and humidity.
- If the system has been designed from first principles or as a hydroponic add-on to an existing aquaculture system.
- System quirks such as designing a system to fit into a limited physically space.

This complexity and variability make it hard to compare different systems (Forchino et al. 2017). However, a design used for the University of the Virgin Islands' floating raft system has been adopted by several research groups and is likely to be the closest example of a 'standard' system (Bailey et al. 1997; Tokunaga et al. 2015). Variability is increased by differences in operation and management: feed composition and the ratio of feed to fish to plant biomass, oxygenation and filtration methods, water flow rates (Endut et al. 2009; Tokunaga et al. 2015).

Any economic comparisons are complicated by variability in the cost of energy, labour costs and different sales revenues in different countries (Goddek et al. 2015). Different groups also use various metrics: some authors provide 'full economic costs' and 'gross earnings' (Bailey et al. 1997; Holliman et al. 2008); others publish 'projected cash flow' and 'rates of return' (Adler et al. 2000; Tokunaga et al. 2015); some measure profitability as revenue/m^2/production cycle (Petrea et al. 2016) or calculate a 'break-even sale price' of their crop (Xie and Rosentrater 2015). Nonetheless, the exercise is still useful and common patterns do emerge when the data are curated, pooled and compared.

Economic Aspects of Aquaponics: Estimates of Production Costs

The largest expense in pond aquaculture is generally feed, representing 40-60 percent of total operating expenses (Holliman et al. 2008). However, only 30-35 percent of the feed consumed by the fish is utilised for growth with 65-70 percent lost in the water as faeces (insoluble) or as soluble ammonia. This must be removed from the system at some expense (Holliman et al. 2008). Channelling this by-product into aquaponic crop production generates value and removes the need for expensive waste disposal (Holliman et al. 2008). This makes economic sense; even more so when we consider that fertilisers used in hydroponics can contribute 5-10 percent of overall operating costs (Tyson et al. 2011). Robust economic models and financial forecasts are desperately needed.

The literature regarding aquaponics mainly focuses on technical issues. While this is useful in consideration of production capacity and yield, financial metrics (production cost, energy consumption, market prices) are generally not available. Early literature on the economics of aquaponics focused on models (Adler et al. 2000; Holliman et al. 2008; Engle and Beem 2017) but these usually lack details about costs and risks associated with operating an actual farm, such as equipment failures, employee benefits (if in the USA), fish survival rates, production failures due to disease, marketing costs, post-gate delivery costs, waste disposal and market price fluctuations.

Tokunaga et al. (2015), Xie and Rosentrater (2015) and Petrea et al. (2016) provide economic data across different scales ranging from large commercial through small modular scalable farms to lab-scale farms. Tokunaga et al. (2015) provide a comprehensive economic breakdown of commercial aquaponics, simulating the costs and potential earnings of an aquaponics farm based in Hawaii operating over a 30-year lifespan.

Tokunaga et al. (2015) based their study on data from three active, commercial farms in Hawaii. They then used these live data to estimate operating costs, including outgoings that are often overlooked, such as labour costs, post-harvest costs (including product processing and packaging), employee benefits, utilities costs, land rental, income tax, cold storage for harvested plants and fish, and a breakdown of fixed versus variable production costs. With this much detail they were able to calculate costs and returns of each component of the farm. They discovered that the three largest costs are labour (48 percent), electricity (23 percent) and fish feed (11 percent). Labour costs are often the largest in hydroponics (33 to 62 percent) (Bailey et al. 1997; Adler et al. 2000; Holliman et al. 2008; Tokunaga et al. 2015) due to the many manual tasks involved, such as crop production, planting seeds, tending to seedlings, harvesting, post-harvest processing, packaging – which accounted for 44 percent of all labour hours in Tokunaga et al.'s analysis (2015) – and finally deliveries. In many studies, labour costs represent the highest annual expenditure (32-60 percent) of entire aquaponics operations (Adler et al. 2000; Holliman et al. 2008; Tokunaga et al. 2015; Xie and Rosentrater 2015).

High labour costs are inevitable in aquaponics, it is labour-intensive and requires technical knowledge. These costs are difficult to reduce because the salaries tend to increase (Bailey et al. 1997; Tokunaga et al. 2015; Konig et al. 2016). Farms require staffing 7-days a week, and labour-intensive tasks, such as crop and fish harvesting, are difficult to automate. However, several approaches, common in agriculture, may reduce overall labour costs, such as employing fewer, skilled core workers to manage day-to-day operations and using part-time labour for harvesting periods and increasing mechanisation/automation for operations, such as seed sowing and packaging (Bailey et al. 1997; Tokunaga et al. 2015;).

The costs related to the aquaculture component of an aquaponic farm are more variable. This is due to differences in system design, operation, location, local markets and costs. However, there is one common trend: the cost of fish production exceeds the revenue generated by the sale of fish in most cases (e.g., in all cases reviewed, except Tokunaga et al. 2015). Electricity costs/usage vary widely (3-70 percent of operational cost), depending on local prices, location, and climatic conditions (Bailey et al. 1997; Adler et al. 2000; Tokunaga et al. 2015; Xie and Rosentrater 2015; Petrea et al. 2016). However, farms that require supplemental lighting and heating generally find electricity/fuel costs as their highest contributor to their operational costs (Love et al. 2015b; Petrea et al. 2016).

Economic Feasibility/Profitability of Aquaponics

Maximising profit is generally a key motivation for operators; if revenues generated cannot cover costs, the chances of it being adopted as a sustainable food production system are slim to none (Petrea et al. 2016).

The aquacultural component of most aquaponics farms often makes a loss, due to high production costs. However, in most models and case studies aquaponic farms tend to make a profit because of the relatively large revenues generated by hydroponics, which can subsidise the aquaculture component (Bailey et al. 1997; Holliman et al. 2008; Love et al. 2015a; Xie and Rosentrater 2015; Boxman et al. 2017).

The economic feasibility of the aquacultural component can be improved by cultivating species of fish tailored to suit local markets. Holliman et al. (2008) reviewed the viability of a decoupled aquaponic system growing tomatoes and either tilapia (e.g., *Oreochromis niloticus*) or catfish species (e.g., *Ictalurus punctatus)*. They found a farm was not profitable if it grew catfish, because of losses incurred by the aquaculture system due to a high production cost of catfish and its relatively low sale price. However, when the same system was used to cultivate tilapia, it generated a profit. The aquaculture system still operated at a loss, but the revenue from tomato production was able to cover this cost and produce a profit.

The literature also describes economies of scale: as the size of the farm increases, production cost per kilogram of fish and vegetable crop decreases (Bailey et al. 1997; Xie and Rosentrater 2015) and a sufficiently large farm could yield a profit (Bailey et al. 1997). However, a large farm may produce too many fish, saturating the local market and driving down the price of fish (Tokunaga et al. 2015; Engle and Beem 2017).

Xie and Rosentrater (2015) show how economies of scale drastically affect production costs; using a small lab-scale with 8 m^2 of hydroponic growing space to cultivate basil and 0.5 m^3 of Nile tilapia (*Oreochromis niloticus*), with a relatively high sale price of $9 per kg, they required an unrealistic price of 221 $/kg for basil just to break even. They then used the data from this small case study to determine the relative costs of different sized farms, finding that a farm 300 times the size of the original would need to sell basil at 21 $/kg (which is still relatively high) to break even. However, this break-even point should really be lower. The scaled-up farm model consists of 300 units of the original system, whereas larger systems actually use different, larger components (not 300 sets of small components). This would reduce the capital and operational costs. Further, the break-even high sale prices in Xie and Rosentrater (2015) are also impacted by the system being located indoors and using supplemental artificial lighting and heating.

Farm location and climate are major factors determining profitability of an aquaponic farm. Love et al. (2015a) found that farms located in regions with mild winter temperatures (minimum winter temperature of 0°F/-18°C or above) were four times as likely to be profitable than farms in colder areas with seasonal temperatures below 0ºF /-18ºC, due to the high heating and lighting costs associated with extending the growing season in regions with low winter temperatures and short winter day lengths.

Love et al. (2015b) conducted one of the few economic analyses of aquaponics carried out outside of a tropical climate, in Baltimore, Maryland (USA). Baltimore has a humid sub-tropical climate with high temperatures and long-day lengths in the summer and low temperatures and relatively short-day lengths in the winter. Energy costs varied from month-to-month, depending on whether the farm needed to be heated or cooled and whether supplemental lighting was required. The winter months from December to February accounted for 42 percent total annual electricity and 54 percent of the total annual energy use due to the use of in-tank water heaters, propane air heaters and supplemental fluorescent lighting (Love et al. 2015b). Even at these high levels, the electricity and energy use were only just enough to prevent the complete failure of the farm. The water in the aquaponic system was maintained below the optimum growth temperature for Nile tilapia (*Oreochromis niloticus*), to prevent high water temperature causing the crops to bolt in the cold air. In turn, this led to reduced fish growth rates and feed conversion ratios and reduced revenue. During the summer months, crops suffered from heat stress and pest infestations (due to the crop's weakened state) despite shading of the polytunnel (up to 50 percent) and the use of ventilation fans. This illustrates how climate impacts on the profitability of an aquaponic farm, with high energy use required to provide adequate heating in winter and cooling in summer, lost revenue due to reduced growth rates and pest outbreaks.

Culture of plants at higher latitudes or indoors requires supplemental lighting. There are a few factors that affect the costs associated with this:

- The efficiency of the type of lighting: metal halide versus mercury versus high-pressure sodium versus LED bulbs.
- The photoperiod needed for the crop grown (dependent on the latitude of an outdoor farm).
- If the farm is indoors and requires 100 percent artificial lighting.

Petrea et al. (2016) showed electricity costs (58-72 percent of total) were the highest operational expense for their indoor farm. However, they also demonstrated that crops requiring a shorter photoperiod used less electricity and cost less to produce than crops requiring longer photoperiods. However, due to the differing sale prices of each crop, the length of photoperiod required for a crop to grow did not affect profitability. They also showed that the use of energy efficient fluorescent bulbs reduced costs compared to crops grown using energy efficient metal halide bulbs (Figure 11.6).

Figure 11.6: Hydroponically raised lettuce grown under artificial LED lighting in a basement. The basement provides a stable environment. Not only does LED lighting minimise the energy consumed in lighting, reducing energy costs, but also the heat from the lights is less, and thus more easily managed than from incandescent bulbs.

Photograph © Laurence Anderson.

One approach to making an aquaponic farm more financially viable in a climatically unfavourable location would be to operate the farm inside a well-insulated building or a basement, rather than in a greenhouse (Love et al. 2015b). This dampens the effect of large temperature fluctuations on fish and plant crops enabling them to grow at optimum temperatures, as well as minimising heat loss (and cost) in the winter, compared to a greenhouse (Love et al. 2015b). However, this approach loses out on solar heat gain that is provided by a greenhouse and requires artificial lighting (Love et al. 2015b). This trade-off between temperature stability versus lack of natural light could be favourable from a power usage perspective if efficient low-power LED lighting were used. However, production in a well-insulated building also introduces potential issues with airflow and humidity, which may necessitate the use of a heating, ventilation and air conditioning system with associated increases in energy use.

Farm management has a significant impact on profitability. As well as a judicious choice between the above methods, an adept manager can employ other sophisticated management techniques. Tokunaga et al. (2015) showed that they could reduce their electricity costs by about 30 percent by switching their cold-storage unit off whenever it was not needed. Love et al. (2015b) showed energy savings in an aquaponic farm during the winter if in-line heat recovery units were installed between their aquaculture and hydroponic components, ensuring the fish tanks were kept at an optimum temperature, while irrigating winter crops with cooler water to prevent bolting. Implementing renewable sources of energy such as photovoltaic or solar water heating may also reduce energy costs (Love et al. 2015b; Petrea et al. 2016).

Finally, Blidariu and Grozea (2011) identify the importance of a strong marketing strategy by tapping into a wide range of markets, such as farm direct (farm gate, farmers' markets, agri-tourism), hotel, restaurant and industrial markets (white tablecloth, local restaurants, restaurant chains, hospitals), specialty retail markets (health food, whole food, ethnic, organic) and vegetable/herb wholesale and garden retail centres. They also identified the potential of increasing profit through the production and marketing of value-added products, such as salad mixes, pesto, essential oils and flower arrangements.

Greenfeld et al. (2019) carried out a meta-analysis to summarise the economic benefits of aquaponics. They surmised that there is a widely held view that larger systems are more likely to be profitable than smaller ones, profitability is highly dependent on retail prices and commercial aquaponics can be profitable with creative business planning. This view is largely supported by the literature reviewed, many in common with Love et al. (2015a), but also including Dasgupta and Bryant (2017) who compared production costs in aquaponic and aquacultural systems to show that aquaponics was only profitable when large fish and vegetables were sold. The results by Villarroel et al. (2016) were also included in the review. They compared sixty-eight European producers reporting income generation from the sale of fish and plants, concluding that this new industry was not currently profitable, but might become so in the future.

Difficulties, Risks and Challenges

The ability to make a profit is one of the largest barriers limiting the adoption of aquaponics as a food production technology. This in turn poses an unacceptable risk to potential investors and, consequently, there is a lack of available start-up capital. Many of the papers cited here focus on whether an aquaponics farm can turn a profit under optimal conditions but very few consider the risks of irrecoverable failure of the farm. One such risk is the outbreak of disease, parasites or pests in either the aquaculture or the hydroponic systems. Due to aquaponics being a balanced artificial ecosystem containing three separate types of species (fish, plants and bacteria), it is extremely difficult to treat any form of disease in one species without impacting another (Blidariu and Grozea 2011). Nearly all conventional insecticides are toxic to fish, antibiotics and other treatments for fish diseases/parasites may be taken up by and accumulated by plants in an aquaponics system and antibiotic treatments may eradicate the nitrifying bacterial biofilms within a biofilter (Blidariu and Grozea 2011).

Tokunaga et al. (2015) found that a catastrophic failure of the aquaponics farm, such as a loss of crops or fish die-off, could only happen nineteen times in the projected thirty-year lifetime of their model farm, after which the farm would become unprofitable. During their initial research developing three case studies for their model farm, one of their farms suffered a catastrophic failure resulting in the loss of one of the farm's key vendors. From this example, the development of an effective pest management strategy, aquaponics friendly pesticides and back-up equipment are essential to reduce the risk of catastrophic farm failure.

Another risk is the variability of market prices. Tokunaga et al. (2015) carried out a detailed sensitivity analysis on the impact of price volatility on revenue. They discovered that revenue was most affected by the sale price of lettuce with a 1 percent increase in sale price increasing revenue by 0.8 percent. Operational costs were most sensitive to changes in salaries, electricity and feed costs, with a 1 percent increase in the cost leading to a 0.54 percent, 0.24 percent and 0.13 percent rise in operational costs, respectively. In Tokunaga et al. (2015) the hourly wage was \$9.75; if this increased to \$12.80/hour (a 27 percent total increase, or a 0.91 percent yearly increase) during the farm's thirty-year lifespan the farm's rate of return would drop to zero. Another potential risk factor that cannot be ignored is that the most detailed in-depth economic analyses have been conducted on systems located on islands in a tropical climate (Bailey et al. 1997; Tokunaga et al. 2015). These farms are able to operate year-round without supplemental lighting or heating and, consequently, have much lower power consumption and overall operating costs than farms located in temperate climates. Non-native fruit and vegetables need to be imported and tend to cost more in such islands. The high value of crops such as lettuce and fish can, therefore, make it more economically viable to produce them locally using aquaponics.

Another challenge currently facing aquaponics producers is how to dispose of farm waste. None of the papers reviewed costed disposal of dead fish or waste crops into their business plans. Love et al. (2015b) noted that large farms would need a method to dispose of the suspended solids from aquaculture and this can represent a substantial cost and environmental impact. Environmental regulations regarding waste disposal are becoming more stringent and gate fees for waste disposal are increasing. A potential solution is that solid waste can be used as a fertiliser in decoupled aquaponics systems, such as the three loop aquaponics systems designed by Goddek et al. (2016) and by Yogev et al. (2016), in which solid waste is fed into an anaerobic digester for mineralisation before being introduced to a separate hydroponic system.

Finally, we need to take into consideration the acceptance of products produced using aquaponics by consumers (Figure 11.7). Engle and Beem (2017) discussed food safety perceptions expressed by consumers relating to aquaponics produce. They found that consumers were concerned with bacterial accumulation in aquaponics water and whether bacteria from fish would affect the vegetables; also, whether crops were tested with sufficient monitoring of bacteria being carried out. These food safety concerns might have some validity; Love et al. (2015a) carried out a survey of commercial aquaponics producers and found that only 30 percent of farms had on-site cold storage, 11 percent of farms did not have on-site bathrooms and washing facilities and, most importantly, 38 percent of produces lacked any food safety plan.

Figure 11.7: Fried carp fillet – Carp (*Cyprinus spp.*), along with Nile tilapia (*Oreochromis niloticus*) and Catfish species (Siluriformes), are popular fish in aquaponic production. However, they are generally less popular in western cuisine than marine species and game species such as trout (*Oncorhynchus spp.*) and salmon (*Salmo spp.*).

Conclusions

The aquaponics industry has been rapidly expanding and has potential to produce sustainable organic, locally produced food. The few economic studies that are available show that aquaponics farms are potentially economically viable, and that aquaponics vegetable production is profitable, often subsidising fish production and covering all operational costs in the farm.

The economic feasibility of an aquaponic farm is closely linked to labour, energy and fish-feed costs, and finding methods to reduce costs in these three areas would be significant. The profitability of an aquaponics farm depends heavily on its location, with local markets, climate, maximum and minimum yearly temperatures, average photoperiod, consumer attitudes, access to markets and access to skilled and unskilled labour all playing unique roles in whether a farm might be able to be profitable. There are also other considerations that may impact the widespread adoption of aquaponic production. Producers are most likely to be persuaded to adopt aquaponic approaches by economic viability. However, as consumers become more aware of the environmental credentials of their food, they may be prepared to pay more for fish and vegetables produced by aquaponics.

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CHAPTER 12
SUSTAINABLE PRODUCTION OF ENERGY AND ALTERNATIVE FISH FEED BY ANAEROBIC BIODIGESTION AND INSECT CULTURE FROM WASTE BIOMASS UTILISATION

by Juan F. Sierra de la Rosa, Nora Restrepo-Sánchez[55]*, Carlos Peláez, Joe Sánchez and Carlos Uribe*

Introduction

Increasing global populations and climate change entail important challenges in the use of resources to guarantee energy, water and food security. The projections indicate that in the next 30 years, the global population will reach 9 billion, with a subsequent increase in the demand for water, food and energy of 10 percent, 55 percent and 50 percent, respectively, further accentuating the pressure on natural resources (Food and Agriculture Organization 2017; OECD 2012).

As a result of production processes and food, water and energy consumption being closely linked, efficient resource use must be integrated. In order to meet the demand for products while increasing profitability, preserving biodiversity, and limiting climate change, agricultural and animal husbandry systems must be technologically innovative in three fundamental areas:

1) intensification of production,
2) use of alternate sources of protein and
3) reduction of waste.

The last of these has a special importance in the food supply chain, due to its relatively high carbon footprint (van Vuuren et al. 2017).

The project described in this chapter was developed by the University of Antioquia (UdeA) through the Interdisciplinary Group of Molecular Studies (GIEM). The activities of the GIEM in the Morro Moravia, Medellín, Antioquia, Colombia, were implemented for approximately a decade, with finance from the Medellín city council and within the agreement

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for the environmental conditioning of the Morro Moravia. This place is of particular interest because it is a 35-metre-tall mound comprising 1.5 million tons of waste that were deposited in a landfill between 1972 and 1984. After its closure, the Morro was transformed into a cultural and environmental park, with a broad range of different vegetation covering the landscape (Figure 12.1).

Figure 12.1: aerial view of the Morro Moravia, Medellín

Photograph © Medellín Municipality Press (4 January 2018)
Moravia cuenta con emprendedores en turismo comunitario. Alcaldía de Medellín
https://www.medellin.gov.co/irj/portal/medellin?NavigationTarget=contenido/3557-Moravia-cuenta-con-emprendedores-en-turismo-comunitario

Within the framework of this programme, the development described in this chapter was implemented between 2019-2021. It addresses the integration of anaerobic digestion, insect farming and aquaponics, in a circular economy biorefinery system, using as the main input the organic fraction of municipal solid waste. Each unit of the integrated system has the following outputs:

- Anaerobic digestion: production of biogas, liquid fertiliser and digestate
- Insect farming: alternative source of protein for animal nutrition
- Aquaponics: integrated cultivation of fish and plants

The development began around 2014 with the implementation of an exploratory energy and material waste recovery system as a strategy for the productive use of an area of anthropic land, which, due to its characteristics, did not comply with the conditions for establishing a safe human settlement. The first part of the programme consisted of the assembly of a composting process which later expanded into the exploitation of energy production through anaerobic digestion. Later, with the RAE[56] support, it further expanded into a municipal solid waste biorefinery scheme, including food production.

Aquaponic systems recycle water and nutrients, with low space requirements. This makes the system appropriate for rural or urban low to middle income communities throughout nearly all of Colombia. Due to historical, environmental and social characteristics, Moravia represents an ideal scenario for the development of this type of sustainable circular economic production. The system was operated for food security demonstration purposes and the harvested products (fish and vegetables) were distributed amongst the families of the workers of the Morro Moravia Environmental Conditioning programme[57].

The organic fraction of the municipal solid waste (OFMSW) is treated in a heterophase multistage system, within which the first stage consists of the hydrolysis-fermentation (acidogenesis) of the organic matter. A wet solid fraction called digestate is generated. This can go through aerobic stabilisation to produce compost or fertiliser. The digestate can be alternatively used to feed black soldier fly larvae (*Hermetia illucens*), which process it and generate a new stabilised co-product called frass, which is valuable as fertiliser (Figure 12.2).

[56] This project was co-financed with fresh resources from the UK Royal Academy of Engineering (RAE).
[57] Environmental Project of the Morro Moravia.

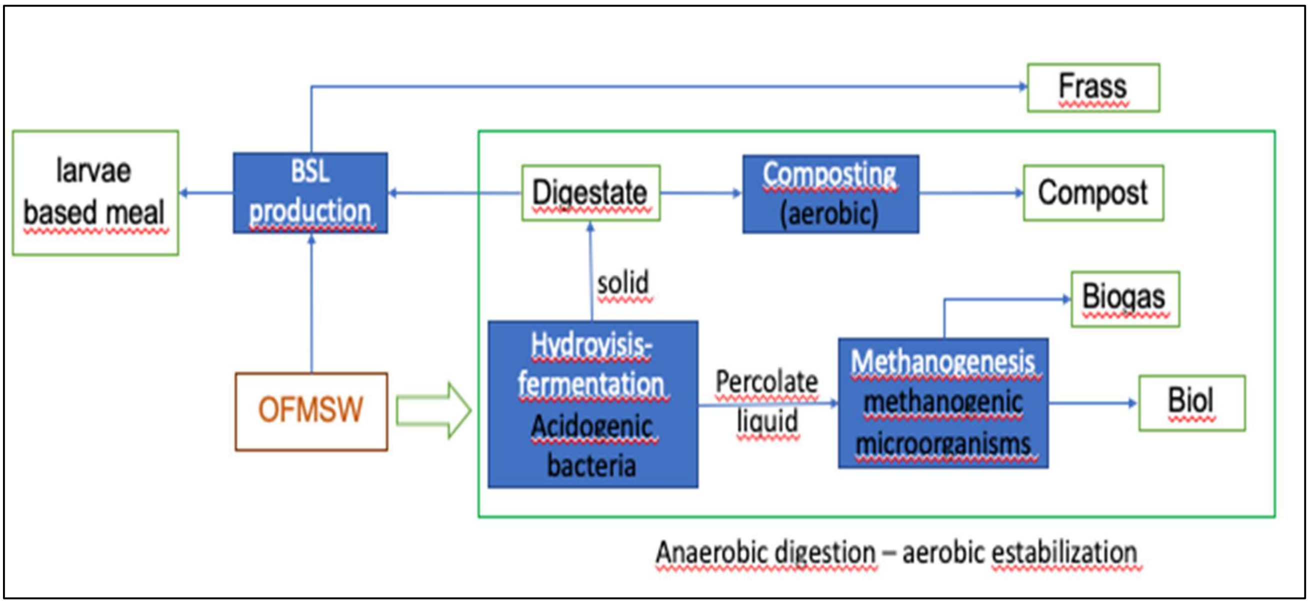

Figure 12.2: Anaerobic Digestion Co-products.

Source © Juan F. Sierra de la Rosa, Nora Restrepo-Sánchez, Carlos Peláez, Joe Sánchez and Carlos Uribe

In the hydrolysis-fermentation process, a liquid percolate is separated, which is rich in soluble organic matter. This percolate is fed to a methanogenic reactor, where biogas is produced as a source of useful energy, along with a liquid fraction containing stabilised organic matter which we call *biol*. This is constituted in the form of a liquid fertiliser. At the start of the process, if there is no demand for the fertilisation product, the OFMSW can also be taken directly to the black soldier fly larvae (BSFL) culture. The objective of this process is to obtain black soldier fly larvae as food for fish. These larvae, in their prepupal stage, are used as part of the food required in animal husbandry, either directly as larvae or transformed into flour by a process of drying and grinding. The estimated yield of BSFL culture is about 25 percent of the organic substrate supplied as food; that is to say, for each 1000 kg of substrate (OFMSW), around 250 kg of larvae are obtained, with a protein content of 42 percent and lipid content of 34 percent.

In order to optimise the nutrient cycle, an aquaponic system was proposed. Such systems integrate aquaculture with hydroponics to simultaneously produce fish and vegetables through a water recirculation scheme. Fish excrete ammonium as a result of the metabolism of the protein they consume. The water that leaves the fish tanks therefore has a high ammonium concentration which passes through a filter of nitrifying bacteria, transforming the ammonium into nitrate. The water, thereby enriched with nitrates and other nutrients, subsequently passes through hydroponic growing units, where these nutrients are absorbed by the plants. The water then leaves the hydroponic units devoid of nutrients and is collected in a reservoir tank to be pumped back into the fish tanks, allowing the cycle to be repeated. In summary, the insect larvae produce food for the fish culture, whose excreta (mainly ammonium) support vegetable production with minimal mineral (iron) supplementation.

The waste products from the aquaponic system, such as sediments, fish and plant harvest residues, serve as inputs for bio-digestion and insect culture processes (Figure 12.3).

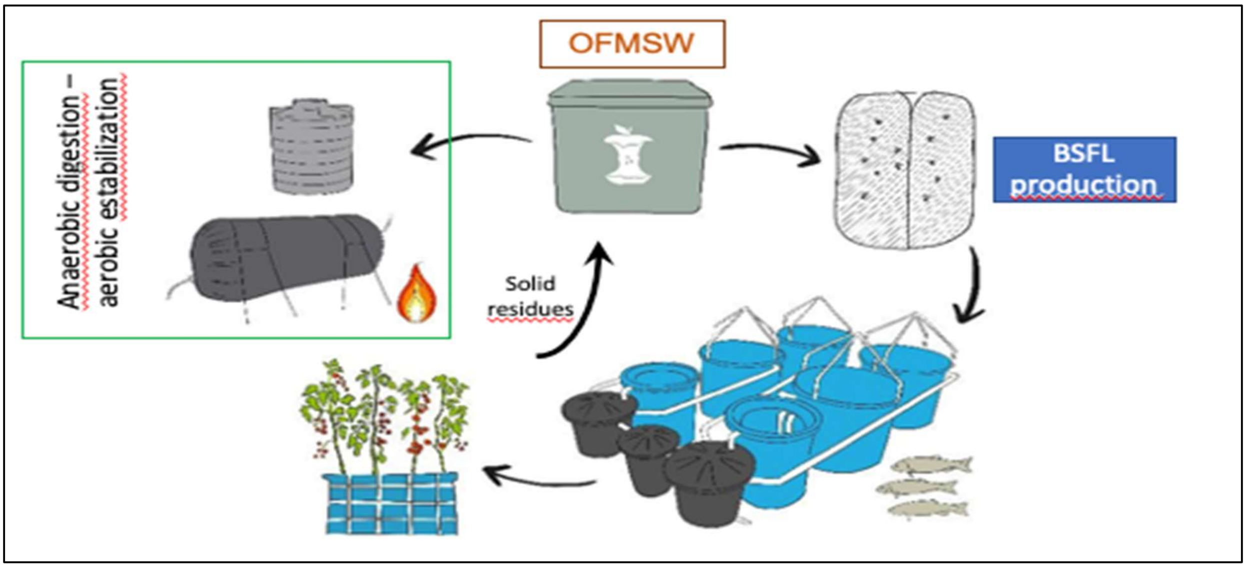

Figure 12.3: Biorefinery Scheme from OFMWS

Source: Bank of GIEM images

The synergy of these three components (bio-digestion, insects/worms and aquaponics) allows for an efficient recycling of nutrients from organic sources which are usually treated as waste, such as, in this particular case, vegetables and fruits discarded by a local supermarket. This biorefinery model has the potential to reduce emissions while producing energy, human food and alternative sources of feed for farmed animals (fish, chickens, pigs, etc.). Furthermore, this biorefinery OFMSW-based scheme is intended to provide business models, based on the efficient use of resources, for small family firms, for both small and medium producers and for communities organised in associativity schemes. In this way, problems related to food security, generation of employment, use of clean energy and of sustainable resources are addressed, while, within a circular economy, reducing the causes of climate change.

The system implemented in the Morro Moravia corresponds to a TRL5[58] prototype (Figure 12.4). It has four fish tanks (100 L each), two conical settlers (500 L each), two aerobic mineralisers (of 250 L each), a biofilter (100 L), four hydroponic substrate cultivation units (1 m^2 each), a hydroponic cultivation module in thin film PVC pipes (NFT[59]) and a reservoir tank (1000L) where the water from the plants arrives to be pumped back to the fish tanks.

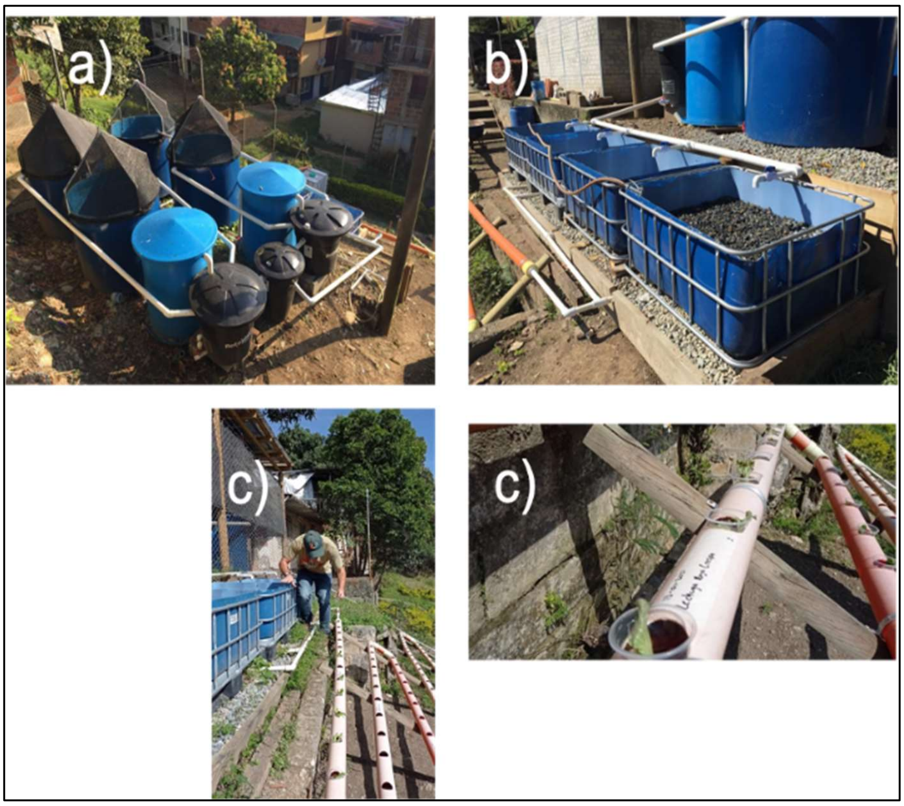

Figure 12.4: Aquaponic system.
a) Aquaculture module composed of fish tanks, sedimentation and mineralisation tanks and biofilter;
b) Hydroponic unit with substrate system for heavy plants and
c) Hydroponic unit with NFT system for leafy light plants.

Photographs © Juan F. Sierra de la Rosa

The aquaponic system was designed to sustain fish production of up to 480 individuals and a vegetable production capacity exceeding 300 seedlings.

[58] Technology Readiness Level. Being at level 5 of TRL means the system is being validated in a relevant surrounding.
[59] Nutrient Film Technique (NFT): Method for growing leafy plants. By directing nutrients through a channel by a stream of water, nutrients form a thin film in the bottom of the channel.

The operational process of the system was designed so that it could be managed by local personnel with a basic level of education. Figure 12.5 shows one of the operators carrying out maintenance work on the biofilter, through which the water that is lost by evaporation must be replaced.

Figure 12.5: Biofilter maintenance ▸

Photograph © Juan F. Sierra de la Rosa

Results

The anaerobic bio-digestion system, fed with the organic fraction of municipal solid waste, was established in the Morro Moravia a few years back within the framework of the environmental recovery programme of the former rubbish dump. The system was consolidated with the processing of around 500 kg/day of the organic fraction of municipal solid waste (OFMSW). The waste was obtained from a supermarket in the neighbourhood which guaranteed proper separation at source, as required in Colombia for feedstock materials to be used in the production of different types of compost and fertilisers. The digestate generated in the hydrolysis reactor finished its stabilisation under aerobic conditions. The compost thus obtained complied with the requirements established by the Colombian regulations mentioned above. The product was used as on-site soil amendment as part of the Morro landscaping programme.

Similarly in the methanogenic stage, a stable production of biogas was maintained, reaching an average constant production rate of 420 L/day (Sánchez 2019). The biogas produced was passed through a cleaning process, where moisture and hydrogen sulfide were removed, and then was stored at low pressure in a biogas reservoir, which is a bag with special characteristics (Figure 12.6). While progress was being made in fine-tuning the equipment for getting the benefit from the biogas in the form of thermal, light or electrical energy, it was burned in torches designed for this purpose. One of its uses of major interest is precisely as thermal energy for stoves used in the preparation of food.

Figure 12.6: Biogas reservoir.

Source: Bank of GIEM images

Once the aquaponic system was assembled, the adaptation of the infant fingerlings began, with the species, black tilapia (*Oreochromis niloticus*), being selected. Four fish tanks were stocked with a total of 390 fingerlings. Two tanks were stocked at low density (65 fish per tank) and the other two at medium density (130 fish per tank), with the aim to observe the effect of the stocking density on fish yield (growth and survival). A design problem with the drains was discovered, which resulted in the accumulation of organic sediments at the bottom of the tanks. This had a critical effect on the higher density option, contributing to a high mortality of fingerlings (approximately 85 percent). This is because species of tilapia inhabit medium- and bottom-water-column levels, which makes them sensitive to contact with sediments of decomposing organic materials and a high bacterial load. In addition to the accumulation of sediments, which increased mortality, the growth of the fishes was found to be affected by the ambient temperature of Medellín. The optimum temperature range for the commercial culture of the Nile tilapia is between 28° and 30°C. The values recorded in the fish tanks of this aquaponic system, however, were between 19.3° and 24.3 ºC; that is to say, between 4 and 9 degrees below the optimum range, reducing fish metabolism, feed consumption and growth.

The fish tanks and the biofilter were monitored for physicochemical variables of water quality. The variables recorded were: the dissolved oxygen content and the concentration of different nitrogen compounds; ammonia, nitrites and nitrates. These variables, assuming an appropriate culture temperature, are the most important for enhancing the fish yield. With these records, it was ruled out that mortality was related to the low oxygen levels or with the high concentration of nitrogenous compounds (mainly in the form of ammonium). The oxygen concentration in the culture units remained above the optimum for the species (>5 mg O_2/l), while the ammonia concentration (≤0.5 mg/l NH_3) remained below the toxic reference value of 2 mg/l NH_3 (Karasu and 2005).

The accumulation of sediment at the bottom of the tanks was resolved by redesigning the drainage grids. With these adjustments, the fingerlings were stocked at a density of 150 fish per tank. Once the accumulation of organic material problem was solved, it was observed that mortality was reduced to zero and that the aquaponic system finally stabilised in terms of water quality and availability of nitrogenous compounds which could be used as a source of nutrition for the hydroponic cultivation.

The seedling plants were sown 40 days after the last two fish tanks were planted, in order to obtain the maturation of the biofilter and the corresponding transformation of the ammonium to nitrate, to be available for the plants. Taking into account the period of high mortality, the hydroponic components were planted at 50 percent of their capacity: two substrate culture containers and 40 thin-film culture (NFT) holes. Two months later, the other two substrate growth containers and an additional 40 holes of NFT were planted. In general, the time elapsed between planting and harvesting of the small-sized vegetables (lettuce and basil) was 40 to 50 days, while for larger-sized plants (zucchini, cherry tomato, pumpkin, aubergine) it was 70 to 80 days, periods which correspond to other reports in the literature for these species (Montes 2005, Beltrano and Giménez 2015).

The culture of insects (black soldier fly larvae, *Hermetia illucens*) was developed on a farm located 40 minutes from Medellín, in the municipality of Heliconia, Antioquia. For the production of the larvae, mixtures of different substrates were tested as food sources, including crop residues and excreta from cattle and poultry. Among the different substrates evaluated, it was decided to advance in a mono-substrate scheme, with the digestate obtained from the bio-digestion of raw poultry manure. Once the rearing was stablished and the larvae were characterised, a larval flour was produced and a fish feed formula was defined, in combination with a commercial feed concentrate (Table 12.1). This formula was generated with the support of Dr Iain Young of the University of Liverpool.

Table 12.1: Fish Feed Composition

Nutrient	**Composition**
BSFL source of proteins	60 %
Starch	17 %
Vegetable oil	15 %
Fish oil	7,5 %
Vitamins and Minerals	0,5%

Analysis of the lipid, protein and mineral contents of the flour compared to maize, showed that the larvae had a high food potential. This formulation will be evaluated in future research. Figure 12.7 shows the dried larvae ready to be processed as flour.

Figure 12.7: Black soldier fly (*Hermetia illucens*) larvae cultured with residual biomass

Source: Bank of GIEM images

The production system for BSFL flour (black soldier fly larvae) continues to operate as a prototype to evaluate the conversion of different types of residual organic substrates. This permits new projects to consolidate the integration of the systems in the biorefinery scheme proposed in figure 12.2 above.

Vegetable Production

As regards vegetable production, Figures 12.8 to 12.12 illustrate the crop development and part of the harvest.

◂ **Figure 12.8:** lettuces grown in hydroponic module in thin film for small sized plants

Source © Bank of GIEM images

Figure 12.9a: ▸
and
◂ **Figure 12.9b:**

yellow zucchini grown in hydroponic module of cultivation in substrate for large sized plants

Figure 12.10: ▸
harvest of curly purple lettuce

Above photographs 12.9, 12.9b and 12.10
© Juan F. Sierra de la Rosa

Figure 12.11: ▸
harvest of a wild
West Indian pumpkin

◂ **Figure 12.12:**
harvest of basil grown
in hydroponic module in thin film.

Above photographs 12.11 and 12.12
© Juan F. Sierra de la Rosa

Fish Production

The fish harvest in the stabilisation phase of the system yielded a total of 389 fishes. For the low-density tanks there was a survival rate of 35 percent, while the high-density tanks only reached a rate of 15 percent. According to the growth reference data for this species, a 21-week (~150 days) tilapia culture at optimum temperature (28-30ºC) would have an approximate weight of 180 g (Food and Agriculture Organization 2009), which contrasts with the average weight of 104.7 ± 33.4 g obtained from the low density tanks and even more so with the 35.9 ± 15.2 g average weight obtained in the medium density tanks.

For fish it is generally accepted that an increase of 10ºC in the culture water (also known as the temperature coefficient – Q10), is equivalent to doubling the growth rate. Since the temperature of the Moravian tanks were between 4ºC and 9ºC below the optimum culture temperature, its considered that the growth rate recorded in the low density tank (65 fish/ tank) corresponds with the expected values. Figure 12.13 shows some of the freshly harvested fish.

Figure 12.13: Harvest of black tilapia (*Oreochromis niloticus*)

Photograph © Juan F. Sierra de la Rosa

The harvested fish were distributed among the project staff. Figure 12.14 shows the operators that supported the gardening process in the Morro Moravia, some of which accompanied the operation of the aquaponic system.

◂ **Figure 12.14:** workers in charge of gardening work in the Morro Moravia

Photograph © Juan F. Sierra de la Rosa

Figure 12.15 shows the preparation of the fish by those in the neighbourhood. This corresponds with a widely used recipe in Colombia, which is the most common and commercial way to serve fish. The frying preparation turns out to be the easiest from a culinary point of view and minimises the smell when serving the product at the table, which is recognised as one of the barriers to fish consumption (Food and Agriculture Organization 2014).

Figure 12.15: ▸ Preparation of fried tilapia

Photograph © Juan F. Sierra de la Rosa

As seen in the picture, a fried fish should always be accompanied by a good fried green banana, which we call *patacón*. In this way it is served with cooked rise and a salad composed of avocado, tomatoes and onion with a basic dressing of salt, oil and lemon.

Conclusion

In Colombia the consumption of fish is much lower than that of other protein sources, although its nutritional benefits are recognised. The distance between the large cities and the sea as well as a weak cultural tradition in the consumption of this food, among other factors, discourages its use in the Colombian population (El Universal 2022). Although, the consumption per capita reached 9.6 kg per annum in 2020, a historic increase, it still places us well below the global average consumption of 19 kg per annum (Food and Agriculture Organization 2014). In this scenario, the possibility of generating centres of production in urban environments can be an excellent alternative way to increase fish consumption. This suggestion should be seen in perspective as a strategy for contributing to food security, even more so if treating fish as a product of high nutritional value. This combined with the articulation of a vegetable production system, points to the projection of urban agriculture.

The synergy of the three components (bio-digestion, insects/worms and aquaponics) permits an efficient recycling of nutrients from organic sources, in this particular case vegetables and fruits discarded from local supermarkets, which are usually treated as waste. This biorefinery model has the potential to reduce emissions, at the same time producing energy, food for humans and alternative feed sources for farm animals.

The fish production phase should be evaluated in other environmental temperature conditions, with the use of other species adapted to mild temperatures or with a configuration that minimises heat loss to optimise fish growth.

Aquaponic systems recycle water in addition to nutrients and require little space, which convert them into systems potentially suitable for low to middle income, rural or urban, communities anywhere in Colombia. This type of production system merits more research and development to optimise productivity along with its easy operation and low maintenance costs.

Epilogue

However, the whole project reported here had to be removed from the Morro Moravia to be replaced by informal 'housing' due to socio-political circumstances that were accentuated during the COVID-19 pandemic, resulting in a massive invasion of informal 'housing'. Figure 12.16 shows a part of the Morro in 2021 with a few shanty constructions of wood and tin. This human settlement on an anthropic and unstable mountain, with all the social connotations, should be the subject of another whole book.

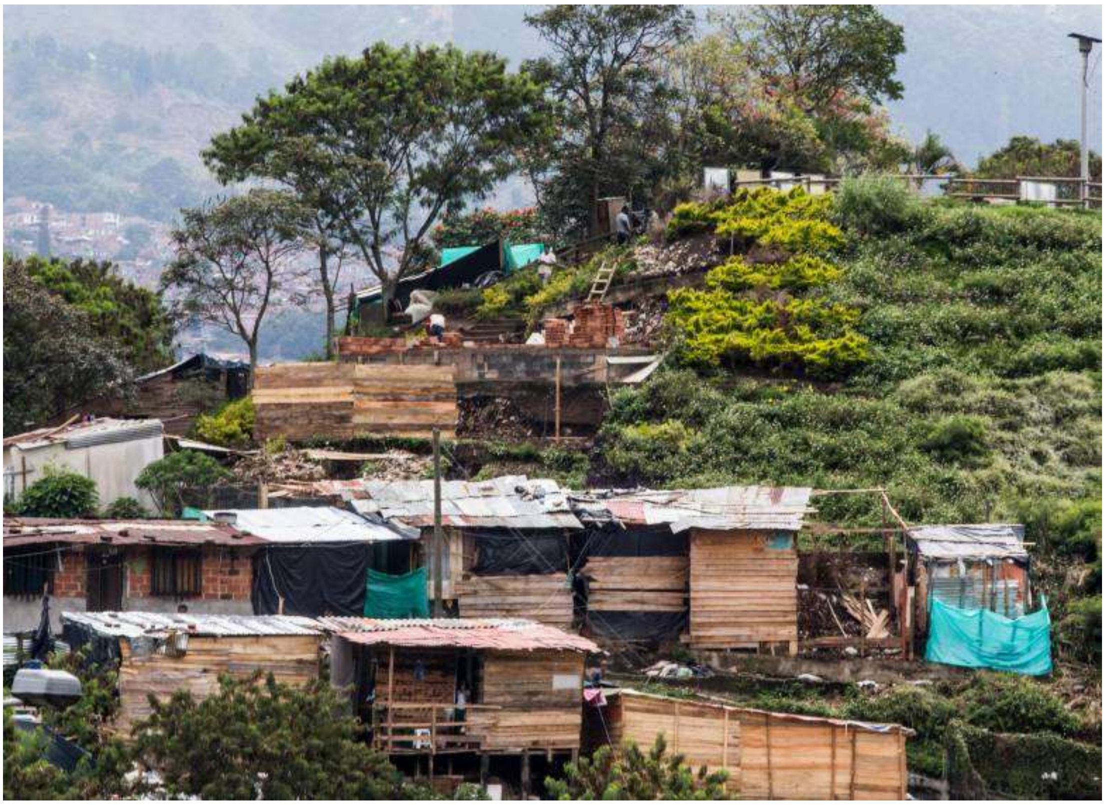

Figure 12.16: The state of the Morro Moravia in 2021 after being invaded by informal housing

Photograph © By Herrera, J. C., (3 March 2022) El morro de Moravia se termina de poblar sin control alguno. El Colombiano *https://www.elcolombiano.com/antioquia/el-morro-de-moravia-se-termina-de-poblar-sin-control-alguno-EF16750307*

Although unfortunately the initiative to establish El Morro as a model of environment and food sustainability was truncated, the results and infrastructure of the bio-refinery project from the organic fraction of urban solid waste were transferred to other places, and work continues on the consolidation of the model.

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EPILOGUE: CHANGE AND CONSIDERATIONS FOR THE FUTURE

by Iain Young, Diana Roberts and Helen Macbeth

Through anthropological and archaeological studies of the distant and recent past, and contemporary ethnography, as exemplified in this book, we know of geographic, cultural and social group differences regarding the human consumption of fish as food, and we can presume much more than has ever been recorded. This diversity may be due to variances in local availability of different fish species,[60] in the technology available for capturing and processing them, cultural beliefs in what is or is not deemed to be suitable as food and dietary preferences, even age and social roles within families or societies. Now, with the impact of climate change on ocean temperatures and currents, together with the effects of increasing industrialisation of international fishing fleets on fish populations, even the localities of marine species that were traditionally a food source for a particular population are changing. So, in this Epilogue we wish to emphasise change and considerations for the future.

An example of a contemporary cultural shift in the edibility of a particular class of fish due to changes in a belief system is explained by Nijman in Chapter 3. He describes how a recent reinterpretation of an Islamic classification has led to the acceptance of eel consumption in Indonesia, where they are plentiful yet previously forbidden. In Chapter 8, O'Sullivan et al. discuss a contemporary change in the UK with increased fish farming, going on to describe opportunities for aquaculture in the coastal waters of the Mersey near Liverpool, echoing projects in Maine mentioned by Messer in Chapter 1. Cheng's Chapter 4 identifies ongoing changes due to the enterprise of recently returned urban-to-rural migrants in Taiwan. Whereas the economic patterns of the Dhofari fishermen, described by Risse in Chapter 7, may seem steeped in longtime sociocultural traditions and values, yet, the Dhofari boats and gear described are contemporary and change can be anticipated as further forces of modernisation, electronic communication, globalisation and unforeseen politics are all likely to contribute to change in their socioeconomic values, even if some other cultural patterns may seem

[60] Throughout this book the terms 'fish' or 'seafood' usually include fin fish, crustaceans, molluscs and cephalopods.

to withstand change. The latter chapters of this book by Magee, Anderson and Young discuss different perspectives on the changing technologies of aquaculture, while considering environmental changes and future food security for humans. The final chapter in the book, by Sierra et al., is submitted as a hopeful model for change in the future. Sadly, however, the project described ultimately failed due to external, political change and impacts from the COVID-19 pandemic.

Historically, culturally and nutritionally the importance of fish as food seems clear. Fish are one of the most used sources of animal protein worldwide (Allam et al. 2020; Maulu et al. 2020). Offering a low cost, yet valuable source of essential nutrients (proteins and fats), vitamins and minerals. Fish are often of greatest importance in low- to middle-income countries where they can account for over 75 percent of an individual's animal protein intake (Maulu et al. 2021). On a planet where 70 percent of the surface area is covered with water, access to wild-caught and/or farmed fish may be able to mitigate the global challenge of food security (Maulu et al. 2021). Furthermore, it is worth noting that Japan, the country with one of the world's highest life expectancies and lowest incidence of obesity-related heart diseases, also tops the charts for consumption of fish and other aquatic products (Tacon and Metian 2013).

Another source of contemporary and transnational change is the increasing scientific knowledge of nutrition and health, and the very varied dissemination and influence of that knowledge. Globally fish consumption is increasing, with production of both wild-caught and farmed fish peaking at about 171 million tonnes in 2016. Of this 47 percent came from aquaculture, making it the world's fastest-growing food production system since the early 1980s. In comparison, only 11 percent of fish production came from aquaculture in 1980 (Food and Agriculture Organization 2018 and 2020; López-Mas et al. 2021). Yet this growth in aquaculture remains relatively low in Europe. In 2019 only around 22 percent of all fish consumed in Europe came from aquaculture (European Commission 2022), and there has been a reduction in the consumption of farmed fish in the European Union (EU), which seems to result from a perception that farmed fish are inferior to wild-caught fish. López-Mas et al. (2021) surveyed over 2,500 consumers from five EU countries about their beliefs associated with farmed fish versus wild-caught fish. They found that many of the respondents held beliefs that were not wholly supported by scientific fact but were based instead on preconceptions and misinformation.

For instance, many believed that wild-caught fish was fresher than farmed, whereas the opposite is usually true because of efficient and faster farm-to-market distribution channels. Many participants believed that farmed fish contain antimicrobial residues and, indeed, they have been found in aquaculture products from various parts of the world (Okocha et al. 2018). The global antimicrobial use in animals raised for food, including aquaculture, was estimated at over 63,000 tons in 2010, and projected to rise by 67 percent by 2030. Residues of antimicrobials in food pose an increasing food safety and public health concern. Not least, the growing threat to public health of antimicrobial resistance (AMR) (Okocha et al. 2018).

Considering this risk, in 2015 the World Health Organization (WHO) established the Global Antimicrobial Resistance and Use Surveillance System (GLASS) to monitor AMR in common bacteria and invasive fungi, and antimicrobial consumption (AMC) in humans. By the end of 2022, 127 countries, territories and areas participated in GLASS (World Health Organization 2022). Between 2011-15 the European Commission (EC) developed an Action Plan to be implemented by 2016 to address AMR. While mainly addressing the problem at the EU-level, the recommendations also included international cooperation and communication (Smith et al. 2016). Based on 2018 levels, the EU aims to reduce the use of antimicrobials in farmed animals and in aquaculture by 50 percent by 2030. A target that is looking achievable as between 2018 and 2022 there has already been a reduction of approximately 28 percent in the use of antimicrobials (European Environment Agency 2024).

As well as antimicrobial pollution, are the high levels of chemical and plastic pollutants entering the oceans and increasingly threatening the lives of marine and coastal organisms – including humans.

Over eighty percent of marine pollution is ‘runoff’ from the land, carrying chemicals from agriculture, sewage and unmanaged urban and industrial waste, including nitrogen-phosphorous from agriculture and aquaculture, pesticides, crude oil and other petroleum products, antifoulants from shipping, pharmaceuticals and personal care products, heavy metals and industrial discharge (Figure 13.1). These can accumulate in seafood, making it harmful for humans to consume (National Oceanic and Atmospheric Administration n.d.).

Figure 13.1. Image showing 'runoff' from land to sea

Image credit:
National Oceanic and Atmospheric Administration

Marine plastic pollution (Figure 13.2) has been cited as a major global threat, and attracted much recent attention, increasing by 1000 percent since 1980, affecting at least 267 species, including 86 percent of marine turtles, 44 percent of seabirds and 43 percent of marine mammals (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) 2019). Microplastics – defined as plastic particles ranging in size from 5 mm to 100 nm – can be ingested by fish and shellfish. Humans can absorb them through ingestion, inhalation or skin contact. The potential damage to health is of increasingly concern. Critically, recent research found microplastic contamination in 26 out of 34 samples of human breastmilk (Ragusa et al. 2022).

Figure 13.2. Not such a paradise – non-biodegradable plastic littering Kanapou Bay, on the Island of Kaho'olawe in Hawaii

Image credit:
National Oceanic and Atmospheric Administration

Other studies have looked at the nutritional profile of farmed versus wild-caught fish. It is commonly held that Omega-3 fatty acids have health benefits and it is often thought that a better balance is found in wild-caught fish. Two omega-3 long-chain polyunsaturated fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are generally regarded as the most important for human nutrition (Gladyshev et al. 2018). The concentration of these varies widely between fish species, but the highest EPA and DHA concentration is found in marine species that eat zooplankton and are fast swimming, particularly species of the order Clupeiformes, notably the herring and anchovy families, or those that migrate from fresh to marine waters, notably Salmoniform species, such as salmon, trout, char and whitefish (Gladyshev et al. 2018). Yet, it is relatively simple to modify the nutritional profile of farmed fish, including their fatty acid profile, by supplementing their feed appropriately (Kwasek et al. 2020).

Nevertheless, flesh quality is usually firmer in wild-caught fish and they usually have lower total fat content (Cahu et al. 2004; Johnston et al. 2006). To confound the situation further, Chen et al. (2024) found from a cohort study of over 400,000 participants, aged 40-69 years, that among those free of cardiovascular diseases regular use of fish oil supplements was associated with an increased relative risk of atrial fibrillation and stroke. Yet among those with known cardiovascular disease, fish oil supplements were seen to mitigate the worsening of disease, i.e. from atrial fibrillation to major adverse cardiovascular events, even death.

The impact of climate change on fish stocks, fisheries, and the communities that rely on these as their main source of food and income is already clear (Barange et al. 2018; Cheung et al. 2021). Over the last twenty years extreme temperature events have had a profound impact to the detriment of marine biodiversity and ecosystems in all ocean basins (Barange et al. 2018; Cheung et al. 2021). It is thought that eighty percent of exploited fishes and invertebrates will decrease in biomass with substantial losses of between three and twelve percent by 2050 in fisheries around the globe (Barange et al. 2018; Cheung et al. 2021).

The impact of these climate-induced changes in fish stocks and shifts in the geographical location of fisheries increases the risk of conflict over these fisheries, creating challenges to current maritime boundaries and disputes involving fishing rights. As fisheries shift between Exclusive Economic Zones[61] conflicts over the rights to exploit them are more likely and can only be avoided by proactive cooperation and equitable decision making (Vogel et al. 2023). It is also speculated that these geographical shifts in ocean productivity and fishery resources can precipitate violent conflict (Lu and Yamazaki 2023). In addition, these impacts can drive human migration as communities attempt to follow the shifting fisheries or lead to migration away from coastal areas as people seek other sources of food or employment (Mendenhall et al. 2020).

Environmental changes and their impact on fisheries can cause conflicts which have become more frequent over the past forty years (Spijkers et al. 2019 cited in Mendenhall et al. 2020), such as the recurrent

[61] Exclusive Economic Zones are areas of ocean where one state has jurisdiction over its resources.

fisheries-related conflicts between North and South Korea (Song 2015 cited in Mendenhall et al. 2020). But what of the impact of human conflict on the environment and fisheries? In June 2023, large quantities of dead algae, fish and jellyfish were washed up on the Romanian and Bulgarian shores of the Black Sea. The war in Ukraine, as well as climate change, pollution, overfishing and invasive species have impacted the environmental conditions of the sea, especially around the Crimean Peninsula, previously well known for its productivity (Radulescu 2023). Between February 2022 and 2024 Russian forces destroyed one-third of Ukraine's fresh water and thereby their potable, industrial and agricultural water supplies, which in turn impacted both current crop irrigation and inflicted potentially long-lasting damage on commercial fisheries, including destroying spawning grounds (Hapich et al. 2024).

It might seem clear to most of us that climate change will impact fisheries, but perceptions of climate vulnerability differ widely, both locally and globally. Furthermore, because perception influences behaviour, perception determines the likelihood of individuals, communities and states taking preventative and remedial actions. On the west coast of the USA, for example, under half of the participants in a survey of members of fishing communities think that they will be personally impacted by climate change (Nelson et al. 2023). In the face of rising costs and increasingly stringent regulations, the fishers were more concerned about these than global issues, such as environmental change. Runnebaum et al. (2023) also found that the fishers' perception of the impact of climate change determined their willingness to engage in adaptive measures. Temperatures in the Northwest Atlantic are increasing, impacting fish migration patterns and productivity. Members of fishing communities in the Northeastern United States revealed that over seventy percent of respondents believe climate change is occurring and over fifty percent believe climate change will harm them personally, but like the fishers from the west coast (Nelson et al. 2023) respondents were more concerned with local and individual issues (regulations, market forces and access to fisheries) than climate change (Runnebaum et al. 2023).

Underpinning all environmental and economic concerns and, indeed, driving the very need for increased yet sustainable food production, is the highly significant aspect of increasing human population numbers. The global human population as of 2023 stands at 8.1 billion and is expected to reach 10 billion around 2060, before slowing and then perhaps even falling slightly by 2100 (Figure 13.3) (Ritchie et al. 2023). For most of human history the population was relatively small, only reaching one billion in 1800. The seven-fold increase since has been driven by an exponential growth rate, peaking at 2.3 percent in 1962-63 and has been falling ever since, standing at 0.9 percent in 2023 (Figure 13.3).

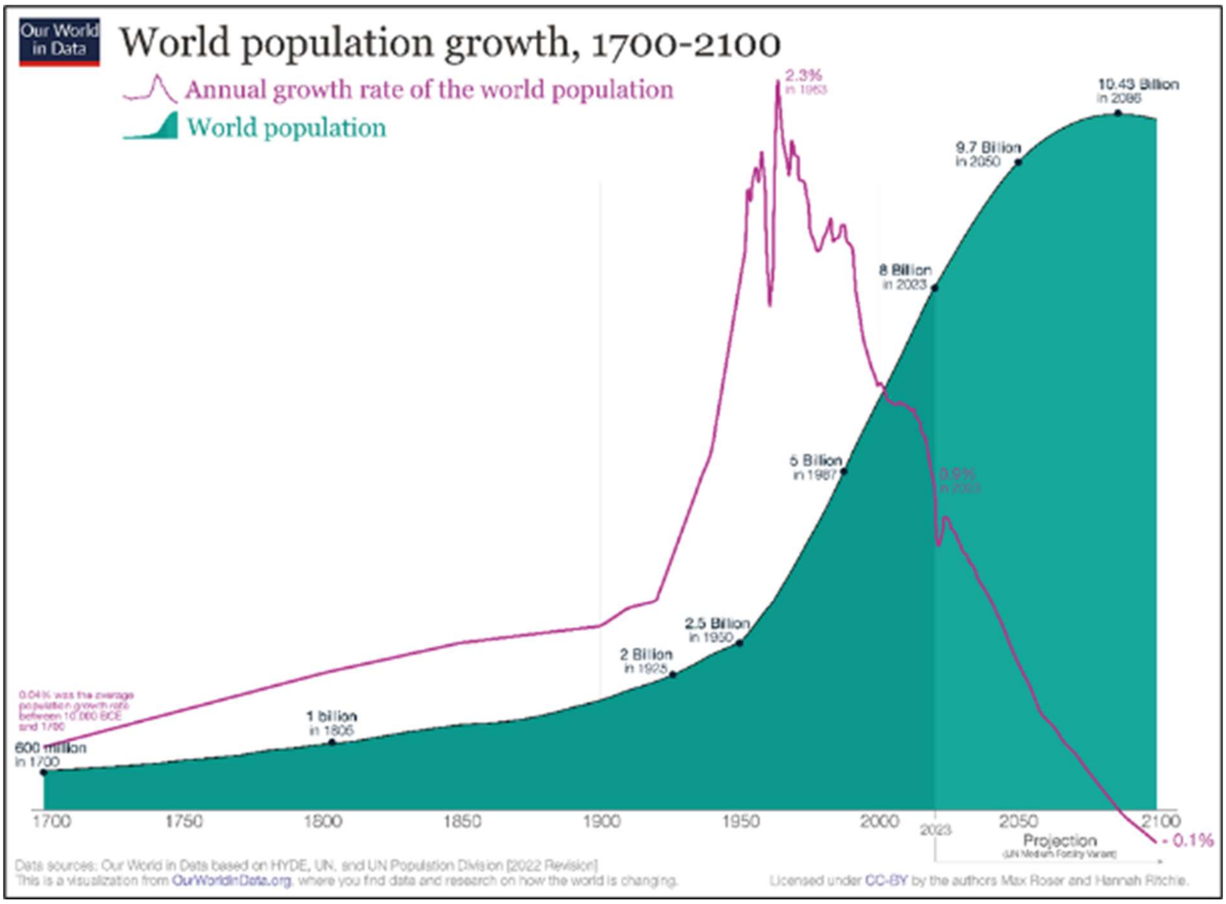

Figure 13.3. Graph showing World Population (green) and Annual Growth Rate (red) over four centuries, between 1700 and 2100

(Ritchie et al. 2023; Roser and Ritchie 2023)

During the last fifty years Asia has experienced the greatest and most rapid population growth.[62] Currently its population is around 4.8 billion and due to rise to around 5.3 billion by 2050. It is then expected to drop back to around today's levels by 2021. The most significant population growth

[62] In 2018 6 out of 10 people in the world lived in Asia and Oceania, largely in China and India with 18.5 and 17.7 percent respectively of the global population (Roser 2018). In 2022, India overtook China, with more than 1.43 billion people. Whereas in China – still the second most populated country in the world with just above 1.4 billion inhabitants – the population started to decline in 2023.

between now and 2100 is expected to be in Africa,[63] growing from around 1.4 billion (around 18 percent of the world population) in 2023 to just under 4 billion (around 38 percent of the world population) by 2100. The result is that by 2100 more than 8 out of every 10 people in the world will live in Asia or Africa (Ritchie 2019).

With respect to food security and in the face of climate change, the ramifications of this are enormous. Particularly the likelihood of increasing extreme poverty in Africa (Ritchie 2019). Socially this is likely to lead to hardship, violence and mass migration. Whereas environmentally this is likely to drive deforestation, desertification, soil erosion, severe droughts drying up inland waters and rivers, and immense loss of biodiversity – both on land and sea.

As numerous Intergovernmental Panel on Climate Change (IPCC) reports (e.g., Intergovernmental Panel on Climate Change 2023) have described, human-induced global warming is having a significant impact on coastal ecosystems, biodiversity and the distribution of marine organisms. This is particularly in tropical regions such as coastal Africa, where climate change is already impacting some regions. For instance, the south-east coast of Africa in the Indian Ocean is one of the regions where the greatest temperature increases have been recorded (Intergovernmental Panel on Climate Change 2019).

By 2050, it is estimated that fisheries catches will decrease by 7.7 percent worldwide – a decrease that could reach 26 percent in West Africa and even more in countries closer to the equator: 53 percent in Nigeria, 56 percent in Côte d'Ivoire and 60 percent in Ghana (Lam et al. 2016). Such a decline in catches will affect the livelihoods of more than 12 million men and women who work in Africa's artisanal fishing sector, as well as affecting the health and nutrition of millions of African families for whom fish is an essential source of protein, vitamins and minerals as the availability of and access to fish declines (Coalition for Fair Fisheries Arrangements 2021). In Chapter 8, O'Sullivan et al. describe the impact on local coastal communities

[63] In referring to 'Africa' as a single entity, it is important to remember it is a vast continent, not a single country, with extraordinary diversity geographically, environmentally, culturally, linguistically, genetically, let alone its biodiversity.

in West Africa of international fishing vessels depleting local offshore fish stocks to supply feed for aquaculture production of salmon in the UK.

To meet the increased global demand, how much food will therefore be needed? Van Dijk et al. (2021) undertook a meta-analysis of projected global food[64] demand and population at risk of hunger for the period 2010–2050. Taking climate change into account, they found that between 2010 and 2050 the total global food demand is expected to increase by +30 percent to +62 percent, and the population at risk of hunger is expected to change by −91 percent to +30 percent.

Currently fish produced from the ocean – either from wild or farmed fisheries, thus excluding land-based aquaculture – accounts for 17 percent of the global production of edible meat (Costello et al. 2020). Investigating the potential to expand production of fish from wild fisheries, finfish mariculture[65] and bivalve mariculture sustainably to meet global food demand in 2050, Costello et al. (2020) found that increases in all three sectors are possible especially in mariculture. Overall, they found that marine fish production could increase by 21–44 million tonnes by 2050, a 36–74 percent increase on current yields. Of all the meat that will be required to feed the nearly 10 billion people by 2050, this represents 12–25 percent of the estimated increase. To realise this, however, will depend on policy reforms, technological innovation and how demand shifts in the face of changing behaviours (Costello et al. 2020).

Therefore, in order to create a sustainable food future for around ten billion people by 2050, we end with a similar sentiment to that with which we started: the necessity of recognising and integrating local perspectives alongside global efforts to respond to the challenges posed by the whole gamut of environmental and economic issues. Since fish must surely be an important component in achieving human food security, then understanding concerns and priorities of individuals and of fishing communities is essential for fostering meaningful engagement and effective implementation of measures aimed at mitigating the impacts of environmental change. By

[64] 'Food' in this context refers to all food types: crops, dairy, fish and meat.
[65] Mariculture has been defined as the cultivation, management, and harvesting of marine organisms in their natural environment (including estuarine, brackish, coastal and offshore waters) or in sea enclosures such as pens, tanks, or channels (Laird 2001).

acknowledging and addressing local perspectives, policymakers and stakeholders can enhance the resilience and sustainability of fisheries management strategies, ultimately contributing to the preservation of marine ecosystems on a global scale. Perhaps we also need to ask the very big and inconvenient question: whether humanity, in the face of such population growth and these profound environmental and economic problems, can afford to continue to consume the flesh of other animals, both aquatic and terrestrial, at the ever-increasing levels found in many societies today? Can we find and develop sufficient new – aquatic and terrestrial – sources of appropriate, essential proteins to meet these demands more sustainably and healthily?

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Photograph on back cover
Langoustines as served at Kylesku Hotel, Scotland

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Anthropological and Cross-disciplinary Perspectives

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Helen Macbeth is a past President of ICAF and a retired Principal Lecturer in Anthropology at Oxford Brookes University, UK.

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