EN

Discussion Paper

The role of aquatic foods in sustainable healthy diets

UN Nutrition

May 2021

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Acknowledgements

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The following individuals and organizations are gratefully acknowledged for providing comments and support during the review process: Richard Abila,[13] Emelyne Akezamutima[13], Ilaria Bianchi[13], Marcio Castro De Souza,[1] Joyce Njoro,[13] Johanna Schmidt[14] and Bendula Wismen.[2]

The report was prepared under the overall management of Stineke Oenema (UN Nutrition).
Poilin Breathnach and Sile O'Broin edited the document; the graphic design is by Faustina Masini.

This publication was made possible by the generous time and expertise provided by FAO, Fisheries Division and the CGIAR Research Program (CRP) on Fish Agri-food Systems (FISH), led by WorldFish.

This work contributes to the CGIAR Research Programme (CRP) on Fish Agrifood Systems (FISH), led by WorldFish. This programme is supported by contributors to the CGIAR Trust Fund.

1. United Nations Food and Agriculture Organization, Fisheries Division
2. WorldFish
3. UN Nutrition
4. Washington University in St. Louis
5. Global Environment Facility (GEF)
6. United Nations Global Compact and Lloyd's Register Foundation
7. Independent
8. Global Action Network on Sustainable Foods from the Oceans and Inland Waters
9. Leibniz Center for Tropical Marine Research (ZMT)
10. French National Centre for Scientific Research (CNRS) and Sorbonne University
11. Oceana
12. Wageningen University and Research
13. International Fund for Agricultural Development (IFAD)
14. United Nations Food and Agriculture Organization, Social Protection Division

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1 Background

In 2017, the United Nations Standing Committee on Nutrition (UNSCN) published a "global narrative" on nutrition, entitled *By 2030 end all forms of malnutrition and leave no one behind* (UNSCN, 2017a). This contributed to the beginning of the United Nations Decade of Action on Nutrition (2016–2025) and described the nutrition landscape, building on a comprehensive set of international targets and goals, including the World Health Assembly global nutrition and non-communicable disease targets, the 2030 Agenda and the commitment and framework for action of the Second International Conference on Nutrition (ICN2).

Although current food systems produce enough food to feed the global population, the cost of a healthy diet is unaffordable for many people. An unhealthy diet also has "hidden" healthcare costs (in addition to the negative health effects) and negative environmental impacts (FAO, et al, 2020). The COVID-19 pandemic is expected to exacerbate food insecurity and undernourishment through disruptions to food supplies and loss of income, with an additional estimated 83–132 million people becoming undernourished (FAO et al., 2020). This highlights the fragility of food systems and the significance of global coordination to promote diets that are socially, economically and environmentally sustainable (FAO et al., 2020; HLPE, 2020).

Despite growing recognition of the importance of sustainable healthy diets, efforts to promote them are still lacking a robust and well-defined narrative. To this end, in 2019, the EAT–Lancet Commission published planetary health guidelines (Willett et al., 2019), while the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) published a set of Principles for Sustainable Healthy Diets in an attempt to define this narrative (FAO and WHO, 2019a). While these principles have played a significant role in helping to frame the narrative, disagreement and debate continue over animal-source foods and defining what is meant by "moderate" consumption.

While terrestrial food production systems provide the majority of foods consumed globally (Duarte et al., 2009), there is growing recognition of the role of fish[1] and seafood[2] (not aquatic foods more broadly[3]) in food security and nutrition, not just as a source of protein, but as a unique provider of omega-3 fatty acids and bioavailable micronutrients (FAO, 2020a; HLPE, 2014; 2017). However, present food systems fail to recognize the diversity of aquatic foods, their potential to contribute to sustainable healthy diets and their potential as a solution to address the "triple burden of malnutrition" (micronutrient deficiencies, undernutrition, and overweight and obesity) (FAO, 2020a). Moreover, certain aquatic

1 Including fish, crustaceans, molluscs and other aquatic animals, but excludes aquatic mammals, reptiles, seaweeds and other aquatic plants (FAO, 2020a).

2 Definitions of seafood vary, but the most common is edible marine fish and shellfish (Merriam Webster). Although the term is broadly used, in this report, we use "aquatic foods" to describe a greater diversity of foods. We use "seafood" in the context of food-based dietary guidelines (FBDG), as aquatic foods more broadly are not currently recognized in FBDG, and when referring to seafood-borne illnesses. Note, however, that food safety is important for all aquatic foods.

3 Animals, plants and microorganisms that are farmed in and harvested from water, as well as cell- and plant-based foods emerging from new technologies (WorldFish, 2020).

foods, such as some finfish species, are often considered for their commercial or economic value rather than their contribution to healthy diets. The Global Action Network on Sustainable Food from the Oceans and Inland Waters for Food Security and Nutrition[4] was formed under the umbrella of the United Nations Decade of Action on Nutrition, in response to the advice of the Committee on World Food Security (CFS) (HLPE, 2014), to promote recognition of aquatic foods for food security and nutrition.

This discussion paper aims to build consensus on the role of aquatic foods in sustainable healthy diets, presenting the breadth of evidence available to inform and steer policy, investments and research to make full use of the vast potential of aquatic foods in delivering sustainable healthy diets and meeting the Sustainable Development Goals (SDGs). Many references in this paper focus on finfish and highlight examples of other aquatic animals and aquatic plants for which evidence exists, as most studies and data on aquatic foods focus on the production or conservation of few economically valuable finfish species rather than the broader nutritional value of the diversity of foods derived from aquatic resources.

Increased attention on aquatic foods is beneficial and badly needed. This paper will be accompanied by another paper on the role of livestock-derived foods (such as meat, dairy and eggs). Together, the papers aim to highlight the role of a diverse range of animal-source foods and aquatic plants, such as seaweed, in sustainable healthy diets.

4 For more information on the Global Action Network, please see: https://nettsteder.regjeringen.no/foodfromtheocean/about-the-network/.

2 Introduction

Our oceans and inland water bodies are a vital source of nutritious food worldwide. Aquatic foods include a diverse group of animals, plants and microorganisms, each with unique qualities and nutrients, such as iron, zinc, calcium, iodine, vitamins A, B12 and D, and omega-3 fatty acids (see Annex 1 for the importance of these nutrients). In addition, the micronutrients in aquatic animals are highly bioavailable (WHO, 1985). Aquatic animals also enhance the absorption of micronutrients such as iron and zinc from plant-source foods when consumed together (Barré et al., 2018). Moreover, consuming aquatic foods presents an opportunity for greater sustainability, as the production of aquatic animal-source foods has a lower environmental impact than the production of most terrestrial animal-source foods (Hilborn et al., 2018).

Many rural poor are engaged in small-scale fishing and aquaculture activities (FAO, 2012b; Thompson and Subasinghe, 2011). About 50 percent of all people employed in the primary and secondary sectors of fisheries and aquaculture are women, many of whom work in the post-harvest stage (FAO, 2020a). In addition to their direct and indirect contributions to food security and nutrition through direct consumption and livelihood opportunities, aquatic foods have a "multiplier effect" through animal feed for terrestrial food production. While this can help to improve livelihoods for some, it also raises concerns about the diversion of food to feed and the Right to Food.

The *State of Food Security and Nutrition in the World 2020* highlighted trends in recent years, including the challenges presented by climate variability, the COVID-19 pandemic, economic slowdowns and the high cost of a healthy diet with respect to the efforts to end hunger, food insecurity and malnutrition (FAO et al., 2020).

Since the concept of food security was first introduced in 1974, it has evolved, moving away from quantitative components (emphasizing the production and quantity of food) towards qualitative components (emphasizing nutrient quality and food safety), including equity issues, similar to previous work on access and the human right to adequate food (Sen, 1981) and elements of agency and sustainability (HLPE, 2020).

"Sustainable Healthy Diets are dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable. The aims of sustainable healthy diets are to achieve optimal growth and development of all individuals and support functioning and physical, mental and social wellbeing at all life stages for present and future generations; contribute to preventing all forms of malnutrition (i.e. undernutrition, micronutrient deficiency, overweight and obesity); reduce the risk of diet-related non-communicable diseases; and support the preservation of biodiversity and planetary health. Sustainable healthy diets must combine all the dimensions of sustainability to avoid unintended consequences" (FAO and WHO, 2019a, p.11).

Until recently, dietary recommendations for the consumption of aquatic foods focused on balancing nutritional benefits with food safety concerns over the bioaccumulation of contaminants and pollutants. WHO recommended consuming 1–2 100 g servings of fish per week (FAO and WHO, 2011b), while the European Food Safety Authority (EFSA) recommended that adults consume 300 g of fish per week (EFSA, 2014). More recent recommendations have adopted a more holistic approach, taking into account concerns over the environmental impact of food production. The EAT–Lancet planetary health dietary guidelines promote predominantly plant-based diets with limited consumption of animal-source foods as key to sustainable diets, with a specific recommendation of up to 28 g of fish per day per adult (range 0-100 g/day) (Willett et al., 2019). Unlike terrestrial animal-source foods, consuming aquatic foods from sustainable fisheries and aquaculture has been deemed favourable in terms of a sustainable food system (Willett et al., 2019) and lower environmental impact (Hilborn et al., 2018; Hallström et al., 2019). In addition, the above recommended reference diet has been criticized as failing to recognize cultural and individual dietary choices, as well as for its unaffordability, particularly in many low- and middle-income countries (LMICs) (Drewnowski, 2020; Hirvonen et al., 2019).

The consumption of aquatic foods in some areas of the world is more than the recommended 28 g a day for adults, but consumption varies within countries, communities and even households. We often see estimates of national annual per capita fish consumption[5] compared with the global average (currently 20.5 kg)[6], although global consumption rates are highly disparate (current national estimates range from 0 kg to100 kg per capita annually) (FAO, 2020a; 2020c). This complicates comparisons of per capita consumption between countries or against the global average, as these assume equitable distribution across a population, which is not the case. Per capita consumption is affected by a number of factors, including differences in consumer preferences and behaviour, cultural norms and perceptions, as well as difficulties with the distribution of perishable food items in many areas.

For many poor, rural populations, fish – particularly small fish – may be the most accessible, affordable or preferred animal-source food (Kawarazuka and Béné, 2011). Aquatic food system strategies can help address the complex issue of the "triple burden of malnutrition" to ensure access to nutrient-rich aquatic foods to diversify diets and safeguard food security and nutrition for all (FAO, 2020a). Increasingly, aquatic foods are being recognized as an important component of sustainable healthy diets. However, they are still not fully recognized because many fisheries and aquaculture data are focused on harvesting and production. There is little focus on the value chain of the diverse range of aquatic foods, or on how to tap into their potential to meet the nutritional needs of various population groups, especially the poor and vulnerable.

A transition to sustainable healthy diets that includes an array of aquatic foods requires coherent policy and strong and inclusive institutional and legal frameworks. Certain fiscal instruments and policies can undermine the transition to sustainability, however, and policies on aquatic foods tend to focus primarily on production, economic efficiency, resource management, environment and climate issues. They pay less attention to value chains and the contribution of aquatic foods to people's nutrition and health.

5 These figures for fish consumption include aquatic animals, but exclude aquatic plants, as FAO food balance sheets do not currently include seaweed and aquatic plants.

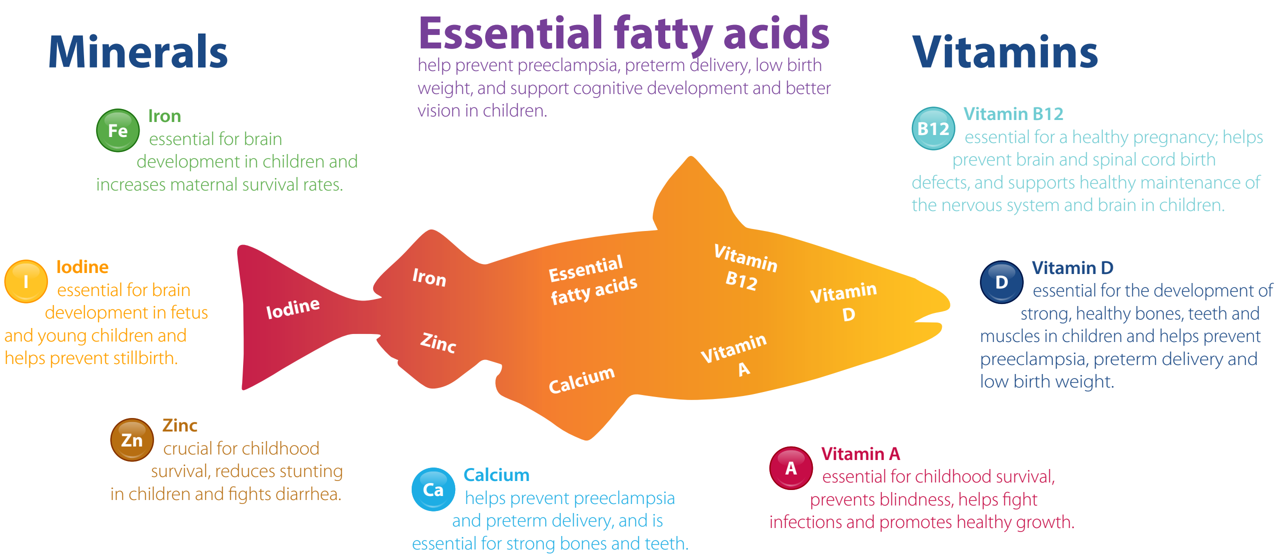
6 Based on apparent per capita fish consumption, which is the average fish food available for human consumption per FAO food balance sheets, expressed in live weight equivalent. For many reasons (including the fact that it does not take into account waste at household level), this is not equal to dietary intake.

3 Overview of healthy diets

Aquatic foods in nutrition and public health

Aquatic foods, especially aquatic animals, have long been valued as a rich source of animal protein and, therefore, considered a key constituent of nutritious diets (FAO, 2012b). However aquatic foods also contain omega-3 fatty acids and micronutrients, which are important for improving nutrition and health outcomes in populations suffering from the "triple burden of malnutrition".

Malnutrition in the form of overweight and obesity is on the rise. Globally, nearly 13.1 percent of adults and 6 percent of children are obese (FAO et al., 2020). This is linked to globalization, urbanization and dietary shifts towards the consumption of fats, sugars, processed foods and terrestrial animal-sourced foods, often referred to as the "nutrition transition" (see Box 1). A recent literature review showed that replacing meat consumption with lean aquatic foods (with the exception of shellfish and fried lean fish) reduced energy intake, leading to weight loss (Liaset et al., 2019). In addition, fish consumption has been shown to reduce blood pressure (Bernstein et al., 2019), lower cholesterol levels (Lim et al., 2012) and reduce the risk of death from coronary heart disease by improving cardiovascular function (FAO and WHO, 2011b; Mozaffarian and Rimm, 2006). Another study concluded that fish consumption reduced all-cause mortality; eating 60 g of fish per day was associated with a 12 percent reduction in risk (Zhao et al., 2019). Research on the positive relationship between fish consumption and the reduced risk of cardiovascular disease as a result of the high levels of omega-3 fatty acids in some marine fish species has prompted some countries to include fish intake in national dietary recommendations.



Box 1.
The role of aquatic foods in the nutrition transition

Nine of the ten countries with the world's highest rates of obesity are Pacific Island nations, where adult obesity rates have soared as high as 70 percent (Andrew, 2016). On top of this, stunting among children under the age of five years remains a serious public health problem, with rates of 49.5 percent in Papua New Guinea and 31.6 percent in the Solomon Islands (Development Initiatives, 2018a; 2018b). This epidemic can be partly attributed to moving away from traditional diets that are rich in fish and plant-source foods towards highly processed foods, including refined starches, oils, processed meats and confectionary (Charlton et al., 2016).

Although fish is identified as a primary food source for Pacific Islanders, it is important to note that access to fresh fish and aquatic foods varies with the seasons, geographic location (urban/rural/coastal) and socio-economy. There has also been a shift away from traditional methods of preparing fresh fish towards higher salt, higher fat options, such as canned or fried fish, typically consumed with other processed foods as part of a diet associated with obesity (Charlton et al., 2016; Dancause et al., 2013).

Although Pacific Islanders consume great amounts of aquatic foods caught in coral-reef fishing, there is growing concern that consumption is leaning towards processed products. This is due to the decrease in catch that has resulted from the overfishing of near-shore resources, rising ocean temperatures and acidification, as well as foreign industrial fleets, tuna exports and urbanization (Andrew, 2016; Charlton et al., 2016). Encouraging Pacific Islanders to maintain traditional dietary patterns in the face of urbanization is a growing challenge, with several publications linking the consumption of imported processed foods to wealth and status (Corsi et al., 2008). Greater efforts are needed to promote dietary diversification, with inclusion of local fruits, vegetables and fish over imported and ultra-processed foods (Charlton et al., 2016; Englberger et al., 2010).

The burden of child undernutrition remains a global threat, with 21.3 percent of children under the age of five years stunted, 6.9 percent wasted and 340 million suffering from micronutrient deficiencies (FAO et al., 2020). In addition to contributing to greater dietary diversity and boosting the micronutrient intake of women of reproductive age (Yilma et al., 2020), the consumption of aquatic foods in the first 1 000 days of life – from conception to a child's second birthday – is associated with positive birth outcomes, a better nutrient composition of breastmilk (Fiorella et al., 2018), reduced stunting (Marinda et al., 2018), a decline in the prevalence of severe acute malnutrition (Skau et al., 2015; Sigh et al., 2018), greater cognitive development and higher IQ (Hibbeln et al., 2006; 2019), as well as better school and work performance later in life. Evidence also suggests that eating fish early in life can promote positive behavioural and mental health outcomes and prevent certain allergies, such as asthma, eczema and allergic rhinitis (Bernstein et al., 2019).

Infants and young children need more nutrients per bodyweight for cognitive and physical growth than adults, but have a small stomach and gastrointestinal tract, so they must consume nutrient-rich foods. After the first six months of exclusive breastfeeding, children must be introduced to a diverse range of complementary foods (in addition to breastmilk), including aquatic foods, such as dried small fish and fish powder, to meet their micronutrient needs (see Box 2). There are food safety concerns associated with aquatic food consumption in the first 1 000 days, however, a FAO–WHO Expert Consultation found that the benefits of fish consumption outweigh the risks associated with the mercury and dioxin content of some fish species and that when a woman consumes fish before and during pregnancy, there are improved neurodevelopmental outcomes in her infant and young child (FAO and WHO, 2011b).

Box 2.
Developing nutrient-rich fish powder for the first 1 000 days in Malawi and Zambia

A study conducted between 2016 and 2019 in northern Zambia and Malawi documented that small fish species were the most common (and often only) animal-source food, with high seasonal availability, due to periods of heavy rain and a fishing ban for three months of the year (Ahern et al. 2021). Fish species that were highly available and affordable in peak production season were dried and used to make fish powder to boost the nutrition of women and young children in the first 1 000 days of life.

Participants in the study were highly receptive to the integration of fish powder into local recipes (Ahern et al., 2020). The use of solar drying systems to improve small-scale drying and of small machinery for grinding fish, rather than the traditional mortar and pestle, meant that women spent less time drying fish and fish loss was reduced (Ahern et al., 2020). These improved technologies also extended the shelf life of the fish powder (Ng'ong'ola-Manani et al., 2020).

Many efforts to improve public health nutrition focus on two crucial time periods – the first 1 000 days of life and women of reproductive age. However, there is evidence that the crucial first 1000 days extend for an additional 7 000 days throughout adolescence, linking these two crucial time periods, particularly important for adolescent girls (UNICEF, 2019; Crookston et al., 2013; Georgiadis and Penny, 2017; Popkin, 2014). School feeding programmes offer an opportunity to improve nutrition during this crucial developmental period, with evidence of animal-source foods improving growth, cognition and behavioural outcomes for school children (Bundy et al., 2018; Neumann et al., 2003; 2007; Whaley et al., 2003). Still, only a few studies have been conducted that demonstrate improvements in school children's cognition and performance from fish consumption (although not specifically through school feeding programmes) (Handeland et al., 2017; 2018; Skotheim et al., 2017). For example, a study of over 10 000 Swedish students aged 15 years found evidence of a positive relationship between students who consumed fish at least once per week and higher grades (Kim et al., 2009).

It is well-known that some finfish are rich in omega-3 fatty acids, minerals, vitamins and animal protein (HLPE, 2017; Thilsted et al., 2014), but often, data on nutrient composition are only available for the muscle tissue or fillet of the fish, rather than the whole fish or the broader spectrum of aquatic foods. It is less known that small fish species can contribute more micronutrients, especially when consumed whole (including head, eyes and viscera), as is the tradition in many LMICs (Thilsted et al., 2014; Thilsted, 2012a; 2012b; Roos et al., 2007). Small fish consumed whole are rich in bioavailable micronutrients such as zinc, iron and calcium. One study found that calcium absorption from the consumption of soft-boned small fish was comparable to that of skimmed milk (Hansen et al., 1998). In addition, when small fish are combined with other foods, such as vegetables, this boosts dietary diversity and enhances the bioavailability of minerals in plant-source foods (Barré et al., 2018). Thus, the addition of small fish to the diets of populations that predominantly rely on plant-source foods is a potential strategy for improving micronutrient absorption. Fiedler et al., (2016) used disability-adjusted life years (DALYs) to model the nutrition and health impact of a homestead pond polyculture food-based approach promoting consumption of a common small fish (mola) in Bangladesh, with results showing that a 20-year programme would have greater benefits and lower costs than a national vitamin A flour fortification programme.

Table 1 presents data on the nutrient composition of a small selection of the vast range of globally and locally valued aquatic foods in certain regions. The nutrient composition is presented per 100 g of raw, edible parts. Consumption of these diverse, nutrient-rich aquatic foods can be promoted in national food-based dietary guidelines or by stimulating consumer demand for desirable, innovative aquatic food products. In the next section, we present details on food-based dietary guidelines and the development of aquatic food products for ensuring the sustainable use of underutilized aquatic resources.

Table 1.
Nutrient composition of selected aquatic foods per 100 g of raw, edible parts

Name	Total Protein (g)	Ca (mg)	Fe (mg)	Zn (mg)	I (µg)	Retinol (µg)	D3 (µg)	B12 (µg)	Total n-3 PUFA (g)	EPA Fatty acid 20:5 n-3 (g)	DHA Fatty acid 22:6 n-3 (g)
Globally-traded marine finfish species (fillet only)											
[a] Atlantic cod *(Gadus Morhua)*	18,6	12	0,2	0,38	260	1	1	1,1	0.22	0.07	0.15
[a] Atlantic salmon (Salmo salar)	20,0	13	0,4	0,40	12	12	9	4,4	2.52	0.71	1.45
[e] Bluefin tuna *(Thunnus thynnus)*	23,3	8	1,0	0,60		655	227	9,4		0,283	0,89
[e] Alaska pollock *(Gadus chalcogrammus)*	17,2	12	0,3	0,4					0,261	0,075	0,16
Regionally or nationally common marine finfish species											
[d] Cunene horse mackerel *(Trachurus trecae)*	21,0	25	0,8	0,42	27						
[d] Round sardinella *(Sardinella aurita)*	21,0	71	1,8	0,52	24						
Freshwater finfish											
[a] Nile tilapia (fillet only) *(Oreochromis niloticus)*	18,3	15	0,8	0,44	5	1	20	1,3	0.19	0.04	0.15
[a] Nile tilapia (fillet with bones) *(Oreochromis niloticus)*	16,3	883	3,0	7,00	100	1	20	1,3	0.28	0.06	0.23
[a] North African catfish *(Clarias gariepinus)*	18,0	23	0,5	1,07	2	9	1	3,5	0.68	0.17	0.43
Small indigenous freshwater finfish											
[b] Mola carplet *(Amblypharyngodon mola)*	17,3	853	5,7	3,20	17	32.3 c	2	8,0			
[b] Bengal loach *(Botia dario)*	14,9	1300	2,5	4,00	25	nd	0	6,4		96	120
Other aquatic animals											
[a] Common shrimp *(Caridea spp.)*	18,5		1,7		25	2	0	5,0	0.37	0.22	0.15
[a] Mediterranean mussel *(Mytilus galloprovincialis)*	9,6	69	2,5	2,79	140	68	0	14,2	0.38	0.20	0.15
Aquatic plants											
[e] Wakame *(Undaria pinnatifida)*	3,0	150	2,2	0,38		216	0	0,0		0,186	0
[e] Kelp *(Laminariales spp.)*	1,7	168	2,9	1,23		70	0	0,0		0,004	0
[f] Sea grapes *(Caulerpa lentillifera)*	10,4	1874,0	21,4	3,5	5,0				7,6	0,860	

a Species data from the FAO/INFOODS Fish and Shellfish database (FAO, 2017c).

b Selected species are small indigenous fish species from Bangladesh that could contribute more than 25 percent of the daily reference nutrient intake (RNI) for three or more nutrients of public-health significant for pregnant and lactating women and infants if provided in 50 g or 25 g servings, respectively (Bogard et al., 2015b).

c Data on vitamin A components from Bogard et al., (2015b) previously published by Roos (2001).

d Moxness-Reksten et al., (2020) for marine fish species from Angola.

e USDA Food Composition Database (USDA, 2020): https://fdc.nal.usda.gov/fdc-app.html#/?query=seaweed.

f Matanjun et al., (2009).

Food-based dietary guidelines

A recent review on the inclusion of aquatic foods in food-based dietary guidelines (FBDG) in 78 countries in nine regions was conducted (Uyar, 2020). The FBDG were assessed based on the average intake of aquatic foods by the population, as the definition of "moderate" consumption is undefined in the FAO–WHO Principles for Sustainable Healthy Diets, Principle 4. For some populations to reach what would be considered "moderate" levels of consumption, FBDG would have to promote eating more aquatic foods, whereas, in populations with a high aquatic food intake, the recommendation might be to eat less or to maintain current consumption levels. For example, Argentina's FBDG recommend eating more aquatic foods, as the population's habitual consumption is below recommended amounts (FAO, 2015b). Some FBDG include specific qualitative recommendations, for example, that certain species or parts be consumed for their nutrient content, or that people should eat aquatic foods in fresh, frozen, dried, smoked or canned forms. Others, meanwhile, make specific quantitative recommendations (such as frequency of consumption) or recommendations related to sustainability (see Table 2).

Table 2.
Examples of the inclusion of aquatic foods in national FBDG

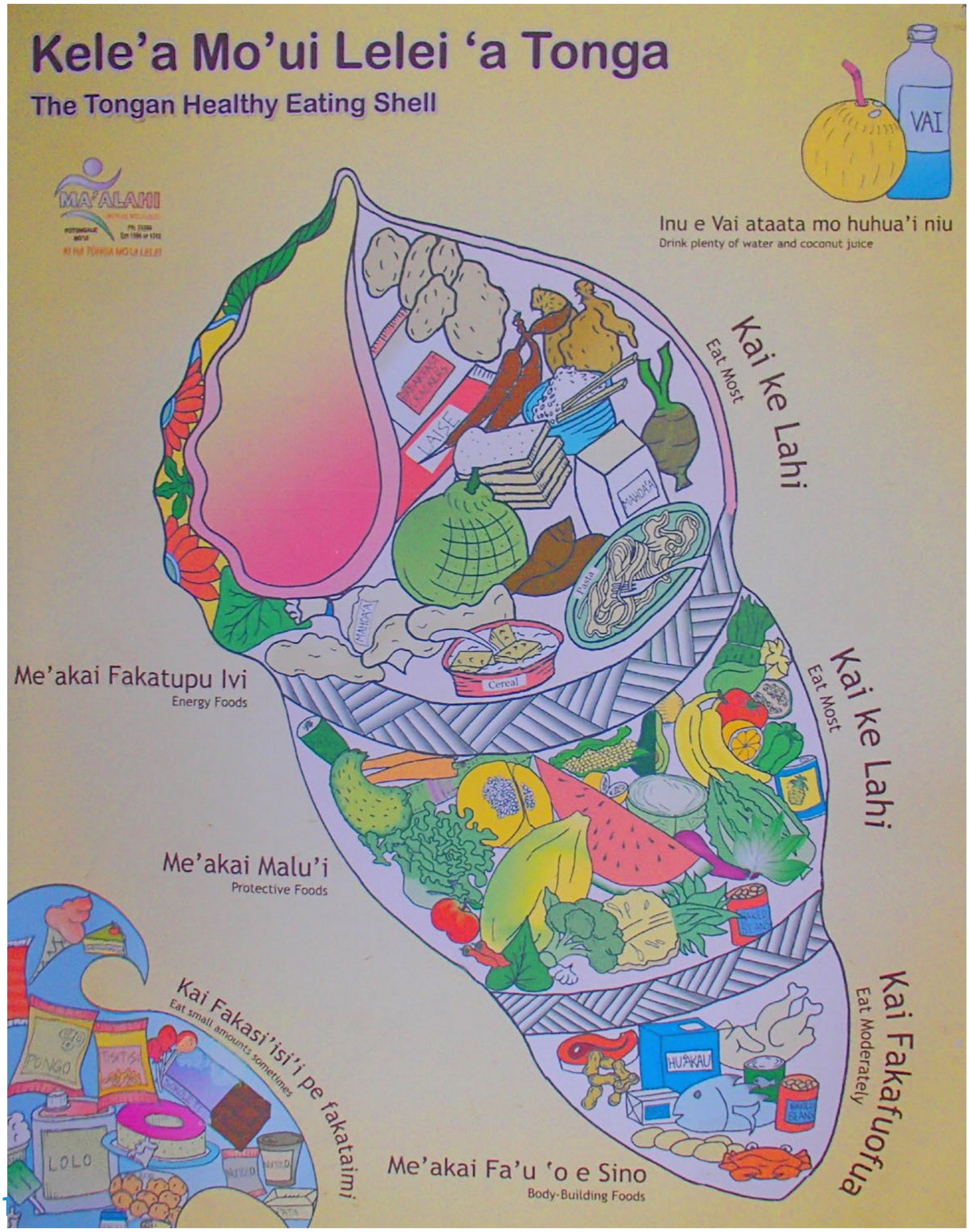
Country	Sample recommendations included in FBDG
Argentina	**Recommends greater consumption (due to low habitual intake) of specific aquatic foods (including algae) and specific parts** • Fish that are eaten with bones, such as sardine, carnelian and mackerel, are alternatives for increasing calcium intake (FAO, 2015b). • Seafood is among the main dietary sources of zinc and is a rich source of iron.
Australia	**Recommends consumption of underutilized species or parts of aquatic foods for specific nutrients** • "Calcium sources such as chewing meat and fish bones, and consumption of small, soft fish bones (e.g. in tinned salmon), and low-lactose dairy foods (such as matured cheese and yoghurt) are recommended in cases of lactose intolerance after the age of 3-5 years," (FAO, 2013c).
Benin	**Recommends consumption of preserved aquatic foods and underutilized parts for specific nutrients** • "For calcium, also consume smoked-dried fish, smoked-dried shrimp and crab shell." (FAO, 2015a).
Denmark	**Recommendations are quantitative (grams per week) and address issues of sustainability** • Recommends 350 g of fish per week, of which about 200 g should be oily fish, such as salmon, trout, mackerel or herring. All kinds of fish count towards this 350 g, including fish cake, frozen fish, canned fish, cod roe, tuna and mackerel, as well as shellfish, such as shrimp or mussel. • The background document of Denmark's FBDG lists aquatic foods from a low-carbon footprint (mussel) to a higher carbon footprint (shrimp) (FAO, 2013a).
Lebanon	**Recommends consumption of diverse species and links to food safety** • "Consume a variety of fish to achieve the desired health outcomes from omega-3 fatty acids, and to minimize any potentially adverse effects due to environmental pollutants such as mercury" (FAO, 2013b).
Philippines	**Recommends consumption of specific species for specific nutrients** • "Very few foods, in nature, contain vitamin D. The flesh of fatty fish such as salmon, tuna, and mackerel and fish liver oils are among the best sources." • "Certain types of aquatic foods such as small fish like dili, sardine and small shrimp (alamang) are rich sources of calcium which can be used by those who are lactose-intolerant or are just plain non-milk drinkers," (FAO, 2012a). See Figure 1.
Sri Lanka	**Depicts diverse aquatic foods and includes quantitative recommendations** • FBDG graphic includes whole fish, small fish, sliced fish, dried fish and prawn. • Recommendations for the number of servings per day (fish, pulses, meat and egg, 3–4 servings per day) and amount per serving (30 g of cooked fish or 15 g of dried fish) (FAO, 2011).

Across all of the FBDG reviewed, graphic representations typically included a whole fish. Specific fish species were more commonly depicted in graphic representations by region, such as salmon in North America and Europe, and pelagic small fish species in sub-Saharan Africa, South and Southeast Asia. The FBDG of Thailand and Sri Lanka illustrated the greatest variety of aquatic foods in graphic form, perhaps, due to the great diversity of aquatic foods common in diets and production systems in these countries. However, Japan's FBDG pictured just one aquatic food, even though the Japanese diet is well-known for its diversity of aquatic foods.

Figure 1.
Philippines FBDG

Source: *FAO (2012a).*

As most (71 percent) of the FBDG in the review were published prior to 2015, they are not aligned with the updated FAO–WHO Guidelines on Sustainable Healthy Diets, published in 2019. Newer FBDG may be more in tune and highlight the important role of aquatic foods in improving population health, while bearing in mind the environmental sustainability considerations of aquatic food consumption now and in the future. FBDG must also take into account the various cultural contexts within nations and make flexible recommendations that consider the whole meal and food combinations to achieve adequate nutrient intake. Pictures or graphics of food plates can often help consumers to understand portion size and the different food groups they should consume. When a diverse range of foods is shown in a graphic or picture, consumers can choose the foods or combinations of food most culturally acceptable to them. FBDG could be improved by including specific recommendations that quantify the amount of aquatic foods to be consumed. Ideally, this should be in the form of a range, as in some contexts, "moderate" consumption may mean eating a greater quantity than at present, while in other contexts, a smaller quantity may be preferable.



Dietary patterns and the consumption of aquatic foods

Dietary patterns

Although most people who cannot afford diets that meet nutritional needs live in Asia and Africa, affordability is an issue for millions of people around the world (FAO et al., 2020). Many people in Europe have cited price as a barrier to the consumption of aquatic food products (EUMOFA, 2017), while in Norway, the declining consumption of aquatic foods is attributed to a 30 percent rise in consumer fish prices compared with a 2 percent increase for meat products (Helsedirektorat, 2020).

For many poor, rural populations in low-income food-deficit countries (LIFDCs), fish – and particularly small fish – may be the most accessible, affordable or preferred animal-source food, contributing to the diversification of diets currently dominated by staple crops and enhancing the nutrient absorption from plant-source foods when consumed together (FAO, 2012b; Thilsted et al., 2014; Bogard et al., 2015a; Barré et al, 2018). Small fish can be harvested, sold and consumed in small quantities and combined with other foods, making them more frequently accessible and affordable to poor and vulnerable populations than other animal-source foods, such as livestock. Dried small fish are particularly important for food security and nutrition, as they are easily processed, using minimal energy and infrastructure (through methods such as sun-drying or smoking) and are more affordable than other animal-source foods (Kawarazuka and Béné, 2011). Also, thanks to processing that extends shelf life and reduces the need for cold storage, dried small fish can be traded over long distances and reach communities far from water bodies (Ayilu et al., 2016).

Dietary patterns may vary based on the availability and accessibility of aquatic foods, which can be influenced by ecosystem variability, climatic conditions, household purchasing power and decision-making and fisheries policies that restrict the harvesting of aquatic foods at certain times of the year (Perry and Sumaila, 2007; Thilsted et al., 2014).The fishing season may fall at the same time as the rainy season and, in the absence of a cold chain or processing infrastructure, lead to high post-harvest loss or spoilage and seasonal variations in consumption. To enable the consumption of aquatic foods throughout the year, shelf-stable aquatic food products need to be developed that can be processed in times of plenty and distributed and consumed in the lean seasons. There also need to be greater efforts to reduce loss and waste by way of better, climate-smart processing, preservation and infrastructure.

Consumption of aquatic foods

Fish consumption globally is estimated to have more than doubled since the 1960s, from 9.0 kg per capita per year to 20.5 kg per capita per year, with the average annual increase in fish consumption outpacing that for all terrestrial animal-source foods (FAO, 2020a). Fish consumption trends have also shifted from a regional perspective. In 1961, Europe, Japan and the United States of America accounted for 47 percent of the world's total fish consumption, but this had dropped to 19 percent in 2017, with the growth in fish consumption in Asia (FAO, 2020a).

Globally, fish accounts for 17 percent of all animal protein consumed. However, in 31 countries – 16 of which are LIFDCs and five are small island developing states (SIDS) – where fish and other aquatic foods serve as the backbone to a healthy diet, fish accounts for more than 30 percent of total animal protein supply (FAO, 2020c). Per capita fish consumption in Africa is nearly half the global average (9.9 kg per capita in 2017), but accounts for more than 50 percent of all animal protein in many coastal countries (in Ghana, Sao Tome and Principe, Sierra Leone, and The Gambia) and 30 to 40 percent in countries with inland water bodies (such as Malawi, Uganda and Zambia) (FAO, 2020c).

It is important to note, however, that official data may not fully account for the diversity of aquatic foods consumed and may underestimate consumption, as the contribution of subsistence fisheries, certain small-scale fisheries and informal cross-border trade in LMICs tends to be under-recorded (FAO, 2020a). Indeed, small-scale fish catches could be underestimated by as much as 65 percent due to the challenges of monitoring and reporting on dispersed, informal and remote fisheries, as well as the informal fish trade (Fluet-Chouinard et al., 2018). Moreover, while fish may be the most common animal-source food in the diets of many LMICs, the amount and frequency of consumption remain low.

Consumption surveys are integral to understanding actual consumption, though they often lack species-level data of aquatic foods or parts consumed and details on intra-household consumption patterns (for example, who eats first, who eats what foods or specific parts). These details are key for a full picture of consumer demand, the nutrients people consume and those wasted, and necessary to shape aquatic food systems to respond to specific and diverse consumer demands and nutrient needs.

As mentioned, nutritional intake varies depending on the species and parts consumed, but also on the method of cleaning and processing. Fish is common in diets in Bangladesh, where it is the second (after rice) or third (after rice and vegetables) most commonly consumed food (sometimes as dried fish) (Thilsted, 2013). In Malawi, Zambia and much of southern Africa, the most commonly consumed aquatic food, especially by the poor, are pelagic small fish from inland fisheries, much of which are sun-dried or smoked (Longley et al., 2014; Marinda et al., 2018). Intra-household differences in consumption have been reported, too. For example, in Bangladesh and Indonesia, fish are not fed to children under the age of five years (Thorne-Lyman et al., 2017; Gibson et al., 2020), while in Zambia and Malawi, the "best" parts of the fish are kept for the head of the household or elders and fish is generally withheld from children, who are only given broth after the fish has been boiled (Ahern et al., 2020). This trend extends beyond traditional societies, as low fish consumption by children is also evidenced in high-income countries such as Norway, the United Kingdom and the United States of America (Kranz et al., 2017; Terry et al., 2018; Bernstein et al., 2019; Norwegian Seafood Council, 2020).

Consumption of aquatic foods varies among population groups, and poor people overall have less access to a sustainable healthy diet than better-off people. Certain low-trophic aquatic foods, such as pelagic small fish, may be more affordable to poorer populations and could potentially fill the nutritional gap in a sustainable way, ensuring that all nutrient needs are covered. Other aquatic foods, such as seaweed, meanwhile, may provide income-generating opportunities for coastal communities.

Diversity, equity and sustainability of aquatic food consumption

Dietary diversity is a simple indicator of micronutrient adequacy in the diet: consuming a range of different foods ensures a wide variety of nutrients (FAO and FHI 360, 2016). Aquatic animals, meat and poultry fall under the category of "flesh foods", one of the 10 food groups that make up the minimum dietary diversity for women (MDD-W). Aquatic plants can be categorized as "dark green leafy vegetables", depending on their vitamin A content, or as "other vegetables" (FAO and FHI 360, 2016). Thus, aquatic foods as a whole can make important contributions to dietary diversity, in combination with diverse terrestrial foods. It is important to note, however, that foods within the MDD-W food groups have very different nutrient profiles, highlighting the importance of not only dietary diversity, but also diversity within food groups (Bernhardt and O'Connor, 2021). In addition to ensuring that a variety of nutrients are consumed from various food sources, diverse food production systems serve as a backbone for resilience, making food systems easily adaptable and sustainable (Schipanski et al., 2016; Dwivedi et al., 2017; Bernhardt and O'Connor, 2021). A recent study in Bangladesh found that households engaged in both homestead aquaculture and horticulture activities had better diet quality than those engaged in only one activity (Akter et al., 2020).

The FAO has recorded about 2 400 aquatic animals in fisheries and aquaculture, of which more than 1 700 species, or 85 percent, are finfish landed in marine capture fisheries globally (FAO, 2020a). Pelagic small fish comprise the main group, followed by gadiformes (cod), tuna and tuna-like species. The top species for marine capture include anchovy, Alaskan pollock, Skipjack tuna and Atlantic herring (FAO, 2020a). Still, pelagic fish are only the second-most consumed species, at 3.1 kg per capita per year (behind freshwater and diadromous fish – such as Atlantic salmon – at 8.1 kg per capita per year), as a significant quantity of pelagic small fish catch is used for fish meal and fish oil production (FAO, 2020a).

While the above groups of fish are the most consumed globally, a wide range of species are consumed at regional and national level, even within countries or households, as consumption is affected by location, seasonality, time and household socioeconomic status (Thilsted et al., 2014). In the European Union and the United States of America, for example, four of the top five aquatic foods consumed are the same – tuna, salmon, Alaskan pollock and shrimp – whereas the fifth differs – cod in the European Union and tilapia in the United States of America (EUMOFA, 2019; Mutter, 2020).

In Bangladesh, in contrast, farmed carp and tilapia are highly consumed, as well as a mix of small indigenous fish species (SIS), for example, puti (*Puntius spp.*) which are fished from inland water bodies by small-scale fisherfolk. Detailed consumption surveys from 1996 to 2007 found that puti, taki and mola (all SIS) were the most consumed species in many wetland areas (Roos et al., 2007; Belton et al., 2014). Such inland SIS are shown to be more nutrient-rich than farmed species (Bogard et al., 2015b). In urban Lusaka, greater household wealth has been associated with more frequent and more diverse fish consumption and the consumption of larger-sized fresh fish (Genschick et al., 2018). Significantly higher tilapia consumption was found in the highest wealth quartile, whereas dried kapenta, a mix of small fish species (*Limnothrissa miodon* and *Stolothrissa miodon*), was more common in the two lowest wealth quartiles. Households in the poorest quartile consumed an average of five fish species, compared with 11 in the wealthiest quartile.

While there are species that may be commonly consumed globally or regionally, diversification of the types and species of aquatic foods consumed is necessary to build the resilience and sustainability of aquatic food systems now and in the future. There are already positive examples of the use of aquatic biodiversity for food security and nutrition, enabling food systems to adapt to change (Freed et al., 2020a). A recent study on fish–rice systems in Cambodia identified over 100 wild aquatic species, nearly all of which were used for household consumption, accounting for around 60 percent of the aquatic foods consumed by households throughout the year. Households adapted to seasonal availability by modifying their harvesting efforts to different habitats within the system (Freed et al., 2020b). This and other studies demonstrate that access to a diverse range of aquatic foods is integral to rural food security and nutrition in Cambodia. Indeed, this is recognized in Cambodia's National Strategy for Food Security and Nutrition (Kingdom of Cambodia, 2014).

The importance of overall dietary diversity and the consumption of diverse aquatic foods is not only relevant in rural subsistence systems, but also in developed market systems. For example, the National Health Service of the United Kingdom advises that "to ensure there are enough fish and shellfish to eat, choose from as wide a range of these foods as possible. If we eat only a few kinds of fish, then numbers of these fish can fall very low due to overfishing of these stocks" (NHS, 2018).

In other words, we should eat what is available, or the "catch of the day", and diversify our aquatic food consumption to include low-trophic species to reduce the risk of overfishing certain species and to ensure resilient aquatic food systems. We should aim to harvest and consume a diverse range of aquatic resources, in line with their natural biomass availability along the food chain. The current harvesting of aquatic foods is highly unbalanced, skewed towards high-trophic, less productive species rather than low-trophic species, such as freshwater pelagic small species from African inland waters, which are highly productive, reproducing their own biomass up to five times a year (Kolding et al., 2019). In total, aquatic systems contribute only about 2 percent to global food production by volume (Duarte et al., 2009). This is largely due to many people, especially in high-income countries, preferring carnivorous large fish species over aquatic resources at the low end of the food chain (Duarte et al., 2009; Olsen, 2015).

The EAT–Lancet Commission recently published a report with a "blue lens", questioning what different pescatarian diets mean for human health and planetary boundaries, with a call to improve the understanding of the health and environmental implications of shifting from western dietary patterns, including salmon and tuna, to lower trophic species, such as carp, mussel and algae (Troell et al., 2019). A few studies have documented the environmental impacts of producing and consuming various aquatic foods, concluding that low-trophic species, such as small fish and bivalve mollusc, deliver more nutrients with a lower environmental impact than other animal-source foods or vegan diets (Hallström et al., 2019; Kim et al., 2019).

However, in promoting the consumption of low-trophic aquatic foods, it is important that they be prioritized for direct human consumption, rather than animal feed (including aquaculture feeds for larger carnivorous species). A recent study on the Scottish farmed salmon industry concluded that there were nutritional benefits for the population when diversifying their aquatic food consumption. In particular, the study recommended consuming a wide variety of oily small fish and mussels, as this could provide similar levels of omega-3 fatty acids, in addition to other micronutrients, thereby reducing both the intake of Scottish farmed salmon, and the number of small fish required for salmon feed (Feedback, 2020).

Hicks et al. (2019) have shown that if marine capture fish are used for domestic consumption in many LIFDCs, this would result in a significant reduction in micronutrient deficiencies. The expansion of the fish meal and fish oil industry has been rapid in recent years (Freon et al., 2013), particularly in West African countries, such as Mauritania, where round and flat sardinella (*Sardinella aurita* and *Sardinella maderensis*) and bonga (*Ethmalosa fimbriata*) are being captured for fish meal and fish oil, despite their importance to food security, nutrition and the livelihoods of local fisherfolk (Greenpeace International, 2019). While this is a controversial issue for the use of sardinella in Northwest Africa, the issues regarding direct consumption of small fish and targeting them for reduction to fish feed in other areas of the world may be different. Despite the year-round availability of anchovy in Peru and efforts to promote direct human consumption, it is primarily used for fish meal and oil, due to incentives that encourage landing for reduction purposes (Majluf et al., 2017; Freon et al., 2013; Christensen et al., 2014). In the Baltic region, a recent study showed constraints on the availability of Baltic herring for direct consumption despite the preference of traditional Baltic herring dishes by many consumers, due to feed-directed fishing (Pihlajamaki et al., 2019). Demand for fish as animal feed exceeds supply, due to the expansion of aquaculture and livestock production, maintaining the profitability of fish meal and fish oil production (OECD and FAO, 2020). Although there has been a downward trend in use of these nutrient-rich small fish in fishmeal for aquaculture feed, small fish are still diverted from direct human consumption to animal feed and other uses, raising questions about the sustainable expansion of aquaculture and the need for novel feed ingredients (see Global Panel (2021) for projections on the potential of novel feed ingredients).

Future foods: A menu of solutions for future aquatic food consumption

Promoting consumption of low-trophic aquatic foods

In addition to the commonly known aquatic food species (such as tuna, salmon, tilapia, crab and shrimp), there is a wide variety of aquatic animals and plants that are often overlooked in terms of their potential to deliver micronutrients, omega-3 fatty acids and protein and which offer alternatives to the large fish species and terrestrial animal-source foods common in today's diets. Encouraging people to eat low-trophic aquatic foods is undoubtedly the prime strategy for using our aquatic nutrient resources more efficiently and mitigating the environmental impacts of food production.

This means we must become more aware of the potential of low-trophic aquatic animals, such as bivalve mollusc, shellfish, seaweed, polychaetes, echinoderms and jellyfish, as food and for delivering nutrients. Balanced harvest of more productive biomasses at the low end of the aquatic food chain has been proposed as a possible way of significantly enhancing the resilience of global food systems by utilizing diverse species and taking advantage of peak biomass accumulations in nature, which are reported to thrive regardless of anthropogenic impacts (such as overfishing or climate change) (Kolding & van Zweiten, 2014; Kolding et al., 2019). However, there have been concerns that this harvesting approach can lead to greater fishing intensity of forage fish and other aquatic foods, compromising the protection of threatened species (Zhou et al., 2019). Harvesting at lower trophic levels than at present could result in higher levels of marine food production, however, this must be balanced against the risks, such as nutrient depletion and ecosystem imbalance, as we have seen, for example, with large-scale seaweed or shellfish production (van der Meer, 2020).

A good example of untapped aquatic biomass for food at the global level is jellyfish, which has been consumed in China for more than 1 700 years and valued for their health benefits (Hsieh and Rudloe, 1994; Raposo et al., 2018; Gu and Lin, 1985). There are roughly 200 jellyfish (*Scyphozoans*) species, of which only the *Rhizostomeae* class is deemed safe for human consumption (Hsieh and Rudloe, 1994; Amaral et al., 2018). Jellyfish can play an important role in the context of global food security and nutrition as a novel nutrient-rich aquatic food, rich in minerals and animal proteins and low in energy content and negligible fat content (Bonaccorsi et al., 2020). With the potential increase in jellyfish biomass around the world, (Youssef et al., 2019), they should be considered as a source of nutritious human food.

Sea cucumber has long been used as a food and in folk medicine, primarily in Asia and the Middle East (Bordbar et al., 2011). A decline in sea cucumber fisheries due to high demand from the Asian dried seafood market has spurred global sea cucumber aquaculture (Eriksson et al., 2011). Sea cucumber contains multiple essential micronutrients, such as calcium, magnesium, iron, zinc and vitamins A and B (Bordbar et al., 2011). In addition, sea cucumber fishing and farming are important livelihood opportunities and a source of income for rural communities in several countries, including Fiji, Kenya, Kiribati, Madagascar, Mauritius, Mozambique, Tonga and the United Republic of Tanzania. National consumption, however, is low (Eriksson et al., 2011; Purcell et al., 2016).

More commonly known low-trophic species, such as bivalve molluscs and shellfish, are good sources of omega-3 fatty acids and zinc and some species are particularly rich in iron and vitamin B12 (Nettleton and Exler, 1992; King et al., 1990). Globally, however, the consumption of bivalve molluscs, such as mussels, remains low – in some countries, mussels are not part of the local diet, while in others, consumption is around 3 kg per capita per year (Monfort, 2014). Mussel consumption has been shown to be more common in Europe, New Zealand and the United States of America, although still a niche product (Government of New Zealand, 2017; NZTE, 2017; King and Lake, 2012), and varies according to socioeconomic characteristics and consumer age (ISMEA, 2009). Indigenous populations are also reported to consume mussels frequently (Tipa et al., 2010). A recent trial of mussel consumption found that those who consumed mussels three times a week had better omega-3 fatty acid status, which is associated with a 20 percent reduction in the risk of sudden cardiac death (Carboni et al., 2019). Oysters and clams are also rich in omega-3 fatty acids, with oysters having a higher omega-3 fatty-acid concentration than wild salmon or anchovies (Tan et al., 2020). While diets in Asia have included a greater variety of aquatic foods, such as seaweed and aquatic plants and low-trophic aquatic animals (such as sea cucumber and jellyfish), the consumption of these foods on a global scale is currently negligible.

Promoting consumption through convenient aquatic food products

Making better use of what we already have can contribute to sustainable healthy diets. We can improve processing and prolong the shelf life of aquatic foods in times of plenty to smooth consumption in times of scarcity. To this end, innovative products that make underutilized species desirable and accessible to consumers all year round could be marketed through both formal and informal channels (supermarkets, shops, rural markets and household processing). There has been increased attention on the use of low-trophic, underutilized aquatic foods for products such as semi-prepared foods, snacks and seasonings, jellyfish chips, fish chutney, fish powder, fish cakes and fish sausages (FAO, 2020a).

Box 3.
Seaweed and aquatic plants

Seaweed refers to about 11 000 different species, including algae, halophytic plants (such as Salicornia) and water lenses (such as *Lemnar minor*) that grow in the world's aquatic saltwater environments. Rich in carbohydrates, protein, omega-3 fatty acids, minerals and vitamins, and low in total fat, seaweed and other algae hold untapped potential to contribute directly to sustainable healthy diets. In 2018, the global seaweed production was about 33 million tonnes in wet weight, worth over USD 14 billion (FAO, 2018c). While seaweed constitutes a regular part of human diets across East Asia, it is uncommon in diets elsewhere (FAO, 2020a). Seaweed and aquatic plants are not currently included in FAO food balance sheets and the importance of seaweed gleaning for food security and nutrition may be under-recognized.

Seaweed is a rich source of micronutrients, such as iodine, iron, zinc, copper, selenium, fluorine and manganese, as well as vitamin A and vitamin K. It is the only non-animal-source food of vitamin B12 (Watanabe et al., 2014; FAO, 2018c). It is an excellent source of fibre and some seaweeds contain sulphated polysaccharides that have been shown to increase the growth of beneficial gut bacteria (Lopez-Santamarina et al., 2020). Seaweed products can be used to provide iodine for thyroid function in place of iodized salt, thus avoiding salt consumption (Yeh et al., 2014). Studies over the past decade have linked high seaweed consumption in Asia with reduced risk of cardiovascular disease, cancer and diabetes, and have demonstrated a positive correlation between seaweed consumption, iodine intake and life expectancy (Brown et al., 2014). Still, concerns have been raised that seaweed consumption is associated with excess intake of iodine and heavy metals (cadmium, arsenic, mercury and lead). The risk of excess iodine intake from seaweed consumption can be mitigated by cooking and replacing some seaweed with vegetables (Yeh et al., 2014).

Beyond direct contributions to nutrition and food security, seaweed and aquatic plants can contribute to sustainable food systems by improving fish habitat, marine biodiversity and ocean restoration, sequestering carbon and improving water quality, decreasing the use of antibiotics in aquaculture and terrestrial animal production, and providing organic fertilizer and biodegradable packaging for food and other products (Bjerregaard et al., 2016; FAO, 2018c; Kreeger et al., 2018; Morais et al., 2020; Lloyd's Register Foundation, 2020).

The current and projected increase in the production of jellyfish has raised the issue of how to make best use of gelatinous biomass, resulting in niche products, such as the aforementioned jellyfish chips and providing unique sensory dining experiences (Bedford, 2019; Youssef et al., 2019). Certain aquatic food products are already in widespread use in some regions, such as fermented shrimp paste and fish sauce in Asian countries. Because of consumer preference for ready-to-cook foods, semi-prepared or frozen mussel products are marketed in various forms, such as canned smoked mussels, frozen mussels in Thai curry sauce and frozen mussel pre-cooked in white wine, garlic and butter (NZTE, 2017).

Similarly, small fish and seaweed can be made into semi-prepared foods or powders that are convenient to prepare, easy to share, easy to mix into dishes (increasing the bioavailability of nutrients in other foods) and storable for long periods of time. Amid evidence of important developmental outcomes in the first 1 000 days and of intra-household dynamics suggesting that young children often do not consume fish (Ahern et al., 2020; Thorne-Lyman et al., 2017), product research and development is increasingly drawing on locally available and affordable aquatic foods, targeting consumption by young children (Bogard et al., 2015a; Sigh et al., 2007, Ahern et al., 2020).

Lab-grown aquatic foods

In recent years, lab-grown foods, including seafood alternatives, have garnered attention as they require less land and water than conventional aquaculture products. There are also fewer concerns over biosecurity and the bioaccumulation of mercury and polychlorinated biphenyls (PCBs) in these foods than higher-trophic aquatic animals (Marwaha et al., 2020). Lab-grown aquatic foods are produced using cells from aquatic animals (cell-based) or cells from plants (plant-based) and they imitate the taste, texture, appearance and nutritional properties of aquatic foods (Yi, 2019). However, concerns remain over cost, equity and consumer acceptance, as well as the regulatory framework for such foods.

The production of lab-grown foods requires significant investment, which many laboratories are trying to offset by developing imitations of high-market-value aquatic species, such as bluefin tuna and lobster, which will probably restrict access to high-income consumers in luxury markets. Little research has been done to understand the palatability and acceptance of these products, amid concerns over the unknown health effects and nutrient quality of lab-grown foods.

4 The sustainable supply of aquatic foods

Sustainable supply of aquatic foods: Capture fisheries and aquaculture

Global capture fisheries production including aquatic plants, was 97.4 million metric tons in 2018. Eighty-eight percent of that was from marine waters, with the remainder from inland waters (FAO, 2020c). These figures may under-represent the inland fisheries catch, however (Fluet-Chouinard et al., 2018). Marine capture fisheries include small-scale and near-shore fishing, as well as large-scale, commercial operations that rely on motorized vessels dragging huge nets in ever more distant waters.

Greenhouse gas (GHG) emissions are the primary environmental impact of these large-scale operations, accounting for 4 percent of all GHG emissions from global food production (Watson et al., 2015; Cashion, 2018). Fishing vessels around the world (both marine and inland) consumed 53.9 million tonnes of fuel in 2012, emitting 172.3 million tonnes of CO2, or about 0.5 percent of total global CO2 emissions that year (FAO, 2018).

Large-scale operations rely on fishing methods designed to capture large quantities of aquatic foods. They include purse seining (encircling) and midwater trawling (dragging) nets for smaller open-water fish species, such as sardine, mackerel and herring; long-lines and gillnets for larger pelagic fish, such as tuna, salmon and swordfish; bottom trawlers for demersal whitefish species and shrimp; and pots, traps and dredging for benthic invertebrates, such as lobster, crab and prawn. Methods that produce large amounts of bycatch (non-target species), such as gillnets, long-lines, seines and trawlers, or that severely alter sea-floor structure, such as bottom trawling, negatively impact the biodiversity of aquatic systems, which are essential for building stable and resilient ecosystems, safeguarding food production and supporting critical ecosystem services (Loreau and de Mazancourt, 2013; Sciberras et al., 2018; FAO, 2020). Consequently, certain measures have been implemented to reduce bycatch, from simple hook substitutions to gear bans and full fisheries closures (Gilman et al., 2007; Sales et al., 2010). Overly intensive fishing of high-trophic species can also negatively impact biodiversity by altering aquatic community structures (Essington et al., 2006; Pauly, 1979).

Small-scale fisheries are a key livelihood activity for many coastal communities, providing more than 90 percent of jobs in marine fisheries globally (World Bank, 2012). An estimated 95 percent of inland catch is consumed locally, contributing directly to food security and nutrition (FAO, 2020a). These operations often use smaller nets and tools to harvest more diverse aquatic species – for example, bagan (or bagang) nets to catch small fish, squid and shrimp in Indonesia, and shore-operated lift nets, scoop nets, hand-cast nets, small ring nets, spears, hooks and lines for larger pelagic fish. In general, these methods produce lower rates of bycatch, cause minimal structural damage to marine habitats and use less fuel, as fishing is closer to shore. As many aquatic foods from these fisheries are consumed locally, their transport CO2 footprint is also far lower than foods that are traded globally (World Bank, 2012). However, overfishing can occur in small-scale fisheries if they are not properly managed, as well as in poorly managed industrial fisheries (Gough et al., 2020; Allan et al., 2005)

Adequate data are still needed on the current status of small-scale fisheries and inland fisheries, with up to 70 percent of inland fisheries (primarily in LMICs) lacking any kind of formal assessment, making it difficult to determine the health and status of their stocks.

In addition, small-scale fisheries and aquaculture offer livelihood opportunities to rural women, as activities may be in close proximity to the household (FAO, 2015c). Evidence has shown that when women earn and control income, they tend to spend it on food and education. Unfortunately, gender-disaggregated data on roles in fisheries and aquaculture are often lacking.

Aquaculture is a rapidly expanding landscape for aquatic foods, with production reaching an all-time high of 114.5 million tonnes in 2018 (FAO, 2020a). The environmental impacts of aquatic food farming vary depending on method, species, scale, practice, facilities and integration with other food-producing activities. Global growth in aquaculture has provided some benefits to the environment by alleviating pressure on wild stocks, replenishing depleted stocks and providing ecosystem services, such as bioremediation, waste removal and habitat structure (Troell et al., 2014). At the same time, negative environmental impacts have ensued as aquaculture practices have intensified. These include the monoculture of certain aquatic species, pollution from effluent (fish waste), the eutrophication of water bodies, land-use change and habitat destruction, increased competition for land and water resources, disease transmission and the introduction of invasive species (Ahmed et al., 2019).

However, if aquaculture is to be a sustainable source of food supply and improve food security and nutrition, we must tackle the challenges associated with feed ingredients, the diversity of species produced, land and water usage and equitable distribution. Fed aquaculture currently accounts for 70 percent of all aquaculture production globally (FAO, 2020a; Belghit et al., 2019). In 2018, 18 million tonnes of fish captured globally were used to produce fish meal and oil – the majority of them marine pelagic small fish (Cashion et al., 2017). According to a recent study, 90 percent of fish destined for non-human consumption was of food- or prime-grade quality, most of it harvested in highly food-insecure areas of the world (Cashion et al., 2017).

Crop replacements in aquafeeds for marine fish have also come under scrutiny for their impact on resource and land use, especially when cultivated in large-scale monocropped systems (Fry et al., 2016). Overall, fish feeds are the largest source of GHG emissions and production costs in aquaculture (MacLeod et al., 2019). There is also a focus on the production of finfish (92 percent of total aquatic animals harvested in freshwater systems), with carp species making up more than 50 percent of all inland aquaculture production, alongside tilapia and catfish (FAO, 2020a).

Mariculture (aquaculture at sea) is an area of interest for aquaculture expansion, given the pressure on land use and finite freshwater resources. However, there are concerns over nutrient flows, as these open systems have the potential to negatively impact native aquatic populations through disease transmission or competition from escaped farmed species (Barrett et al., 2018). Filter-feeding species have been shown to bioremediate effluent and pollution when farmed in large quantities close to mariculture farms, forming a type of aquaculture filtration system known as an integrated multi-trophic aquaculture system (Kerrigan, 2016).

Claims about the expansion of mariculture are contested. Expansion requires the decoupling of aquaculture and wild fisheries for feed, as well as improved regulations to maximize production potential and an increase in consumer demand for sustainably farmed fish (Costello et al., 2019). However, it has also been criticized for failing to deliver food security and nutrition objectives, as the cost of offshore farming necessitates the production of high-market-value species, fuelling exclusionary and inequitable social outcomes (Belton et al., 2020). Mariculture has attracted much attention for its potential based on available area for marine aquaculture, but is critiqued for not taking mass and energy fluxes into account and detracting attention from fishing methods that take advantage of the trophic efficiency of marine ecosystems (van der Meer, 2020).

This is not to say that current aquatic food production methods will fail to deliver food security and nutrition in a sustainable way, as combinations of marine and freshwater aquaculture, as well as marine and inland capture fisheries, have great potential to meet equitable food security and nutrition goals. Freshwater aquaculture approaches that are often practised on a small scale, such as polyculture and integrated agriculture–aquaculture systems (see Box 4), have shown a rise in overall productivity through more efficient feed use, the use of locally available inputs and better water quality and waste reduction (Edwards, 2015; Limbu et al., 2017). They also diversify on-farm production to include a variety of foods and aquatic species, boosting dietary diversity and livelihood.

Box 4.
Nutrition-sensitive integrated pond polyculture in Bangladesh

In Bangladesh, there are about 3.9 million small homestead ponds that are suitable for fish production. In 2011, WorldFish and its partners introduced a nutrition-sensitive pond polyculture approach for homestead ponds. The entry point was the production of small indigenous fish species, such as the micronutrient-rich mola (mola carplet, *Amblypharyngodon mola*), farmed alongside large fish species, particularly carp. This resulted in an increase in total fish production and productivity, as well as an increase in the overall nutritional quality of the total production (Thilsted, 2012a).

Vegetable production was integrated into the pond dykes and homestead garden. The focus was on micronutrient-rich vegetables, including orange sweet potato and dark green leafy vegetables. WorldFish undertook nutrition messaging and social behavioural change communications with a focus on increasing the consumption of small fish by women and children in the first 1 000 days of life. Women were engaged in pond polyculture, facilitated by on-farm training and support from extension workers.

This integrated, nutrition-sensitive pond polyculture resulted in an increase in the intake of fish and vegetables by households, women and young children, as well a rise in household income from the sale of fish and vegetables, with women reporting more control over the income. Using a cost-benefit analysis based on disability-adjusted life years, it was estimated that the pond polyculture of small and large fish alone was a cost-effective approach to reducing the burden of micronutrient malnutrition in Bangladesh (Fiedler et al., 2016). The approach is now being practised in homestead ponds across Bangladesh and in other Asian countries, including Cambodia, Myanmar, India and Nepal.

However, species diversification must take into account the lack of seed or hatchery technology for some species, as well as the economic viability of and returns from aquaculture activities, which often result in a preference for farming high-market-value species rather than prioritizing aquatic food diversity. While certain production methods demonstrate sustainability, certain species, such as molluscs, pelagic small fish and seaweed, are also more sustainably produced than other species, such as catfish (Rebours et al., 2014; Buschmann et al., 2017; Hilborn, 2018; Hallström et al., 2019). Shifting dietary recommendations and preferences from GHG-intensive species to foods of this kind, with a lower environmental impact and higher nutritional values, could be a key step in adopting more sustainable healthy diets (Hallström et al., 2019).

Beyond this discussion on the sustainable production of aquatic foods, various aquaculture production methods (including pond polyculture), as well as the synergies and trade-offs involved in the sustainable expansion of aquaculture to meet demand for healthy diets, are presented in more detail in the Global Panel report (2021).

The sustainable supply of aquatic foods: Fiscal instruments and policies

A transition to sustainable aquatic foods requires coherent policies, complemented by strong, inclusive institutional and legal frameworks. However, some policies, such as fisheries subsidies and fiscal instruments, can undermine the transition to sustainability. Subsidies are direct or indirect financial contributions made by governments to promote a specific activity or policy, and confer a “benefit” on a domestic industry. They may be in the form of a direct payment, the provision of goods or services, a price support or the foregoing of tax revenue otherwise due (Mohammed et al., 2018). These fiscal instruments and policies can affect fish stocks, both within exclusive economic zones and in areas beyond national jurisdiction (the high seas), with an impact on coastal communities that rely on these aquatic resources for their livelihoods, food security and nutrition (Popova et al., 2019). Recognizing the interconnected socioeconomic and nutritional impacts of high-seas governance and ocean property rights – in relation to industrial fishing, as well as mariculture and non-fishing activities, such as the dumping of industrial waste – is an integral step in reforming ocean governance.

Nevertheless, food production subsidies are needed, as the subsidization of nutritious foods can be an effective way of ensuring their affordability, especially for the poor (FAO et al., 2020). The current efforts of the United Nations General Assembly, ongoing negotiations at the World Trade Organization and SDG target 14.6 all call attention to the conservation and sustainable use of marine resources in areas beyond national jurisdictions and to the reform of subsidies and economic incentives in fisheries management to deliver positive social, ecological and economic outcomes (Mohammed et al., 2018; Popova et al., 2019). Mainstreaming nutrition and equity into subsidy considerations should be at the top of the agenda, to ensure sustainable healthy diets for all. Social impacts should be mitigated by funds redirected or earmarked for social programmes and targeted support for certain groups, such as small-scale fishers, women and youth (Harper and Sumaila, 2019).

The sustainable supply of aquatic foods: Reduced food loss and waste

Aquatic food loss and waste compromise the diets of millions of people, especially the poor, by depriving them of nutrient-rich foods. Food loss and waste translate into decreases in both the quantity and quality of foods available, economic losses from reduced market value and losses along the value chain. It is estimated that 35 percent of the global harvest in capture fisheries and aquaculture is either lost or wasted every year (FAO, 2020a).

However, there are large discrepancies in the estimates of fish loss and waste (Akande and Diei-Ouadi, 2010) and robust assessments are lacking, particularly in LMICs (Kruijssen et al., 2020). Reducing food loss and waste in all food sectors is globally recognized as a challenge that needs to be addressed, as stated in target 12.3 of the SDGs: “By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses” (United Nations, n.d.). A reduction will make more food available without putting more pressure on the environment. The 2014 HLPE report on sustainable fisheries and aquaculture for food security and nutrition also gave this advice: to “support and promote initiatives to minimize fish discards and post-harvest losses and waste at all steps of the fish value chain” (HLPE, 2014).

Food loss refers to a decrease in quantity or quality, mostly during production, processing or marketing, resulting in food that is unfit for human consumption. Waste is typically related to behaviours such as the disposal of edible food (Parfitt et al., 2010). However, overconsumption can also be considered a form of food waste, putting equity and food distribution in the spotlight (Tlusty et al., 2019). Loss is high in LMICs due to poor handling, processing, storage and marketing practices, whereas waste is greater in high-income countries (at retail and consumer level) (Thilsted et al., 2016).

Loss is further influenced by the species and physical characteristics of the fish, quantity of fish handled, seasonality, geographical location and market value of the fish (Kruijssen et al., 2020). Quantitative losses are more commonly assessed than qualitative ones. Small fish species of low market value are subject to greater physical and quality losses, particularly in areas where simple fish processing technologies (such as sun-drying) are affected by external factors such as seasonal rains. Quality loss poses a challenge in fish value chains in many LMICs due to lack of infrastructure, good processing practices or decent technology (Diei-Ouadi et al., 2015).

Sociocultural and gender norms, which may limit women's access to and control over resources, technology, assets, training and education, are among the major reasons for food value-chain inefficiencies, often causing higher losses in those areas of the fish value chain where women tend to work (such as processing and marketing) (FAO, 2018b). Studies of nutritional loss in fish value chains have focused on the effect of processing, storage and preparation methods on the nutrient retention of the final product, primarily microbial decomposition and lipid oxidation (the loss of omega-3 fatty acids). However, they rarely include the nutritional consequences of these types of degradation (Aubourg, 2001; Kruijssen et al., 2020).

Increased attention is being paid to reducing food loss and waste across aquatic food value chains, probably to maximize economic returns and, secondarily, to ensure sustainability. While there are studies and food composition data available for aquatic foods in their raw, sun-dried, smoked, frozen and canned forms, these tend to focus on highly traded finfish species and the processing methods common in high-income countries. There are few studies on nutritional loss along entire value chains (Kruijssen et al., 2020). There is some evidence on other aquatic species, such as shrimp (ILO and NORAD, 2016; FAO and ILO, 2020), mud crab (SmartFish, n.d.) and squid (FAO, 2017b).

There is also little evidence of food loss and waste assessments in aquaculture value chains, possibly on the assumption that there is more control over harvesting, handling and distribution than in capture fisheries. Much waste is due to consumer preferences, such as the tendency in some western countries to only eat certain parts of the fish (the fillet). However, there are examples of parts not consumed in Nordic countries being exported to LMICs (for example, dried, salted cod and other fish heads to Nigeria) (Salaudeen, 2013). Exploring the use of safe, nutrient-rich, edible parts that are usually lost or wasted for consumption can offer a viable solution (Box 5).

Box 5.

Repurposing low-cost fish species and by-products for school feeding programmes in Ghana

The factory remnants of tuna frames, as well as three under-utilized fish species (one-man thousand, anchovies and flying gurnard, or Dactylopterus voltans), were dried and ground into fish powder, then added to meals for school children in Ghana. Four local dishes were prepared and assessed by school children for their acceptability, based on a hedonic scale. This produced particularly high scores for anchovy and okro stew with rice, tuna-frame-powder stew with rice, and flying gurnard stew with rice. Proximate analysis showed the protein content of all fish powders and tuna-frame powder to be high, and later nutrient analysis of the tuna frames and by-products showed a high iron content. The study demonstrated the potential of low-cost, highly nutritious, under-utilized fisheries resources and by-products for improving the nutritional value of traditional dishes, while reducing food loss and waste and encouraging sustainable healthy diets.

Source: Glover-Amengor et al., (2012); Abbey et al., (2016).

Sustainable supply of aquatic foods: Projecting the contribution of fisheries and aquaculture to nourishing the world in 2030 and beyond

FAO forecasts the share of fish production for direct human consumption to continue to grow, reaching a total of 183 million tonnes by 2030. This translates into annual per capita apparent fish consumption of 21.5 kg, up from 20.5 kg in 2018. Based on FAO analysis, total fish production (excluding aquatic plants) is projected to expand to 204 million tonnes in 2030, up 15 percent in absolute terms (FAO, 2020a) (see Box 6 and Annex 2 for more).

Capture fisheries are projected to remain at current levels (with some fluctuations linked to the El Niño weather phenomenon affecting catches in South America), with an increase in catches in all areas as they recover from previous over-exploitation, as well as underfished resources and better utilization of the harvest (through reduced on-board discard, waste and loss). Management of wild stocks must consider the impacts of climate change (FAO, 2020a). Pollution and ocean acidification may deteriorate tropical and subtropical reefs and reduce fish availability; combined with poleward migration of many fish stocks due to warming waters, can result in detrimental impacts on nutritionally vulnerable populations in LIFDCs, who rely on fish for micronutrients, animal protein and livelihoods (Golden et al., 2016; Landrigan et al., 2020). However, evidence of negative impacts is also present in commercial and subsistence fisheries in areas of high-income countries, such as southeast Alaska, where shellfish are a large component of the local diet (Mathijs et al., 2015).

Box 6.
Projections for aquatic food production beyond 2030

The FAO Fisheries Division has conducted preliminary projections to 2050, based on a number of simplistic expectations of sectoral growth, and produced three plausible scenarios for consideration and action.

- **Business-as-usual scenario** – Marine capture fisheries grow by a modest 0.05 percent per year from 2030 to 2050, while inland capture fisheries grow 0.3 percent annually over the same period, partially due to better reporting systems. The percentage of marine capture fisheries not used for direct human consumption is 21.3 percent of the total marine capture for 2031, decreasing 0.05 percent annually thereafter as technological improvements get underway.

- **High-road scenario** – This scenario projects a number of positive outcomes that allow aquaculture development and intensification along sustainable lines and ensure that marine capture fisheries move steadily towards the estimated maximum sustainable yield for oceans and seas. Growth rates are modest, but significant as production increases and reflect more extensive investment in mariculture. Marine and inland capture fisheries grow by 0.7 percent and 0.55 percent per year to 2030, respectively, however, yields of both are subject to a 4.05 percent decrease in 2050, consistent with RCP2.6 ("strong mitigation") projections for climate change impacts in capture fisheries (FAO, 2018a). With improved technologies and reduced loss and waste, the proportion of marine capture fisheries not used for direct human consumption decreases from 21.3 percent in 2020 to 19.35 percent by 2050.

- **Low-road scenario** – This scenario projects a number of failures in aquaculture and unsustainable practices, leading to a deterioration in many new ventures, resulting in limited growth. Capture fisheries, both marine and inland, see continued deterioration of the resource base, estimated at a 0.25 percent production loss per year to 2040, rising to 0.5 percent in 2050. It also foresees a 9.6 percent loss in the 2050 yield, consistent with RCP8.5 ("business-as-usual") projections of climate change impacts (FAO, 2018a). The proportion of marine capture fisheries not used for direct human consumption remains at 21.3 percent, with no benefit from further technological innovation.

More details on these projections are presented in Annex 2.

Aquaculture is seen as the driving force behind growth in the availability of fish and is forecast to reach 109 million tonnes in 2030, a 32 percent increase from 2018, despite a projected decline in the rate of expansion (FAO, 2020a). Freshwater species, such as carp and catfish, will increase their contribution to global aquaculture production, while higher-market-value species, such as shrimp, salmon and trout, will grow more slowly due to higher prices and the reduced availability of fish meal. Aquatic food farming is expected to be the way forward in bridging the gap between global demand and supply, while potentially reducing anthropogenic pressure on wild aquatic populations (World Bank, 2013; Béné et al., 2015). However, the investment needed for some farming methods (such as mariculture) favours the production of high market-value species, which are unlikely to reach the poor and food-insecure (Belton et al., 2020).

The ability of the capture fisheries and aquaculture sectors to meet demand will depend in part on their ability to increase or maintain production with minimal impact on marine and freshwater ecosystems, while also minimizing losses and waste. Despite projected increases in per capita fish consumption, for aquatic foods to have the greatest impact on food security, nutrition and sustainable healthy diets, we must consider the equity, diversity, affordability and sustainability dimensions.

Projections show per capita fish consumption increasing in all regions except Africa, as population growth outstrips supply on the continent, even when taking into account a forecast increase in fish imports. The highest consumption growth rates are expected in Asia (9 percent), followed by Europe (7 percent), Latin America and Oceania (6 percent). In Africa, in contrast, per capita fish consumption is expected to fall 3 percent to 9.8 kg per capita per year by 2030, particularly in sub-Saharan Africa (FAO, 2020a). This projection is worrying on a continent where fish consumption is already lower than the global average, despite fish being the most common animal-source food.

Moreover, shifting consumption patterns from the traditionally consumed wild small fish to farm-raised, carnivorous large fish have been shown to reduce micronutrient intakes in Bangladesh (Bogard et al., 2015b). If aquaculture is to meet demand for aquatic foods and simultaneously serve the most nutritionally vulnerable, it must take into account consumer preferences, affordability, equitable distribution and sustainable supply – in addition to building the capacity of fish farmers, particularly in Africa.

5 Food safety, risks and benefits of aquatic foods

Food safety concerns over aquatic food products

Aquatic foods are highly perishable, and failures in various areas of the value chain, such as storage and distribution, can lead to the food being contaminated, with adverse effects on diets and health. The majority (80 percent) of outbreaks of seafood-borne illnesses are down to biotoxins (ciguatoxin), scombrotoxin or the consumption of raw molluscs (Huss et al., 2000). Food safety concerns can be biological (due to bacteria, viruses or parasites) or chemical (biotoxins) and can stem from environmental and anthropogenic sources, leading to concerns over the safety of consuming aquatic food products (Jennings et al., 2016).

Hazardous chemicals – for example, persistent bio-accumulative and toxic compounds, such as dioxins, PCBs and heavy metals (mercury, lead or cadmium, for instance) – can build up in fish and bivalves, although they are generally higher in polluted waters or large, predatory marine species as a result of bioaccumulation throughout the aquatic food chain (Hanna et al., 2015; FAO, 2017a). Foodborne viruses, bacteria and parasites are most worrying when aquatic products are consumed raw or undercooked, for example, oysters, clams, mussels, cold-smoked products, marinated products, sushi and ceviche.

In addition to biological and chemical contaminants, marine biotoxins and harmful algal blooms (HABs) are of growing concern. Marine biotoxins are a concern for which most LMICs do not have the resources to establish monitoring programmes. HABs are natural phenomena that have occurred throughout history, caused by certain non-toxic algal species (for humans), which produce exudates that can cause damage to the delicate gill tissues of fish, leading to mass fish mortalities, economic losses and a detrimental impact on food security and nutrition. Climate change can create an enabling environment for HABs, which seem to have become more frequent, intense and widespread in recent decades. Furthermore, benthic HABs, which occur primarily in the tropics, are responsible for the formation of ciguatoxins, the cause of ciguatera poisoning, to which SIDS in tropical regions are particularly vulnerable (FAO and WHO, 2020).

Worryingly, microplastic accumulation in fish may pose a risk to human health. Plastic litter is a major problem for aquatic environments, and microplastics (small-sized plastics of less than 5 mm in diameter) have been detected in the gastrointestinal tracts of many commercial fish and shellfish species (these are often removed before they are consumed by humans) (Garrido-Gamarro et al., 2020). Small fish and bivalves, commonly eaten whole, are the main source of microplastics in aquatic foods, however, preliminary food safety risk assessments have suggested that the contribution of hazardous chemicals from microplastics for consumers of large amounts of bivalves is small. From the current knowledge on microplastics in aquatic foods, there is no evidence that food safety is compromised. The best way to tackle the growing concerns about microplastics in aquatic foods is to improve plastic waste collection and management.

To address food safety concerns, FAO and WHO established the Codex Alimentarius (FAO and WHO, 2009), an international food safety code that includes guidelines, standards and regulations for potential food safety hazards, with specific regulations on food hygiene, sampling and analysis, inspection, certification and labelling of aquatic foods. However, the Codex tends to be applied, for the most part, to aquatic foods for international trade and rarely used in domestic marketing, creating different standards for food safety at local and international levels.

The COVID-19 pandemic put a spotlight on food safety concerns over interactions between humans, animals and our changing environment. The risk of contracting COVID-19 from eating or handling food remains low, however. Greater attention is being paid to proper food handling and preparation practices to mitigate the risk of spreading bacteria and contaminants (CDC, 2020b; FAO, 2020b). Chapter 6 reviews the observed and expected long-term impacts of the COVID-19 pandemic on food security and nutrition and the role of aquatic foods in times of systemic shock.

Health risks and benefits of aquatic foods

Dietary recommendations on the consumption of aquatic foods have typically weighed the food safety risks against the nutrition and health benefits, incorporating well-known risk-benefit analyses from FAO and WHO (2011a; 2011b), the EFSA Scientific Committee (2015) and the United States Food and Drug Administration (US FDA, 2014). These consultations and reports conclude that the benefits of fish consumption – including the reduced risk of mortality from coronary heart disease in adult populations – outweigh the risks associated with methylmercury but at the same time, recommend that people limit their intake of high-trophic aquatic food species due to bioaccumulation of methylmercury.

For specific population groups, such as women of reproductive age and pregnant and lactating women, the modest consumption of aquatic foods, with the exception of few species, lowers the risk of suboptimal neurodevelopment in infants and children (FAO and WHO, 2011; Mozzaffarian and Rimm, 2006). However, the EFSA concludes that it is not possible to make general recommendations on fish consumption for Europe, as each country needs to consider its own fish consumption patterns and carefully assess this against the risks (EFSA Scientific Committee, 2015).

Few risk-benefit analyses of aquatic food consumption exist, as there is a dearth of high-quality data on food consumption patterns of populations, how much of each food item is consumed and the nutrient and contaminant content of foods. Many countries do not have a compositional data overview of foods consumed and very few countries have representative epidemiological studies on aquatic food consumption. The types and amounts of aquatic foods consumed vary greatly globally and the major risk-benefit assessments to date have been primarily based on farmed and wild finfish (VKM, 2006; 2014). In addition, most risk-benefit analyses for aquatic food consumption focus on adults (particularly prenatal and postnatal women); there is a need for further research on other population groups. For example, Bernstein et al. (2019) highlight the need for further research to substantiate the health benefits to children (beyond infancy) of consuming aquatic foods.

6 COVID-19 and aquatic foods

The COVID-19 pandemic has disrupted food supply chains, closed businesses and schools and increased unemployment around the world, hindering access to healthy foods through direct provision (such as school feeding programmes) or indirect means (loss of income). Food price indexes have risen for five consecutive months (to October 2020), further compounding the affordability of healthy diets (FAO et al., 2020; HLPE, 2020; FAO, 2020d).

The aquatic food sector is an important source of employment and nutrition. It is also highly globalized, allowing shocks to proliferate internationally, although some supply chains, small-scale actors and civil-society organizations have shown greater resilience than others (Love et al., 2020). Disruptions to demand, distribution, labour and production in aquatic food supply chains have occurred globally (FAO, 2020a; 2020e), but in some regions, these have been magnified by existing stressors, such as climate change and natural hazards (for example, the wildfires in the United States of America), resource management and political or economic instability (Love et al., 2020). The collapse of export markets has created a space for local producers to meet demand for aquatic foods. However, the limited capacity of local markets and local fishing fleets to meet this demand has highlighted many management issues (FAO, 2020e).

The perishability of aquatic food provisioning is the major challenge, requiring capital-intensive cold chains or processing methods that meet food safety standards to support distribution (Johnson et al., 2020). The marketing and distribution of aquatic foods are highly reliant on the food services sector, resulting in reduced activity for many fish wholesalers and fewer outlets for high market-value species as countries implement movement restrictions and lockdowns (FAO, 2020e). In LMICs, the informal sector has been hard hit due to lockdowns and restrictions on livelihood activities, including fishing, fish farming and post-harvest activities, while households in need have been unable to access safety nets and social networks (Fiorella et al., 2018).

Much of the fish value chain lies in the informal sector and is dominated by rural women, who have been highly affected by restrictions on movement, despite the potentially significant contribution of aquatic foods and products (such as dried small fish) to ensuring food security and nutrition at this time, due to their portability, affordability and extended shelf life. Ensuring worker safety and rights of access for producers and processors in dried-fish supply chains and supporting the redirection of fish to drying where other market channels are blocked could deliver nutritious dried fish products to nutritionally vulnerable people in the wake of the COVID-19 shock in LMICs (Johnson et al., 2020). There is some evidence that the crisis has led to a decline in fishing pressure due to reduced demand, lower prices and lockdowns, which may allow fish stock recovery (Bennett et al., 2020). It may be too early to tell, however, as the pandemic has also limited management systems, survey implementation, control and surveillance systems for fish stocks (FAO, 2020e).

Short-term coping and adaptation measures were observed in the first five months of the pandemic; actors and institutions in the aquatic food sector can learn from these adaptive responses to build robustness and prevent future shocks (Love et al., 2020). A better understanding of the resilience of the aquatic food supply and value chains is needed to address the current and future socioeconomic impacts of COVID-19 and better prepare the world for future shocks. Diversifying food systems and livelihood activities is one coping strategy and a means of transforming and building resilience. This would achieve multiple objectives of improving food security and nutrition, making rural livelihoods more resilient, improving income and conserving biodiversity, so people can better respond to seasonal changes in food availability and to shocks (Freed et al., 2020a; Anderson et al., 2018).

Box 7.

Aquatic food distribution in the Philippines: COVID-19 aid

Recognizing the importance of fish in Filipino diets and in an effort to support healthy eating during the COVID-19 pandemic, the Government of the Philippines supplied aquatic foods - canned sardine, a Filipino staple food and, in limited areas, fresh fish - in food aid packages for families in need of assistance. The Philippines is highly reliant on fish (Golden et al., 2016), ranking second globally in terms of nutritional dependency on their coastal and marine ecosystems (Selig et al., 2018). The Government, in collaboration with philanthropic and religious organizations, coordinated the purchase of fish directly from local fishers for distribution (ADB, 2020; Cabico, 2020; Rey, 2020).

Distribution of food aid was carried out through a combination of house-to-house delivery by local government organizations, the army and delivery services from centralized distribution sites (GFN, 2020; ADB, 2020), so as to limit non-compulsory movement in line with COVID-19 restrictions. The recipients were mostly waged workers, such as pedicab drivers, street sweepers and migrant labourers, who could no longer work due to pandemic-related constraints. While the effort was well-intentioned, challenges related to storage and the distribution of perishable foods such as fresh fish, highlighted the need to balance the nutritional benefits of shelf-stable aquatic food products (such as canned sardines or tuna, dried fish or tuna flakes) with providing essential macro- and micronutrients and the adverse effects of the high sodium intake from canned products (Ong et al., 2020; ADB, 2020; Mangiduyos, 2020).

This is not the first pandemic the world has endured, and it is unlikely to be the last. To this end, in 2008, FAO, WHO and the World Organisation for Animal Health signed an agreement to coordinate activities to investigate and address health risks at the human–animal–environment interface and to develop a strategic framework drawing on the lessons of past viral pandemics (Mackenzie and Jeggo, 2019). This One Health framework is a multisectoral, interdisciplinary and collaborative approach aimed at increasing communication and collaboration between experts such as doctors, veterinarians and social scientists, to attain optimal health for animals, humans and the environment (Henley, 2020; CDC, 2020a). It highlights the need to understand the larger issues behind pandemics, not just treat them as isolated events, recognizing the connections between humans, animals and our changing environment, to fuel a paradigm shift in how we think and act in relation to health for all (Henley, 2020).

7 Recommendations and conclusions

This paper shows the potential of aquatic foods to contribute to a sustainable healthy diet. It clearly indicates the multiple health benefits associated with consuming aquatic foods. It also shows that moderate consumption does not necessarily increase the negative environmental impacts of production; indeed, if supplied and consumed as discussed in this paper, aquatic foods can benefit people's health and the environment.

Greater production and consumption of aquatic foods depend on a host of factors, be they physical or environmental (such as pollution, climate change and ocean acidification), political (fisheries, climate and trade policies) or technological (advances in knowledge systems, livestock and aquaculture feeds, mariculture technology, freshwater aquaculture systems), as well as economic factors, income elasticity and institutional setup (property rights and trade). Changes in consumer behaviour and demand for more diverse and low-trophic aquatic foods will also play a role in putting aquatic foods on the table. Aquatic foods are part of the solution to building resilient food systems and sustainable healthy diets for all, but for this to be fully achieved, they need to be available, accessible, affordable and desired. To this end, a number of strategies are needed.

- Promote changes in consumer behaviour and demand towards more sustainable, diverse and low-trophic aquatic foods. Ensure demand-driven solutions by:

  - promoting the consumption of aquatic foods, particularly for nutritionally vulnerable groups, through tools such as FBDG, public procurement programmes (like school feeding and social safety nets) and public health and nutritional interventions in the first 1 000 days of life;
  - aligning national FBDG with the FAO and WHO Principles of Sustainable Healthy Diets and improving the understanding of "moderate" consumption by quantifying an ideal range for the consumption of aquatic foods, taking into account the complementarity of aquatic foods with other foods, as well as the sociocultural and demographic context;
  - developing innovative aquatic food products that make low-trophic species, underutilized species and by-products desirable and affordable for consumers.

- Sustainably improve the supply of aquatic foods for human consumption and build resilient aquatic food systems by:

  - targeting diverse aquatic foods, particularly low-trophic species with high biomass (such as pelagic small fish, jellyfish and seaweed);
  - focusing on sustainable harvesting and catch use (for example, by encouraging consumers to choose the "catch of the day" and bycatch);
  - promoting sustainable and diversified aquaculture approaches that mainstream nutrition and reduce reliance on feed inputs processed from aquatic foods that can be consumed directly by humans;
  - encouraging the use of wasted by-products and reducing the loss and waste of aquatic foods by improving access to productive resources, technologies, markets, finance and business training to build the capacity of small-scale producers and processors to cope with peak harvest periods and to produce aquatic food products with an extended shelf life that can be distributed in times of low availability and to communities living far from water bodies.

- Encourage the adoption and implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (FAO, 2018d) and the CFS Recommendations on Fisheries and Aquaculture (CFS, 2014) to improve governance of aquatic resources for food security and nutrition, which provide the backdrop for issues such as:

  - ensuring that fisheries management policies protect dependent communities and safeguard physical, economic and institutional access to and availability of aquatic foods; and
  - balancing agricultural (and fisheries) policies and incentives towards more nutrition-sensitive investment and the prioritization of diverse aquatic foods as public health assets rather than commodities.

- Promote policies that prioritize aquatic foods for domestic consumption over export, particularly in areas with high rates of malnutrition.

- Encourage implementation of long-term solutions for improved food safety of aquatic foods including improved governance at all levels, as well as behavioural and systemic changes, such as enabling a better circular economy framework and more sustainable production and consumption patterns. Prioritize the revision of existing regulatory frameworks, institutional arrangements and other instruments related to marine litter and their enforcement, to identify synergies, gaps and potential solutions globally and regionally and, thus, reduce and avoid impacts on aquatic food systems and consumers.

- Reform subsidies to prioritize support for small-scale producers to sustainably harvest and farm aquatic foods for better livelihoods, food security and nutrition. Bring equity considerations to the forefront of the debate and mitigate the social impacts of subsidy reforms (in terms of income, jobs and food supply) by redirecting or earmarking funds for social programmes to promote social equity and gender equality for groups such as small-scale fishers, women and youth.

- Democratize knowledge, data and technologies to co-create meaningful knowledge and usable innovations. Invest in further research to:

  - improve the quality of data collection from capture fisheries and aquaculture of diverse aquatic foods and to gather data beyond production, including processing, distribution and retail, to better understand where improvements are needed in the value chain and to gain insights into consumer demand for aquatic foods to shape production;
  - gather insights into consumption practices in countries, communities and households to better understand consumer preferences (such as which aquatic foods and how much of them are consumed by different population groups, communities or household members, which parts of aquatic foods are consumed, the factors enabling or hindering consumption such as affordability, availability, accessibility, stability, knowledge and behaviour);
  - build data on the nutritional composition of and contaminants in the diverse aquatic foods consumed in LMICs to inform the potential of aquatic foods to contribute to sustainable healthy diets;
  - engage with the private sector to develop desirable products to promote nutritious aquatic foods.

Diverse aquatic foods have an essential role in sustainable healthy diets for many people around the world, now and in the future.

Annex 1

Selected nutrients and their human consumption benefits

Nutrient	Human consumption benefits
Protein	Source of amino acids, needed for growth and muscle mass.
Calcium	Important for bone growth and maintenance and cellular function.
Iron	Iron is an essential component of haemoglobin, myoglobin, enzymes and cytochromes and is necessary for oxygen transport and cellular respiration. It is also critical for optimal growth and cognitive function (Bailey et al., 2015). Iron deficiency is the most common micronutrient deficiency in the world, affecting more than 30 percent of the world's population. It can cause anaemia, which is of significant concern for many women around the world and can lead to low cognitive function and work productivity. Children born to iron-deficient mothers are also more likely to have low iron stores, impaired physical and cognitive development and suboptimal immune systems.
Zinc	Essential for cellular metabolism.
Iodine	The primary function of iodine is in the synthesis of thyroid hormones. It also plays an important role in foetal brain and nervous system development (Bailey et al., 2015; Lazarus, 2015).
Vitamin A	Vitamin A comes from animal sources preformed as retinol or retinyl esters, or from provitamin A carotenoids in plant sources. It is a fat-soluble vitamin with various roles in the body including vision, cell differentiation, immune function, reproduction, and organ and bone formation and growth (Bailey et al., 2015).Vitamin A deficiency has been linked with increased rates and severity of infections and is the leading cause of preventable blindness in children. Vitamin A deficiency is also a primary cause of childhood morbidity and mortality in developing countries, particularly in Africa and Southeast Asia (Bailey et al., 2015).
Vitamin B12	B vitamins are essential for energy production, brain function and nervous system function. Vitamin B12 is only found in animal-source foods.
Vitamin D	Vitamin D is essential for cardiovascular health and bone health.
Omega-3 fatty acids	Important for cognitive development in the foetus, in the first two years of life and during different periods throughout life (for example, "brain spurts" through adolescence). Evidenced for reduction of several chronic diseases (such as cardiovascular disease, high blood pressure, stroke and Alzheimer's) and of inflammatory/metabolic disorders (such as obesity, diabetes and asthma).
Eicosapentaenoic acid (EPA)	
Docosahexaenoic acid (DHA)	

Annex 2

Projections of fish production in 2050 under three scenarios

	Business as usual	Low road	High road
Marine capture (mt)	85.4	65.8	95.5
Inland capture (mt)	13.0	10.1	13.5
Total capture (mt)	**98.3**	**75.8**	**109.0**
Inland aquaculture (mt)	89.9	75.6	98.4
Marine aquaculture (mt)	50.1	45.3	62.0
Total aquaculture (mt)	**140.0**	**120.8**	**160.3**
Total production (mt)	238.3	196.7	269.3
Fish for direct food (mt)	217.4	180.5	248.2
Per capita apparent consumption (kg/year)	**22.3**	**18.5**	**25.5**

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Acronyms

AFOLU	Agriculture, Forestry and Other Land Use
ADB	Asian Development Bank
CARD	Council for Agricultural and Rural Development (Cambodia)
CFS	Committee on World Food Security
COVID-19	Coronavirus disease 2019
EFSA	European Food Safety Authority
EUMOFA	European Market Observatory for Fisheries and Aquaculture Products
FAO	Food and Agriculture Organization of the United Nations
FBDG	Food-Based Dietary Guidelines
FDA	Food and Drug Administration
GEF	Global Environment Facility
GFN	Global FoodBanking Network
GHG	Greenhouse gas
HABs	Harmful algal blooms
HLPE	High-Level Panel of Experts on Food Security and Nutrition
IC2N	Second International Conference on Nutrition
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
ILO	International Labour Organization
ISMEA	Istituto di Servizi per il Mercato Agricolo Alimentare
LIFDC	Low-income food-deficit country
LMICs	Low- and middle-income countries
MDD-W	Minimum dietary diversity for women
NHS	National Health Service
NORAD	Norwegian Agency for Development
NZTE	New Zealand Trade & Enterprise
OECD	Organisation for Economic Co-operation and Development
PCB	Polychlorinated biphenyl
SDG	Sustainable Development Goal
SIDS	Small island developing states
SIS	Small indigenous fish species
UNICEF	United Nations Children's Fund
UNSCN	United Nations System Standing Committee on Nutrition
USDA	United States Department of Agriculture
VKM	Vitenskapskomiteen for mat og miljø
WHO	World Health Organization
WFP	World Food Programme

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