Global Panel on Agriculture and Food Systems for Nutrition

Harnessing aquaculture for healthy diets

This brief sets out the contribution that aquaculture can make to healthy diets and resilient food systems. It provides guidance for policymakers as they consider decisions related to the expansion of aquaculture, balancing issues related to diets and food security, economic growth and employment, and the environment.

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ABOUT THE GLOBAL PANEL ON AGRICULTURE AND FOOD SYSTEMS FOR NUTRITION

The Global Panel is an independent group of influential experts with a commitment to tackling global challenges in food and nutrition security. It works to ensure that agriculture and food systems support access to nutritious foods at every stage of life.

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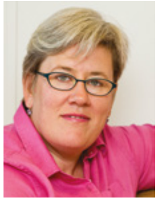

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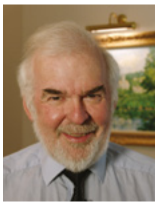

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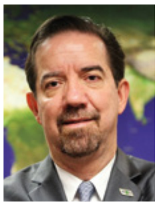

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Executive Summary

Aquaculture has the potential to deliver diverse benefits to low- and middle-income countries. It can enhance the quality of diets and the health of populations through improved nutrition. It provides considerable employment through its value chain, accounting for 20.5 million jobs globally in 2018. For countries in Asia, for example, it can provide a major source of exports to high-income countries. And if implemented and managed sustainably, it provides an alternative to captured fish, thereby reducing pressure on capture fisheries under threat from overfishing and climate change.

However, despite many opportunities presented, aquaculture, together with capture fisheries, is too often sidelined in policies and dialogues relating to nutrition and food systems. These tend to focus much more on land-based food production. Over the next decade, as food systems strive to meet the demands of a growing world population, policy makers need to take much greater account of the aquatic dimension in their food-system policies and strategies.

There is considerable potential for many countries in Africa in particular, and elsewhere, to capitalise on the opportunities and benefits presented by aquaculture. While Asia is at the heart of global aquaculture production, employing 19.6 million in 2018, Africa only employs around 400,000. At present a relatively small number of countries in Africa are expanding their activities substantially.

Worldwide, the production of fish from aquaculture could surpass that of capture fisheries by 2024. But the extent to which this achieved will depend on policymakers taking action to create the right enabling policy environment, and promote investment in value chains. Further expansion of the aquaculture sector also needs to proceed sensitively to manage trade-offs and conflicting priorities, for example relating to land and water use (in the case of inland aquaculture), and also to address major challenges relating, in particular, to sustainability and antimicrobial resistance. Priority actions for different classes of stakeholder are as follows:

Governments:

- Food security and nutrition issues need to be integrated into policy decisions relating to fisheries and aquaculture. Too often decisions focus on economic considerations, neglecting the nutrition and health implications of policies in this sector.
- Fish and related products produced from aquaculture should be fully incorporated into agriculture and trade policies, updated national food-based dietary guidelines, and considered within nutrition and health policies and strategies.
- Entrepreneurship by SMEs involved in aquaculture needs to be encouraged. Governments should encourage access to loans and financial markets to enable capital investments that can

help overcome the barriers faced by businesses that are starting up or increasing production.

- The promotion of inclusive growth should be a priority as value chains are upgraded. Women and local communities should benefit from opportunities for aquaculture value chain development.

- Resolving competition for land (for inland aquaculture versus other uses) requires careful consideration of trade-offs, taking a wide perspective of costs and benefits. Important considerations should include: the nutritional and health benefits of aquaculture products, diversification of food production, enhanced earnings when relatively unproductive land is repurposed, and possible increases in employment.

Multiple stakeholders working together:

The following priorities variously require actions by actors in the public and private sectors, donors and researchers:

- Investment should be encouraged to enhance the variety and profitability of aquaculture feed options across LMIC markets. Governments, their development partners, and private sector entities all have a role to play. The goals should be to increase human capital, skill development, and wider adoption of existing feed-related technologies to countries in the global South. Policymakers should also consider implementing pro-business policies: for example, reducing import taxes on machinery and raw materials for feed.

- Environmental sustainability in new and existing aquaculture systems needs to be a priority, not least in view of the threat of climate change, and the relentless degradation of environmental resources.

- The growing threat of antimicrobial resistant bacteria needs to be addressed by all countries in view of its potential impact on commercial growth, animal and human health, and contamination of the environment and food chain.

- Loss and waste in fish value chains needs to be tackled. It affects business efficiency, it is bad for the environment, and involves loss of valuable nutrients vital for healthy diets.

Researchers:

Science and technology have a key role to play in future aquaculture. A particular priority is the need to identify alternatives to meal and fish oil from capture fisheries, especially those that involve use of local inputs and are scalable solutions in LMICs. The genetic improvement of fish species is also important. There is considerable scope to increase productivity, enhance nutritional value, and improve disease resistance through selective breeding.

1. Introduction

Fish represents a key component of a healthy diet, given the protein, omega-3 fatty acid and micronutrient profile it provides, and the diversity of fish available. It is also one of the most traded food commodities by monetary value, at US$165 billion in 2018, and in many ways exemplifies the interconnectedness of today's global food system.[1] Rising economic growth, increasing urbanisation, and health consciousness are macro trends responsible for the growing demand for fish and other aquatic foods globally, with the greatest growth seen in low- and middle-income countries (LMICs), particularly in Asia. However, the importance of fish in providing nutrition security in LMICs is often overlooked, and fish consumption is much lower in many LMICs than in high-income countries. Despite this, for many poorer countries the fish sector is an important economic, cultural and nutritional resource.

A key issue concerns the sustainability of fish supplies for healthy diets. Capture fisheries have traditionally been the main source of fish worldwide. However, the proportion of fish stocks which are being fished beyond biologically sustainable levels is rising, and the growth in the catch from fisheries has stalled since the 1990s. Aquaculture is now playing an increasingly important role in the sustainable production of fish, and is also a promising approach to increasing the availability of micronutrient rich foods in LMICs. It is arguably the fastest growing agricultural subsector, and while its rate of growth is expected to slow, production is projected to reach the 105 million tons per year that the world needs by 2029.

Unlike terrestrial animal species or crops, most species of fish are genetically unimproved by humans. More than 580 aquatic species are now farmed throughout the world, in freshwater lakes, in the sea, in cages in rivers, and backyard ponds.[2] Rapid gains in the productivity and growth of species such as tilapia have occurred over a very short time and are continuing to accrue. Similarly, technologies used in the feeding and care of fish are also witnessing a revolution, including the replacement of ingredients such as fishmeal and fish oil in some cases, thereby helping to ease pressure on capture fisheries for these ingredients. Aquaculture, however, shares many common inputs with agriculture and animal husbandry including the need for fresh water, land and other agricultural inputs used for feed. With growing pressure to increase the productivity of both agriculture and aquaculture, policymakers are increasingly being forced to reflect on the potential trade-offs associated with investments in these sectors.

Investments such as hydropower, urban water consumption, and river diversion can have very substantial negative impacts on more traditional fish-focused livelihoods, with significant implications for the well-being of local communities. These concern the availability and price of fish within the local food system, and in many countries, the availability of national income from trade. Unfortunately, nutrition and food security are rarely given priority within policy discussions on trade-offs: water and food commodity assets are often managed to maximise economic outputs rather than the nutrition, food security or other needs of local populations.[3–5] This is a particular concern, as the nutrients derived from[6] diverse local fish are often the best available to fill nutrient gaps in local diets, particularly for young children who have high nutritional needs.[5,7]

This brief summarises current developments in aquaculture and discusses the many opportunities and benefits that further growth offers. These relate to food security, nutrition and health, but also to jobs and growth, and the natural environment. However, such benefits are contingent on the decisions that policymakers make to encourage and frame the development of the sector, and to address specific challenges which affect aquaculture. The aim of this policy brief is to provide guidance and advice on how best to approach those decisions. It sets out the contributions that aquaculture products can make to healthy diets and resilient food systems. It also provides guidance for policymakers as they consider decisions related to the expansion of aquaculture, balancing issues related to diets and food security, economic growth and employment, and the environment.

Box 1. Defining key terms used in this brief

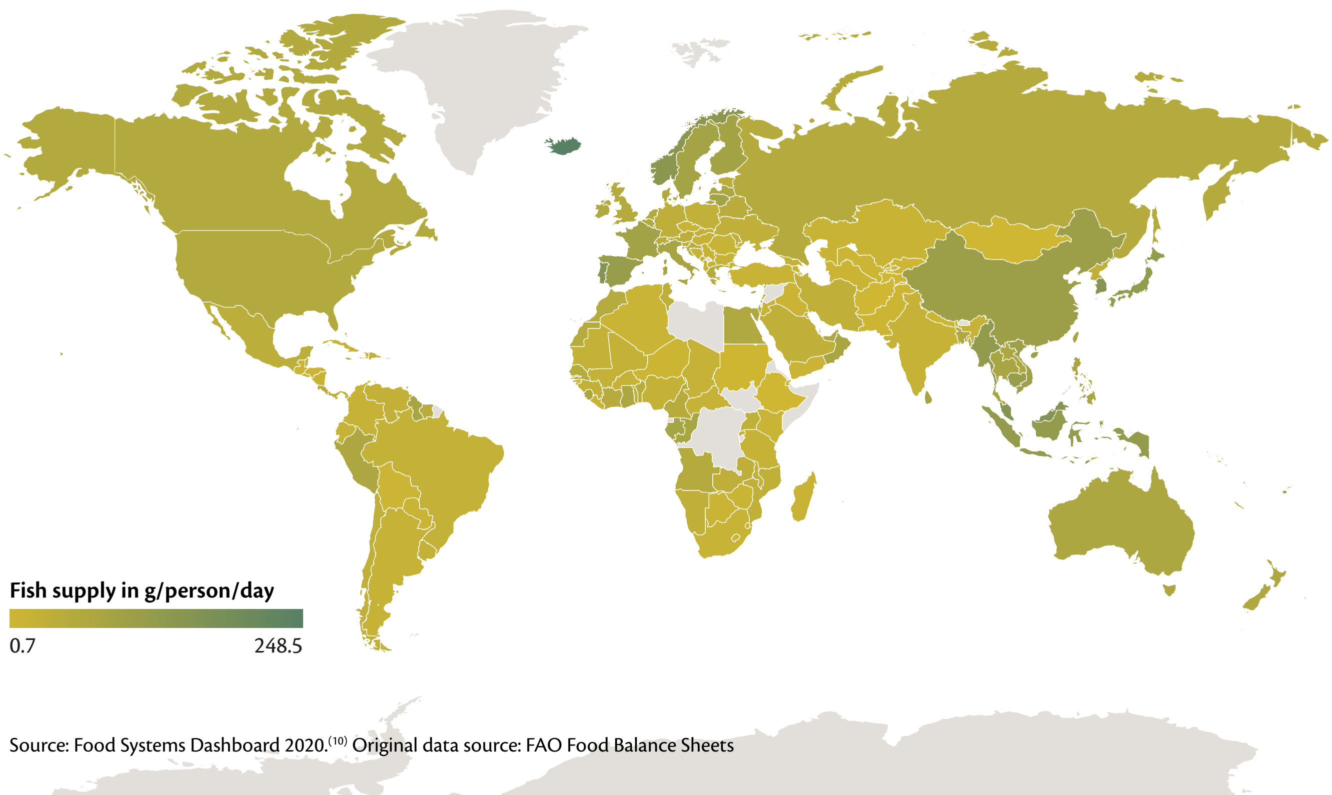
Fish and **seafood** are taken to indicate fish, crustaceans, molluscs, and other aquatic animals, but exclude aquatic mammals, reptiles, seaweeds, and other aquatic plants.

Aquaculture is the farming of aquatic animals both in salt water and fresh water. It involves inputs from the fish farmer in the rearing process to enhance production, such as regular stocking, feeding, and protection from predators, etc.[8] Aquaculture can be a very productive use of resources, with the amount of food produced per hectare considerably higher than with terrestrial farming or livestock rearing. Aquaculture can also include the farming of kelp and seaweed, and even lagoon production of algae like spirulina, which can also contribute to healthy diets, livelihoods and sustainable food systems in their own right. However, the focus of this brief is on the production of fish in aquaculture.

Fisheries is used to describe *capture fisheries* or *wild-catch fisheries*, which refer to fish caught in their natural habitats such as lakes, rivers and oceans.

2. The importance of fish to diets

Figure 1. Supply of fish, g/person/day



Source: Food Systems Dashboard 2020.[10] Original data source: FAO Food Balance Sheets

2.1 Changing patterns of consumption

The consumption of fish from all sources varies widely around the world (see Figure 1).[9] Fish consumption[a] globally grew 3.1% annually from 1961 to 2017, outpacing population growth over the same period, and growth in consumption of other animal source foods, which grew by 2.1% per year.[9] Average global consumption more than doubled over this period (from 9.0 kg to 20.5 kg per capita – live weight equivalents)[9] predominantly due to high-income consumers in high-income countries, and consumers in parts of Asia. This is expected to increase slightly by 2029 to 21.4 kg, but trends are expected to diverge by region, both in amount and the type of fish consumed.

In high-income countries, consumption grew from 17.4 kg/capita/year in 1961 to 26.4 kg/capita/year in 2007 but has been largely unchanged since that time. In contrast, consumption in LMICs increased from 6.1 kg/capita/year to 12.6 kg/capita/year between 1961 and 2017, with a particularly significant increase being seen over the past two decades. There is considerable variation in consumption patterns within countries, but limited data are available (see Box 2).

The global amount of fish needed for human consumption is projected to increase by 16.3% between 2020 and 2029 (OECD, FAO) with the highest growth rate of fish supply foreseen for Africa (25.4%). However the projected population growth will mean that the per capita consumption actually decreases in Africa over the same period.

[a] Due largely to a lack of comparable data from dietary surveys across countries, it is common to rely on FAO's national estimates of "apparent consumption" as a proxy for actual fish consumption by national populations. These estimates reflect the average food available for consumption in a given country and for the purposes of this brief we focus on "food fish" consumption, which excludes fish for non-food uses.

Box 2. Consumption patterns within countries: Bangladesh

Fish is sometimes seen as a luxury good, and in many places is expensive relative to other foods, particularly those that are plant-based. Due to the variability in how dietary surveys are conducted across countries, the available data are unable to show how consumption patterns within countries vary by socioeconomic status. However, there are some exceptions. For example, in Bangladesh, even the poorest quintile of the population (by per capita expenditures) consumes fish every other day (compared with the wealthiest who consume fish nearly five days per week).[11]

2.2 The nutritional value of fish in healthy diets

The contribution of fish to diets is often expressed as the contribution of fish protein to total animal protein consumption or to total protein consumption. While this metric downplays the other nutrients which differentiate fish from other animal source foods, it conveys the importance of fish in the diet and its availability in food systems. Fish is also an important source of omega-3 fatty acids, and micronutrients (see Box 3).

Globally, fish accounted for an estimated 17% of animal protein in 2017 and provided 3.3 billion people with 20% of their average per capita intake of animal protein. This share exceeded 50% in several LMICs including Bangladesh, Cambodia, the Gambia, Ghana, Indonesia, Sierra Leone, Sri Lanka and some small island nations.[9]

Fish is particularly important in the diets of low-income households in many countries. Unlike other types of animal source foods, dried small fish are often sold and purchased in small quantities, making them particularly accessible to consumers with limited purchasing power and refrigeration. Many studies have highlighted the nutritional importance of small fish, particularly when consumed whole with bones and viscera intact, for poor populations throughout the world.[3,12,13]

However, there are some indications that the micronutrient and fatty acid profile of much of the fish currently produced through aquaculture in the Global South may not be as favourable as fish obtained from capture fisheries (in large part due to the quality and nutritional content of feed used).[14,15] This raises the question of what strategies can be used to prevent dietary deficiencies in

> “Too often policy decisions relating to aquaculture and fisheries neglect the implications for nutrition and health. This needs to change.”
>
> **Qu Dongyu, Member of Global Panel and Director General of Food and Agriculture Organisation (FAO)**

Box 3. The diverse nutritional benefits of fish

The nutrition and health benefits of fish are both many and varied and are arguably greater still when displacing the consumption of ‘less healthy’ animal proteins.[3] In a recent review of 92 food-based dietary guidelines from around the world, 77 mentioned fish.[16]

Fish is also often described as a protein source due to its high protein content and complete amino acid profile. However, while humans consume a limited variety of terrestrial animal proteins, we consume thousands of different species of fish with tremendous variation in their nutrient profiles (see Figure 2). Variation also derives from which parts of fish are consumed (for example whole fish with bones vs. fillets), the environment or production system of the fish, and how it is cooked or prepared. This diversity of fish available for consumption is an important aspect of the nutrition security that fish offers. The United Nations Standing Committee on Nutrition recently published a discussion paper which considers the nutrient content and value of fish diversity, particularly low trophic fish, in sustainable, healthy diets.[17]

Some fish are among the richest dietary sources of the long chain omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaemoic acid (DHA), which have important health benefits for humans. Fish consumption is thought to reduce adult mortality through the effect that seafood omega-3 fatty acids have on cardiovascular disease – the leading cause of diet-related death, responsible for 10 million deaths per year.[18] A meta-analysis showed that consumption of 60g fish/day is associated with a 12% reduction in mortality.[19] However, this may be due partly to fish being consumed as an alternative to red meat as a source of animal protein (a food associated with higher content of saturated fat and risk of heart disease), or processed meats which are associated with heightened cancer risk. So overall, the health benefits associated with fish consumption may arise, at least in part, from what it displaces in diets.[20]

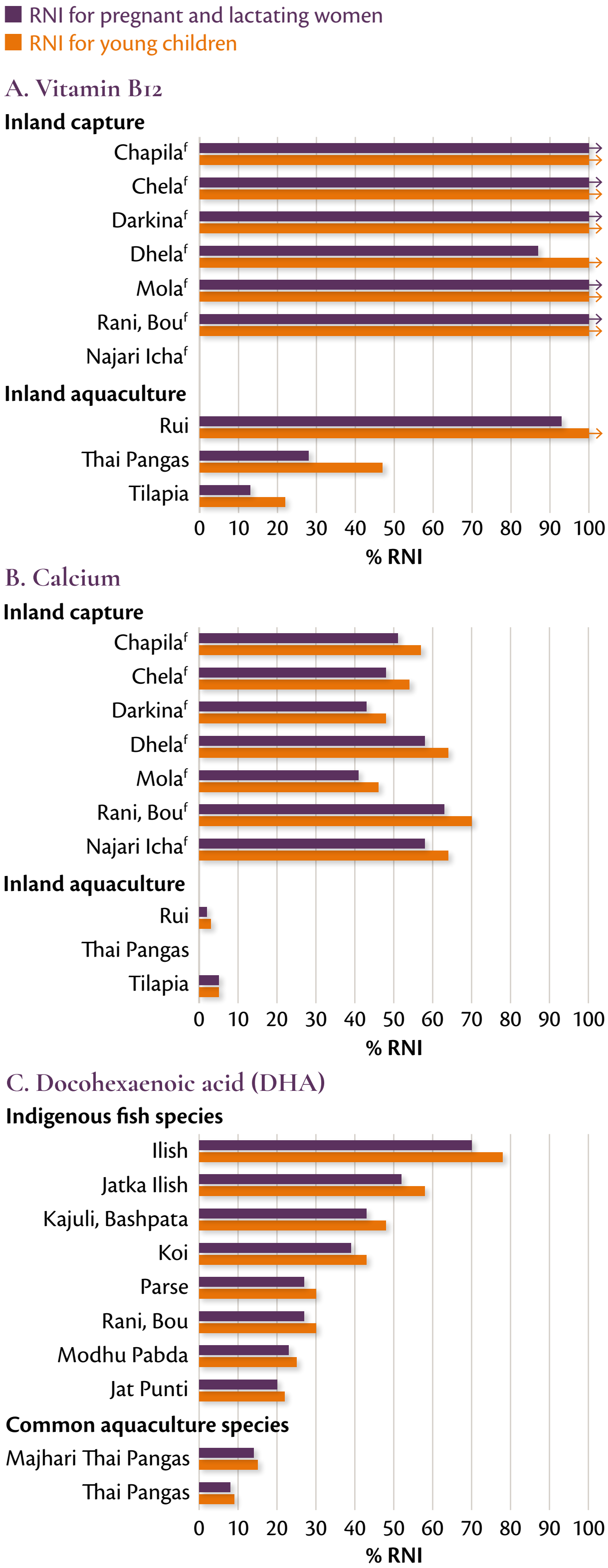
Consumption of fish during pregnancy is especially important for foetal development, specifically neurodevelopment. Low status of omega-3 fatty acids during pregnancy is associated with greater risk of early preterm birth, and supplementation with fish oils has been found to lower the risk.[21]

In recent years, it is the micronutrient content of fish, particularly small indigenous fish eaten whole, that has become increasingly valued, particularly for low income Asian and African settings where large gaps in dietary vitamin A, zinc, iron, B12, calcium and other nutrients exist – the same nutrients that small fish are particularly rich in (see Figure 2).[3,13] However, uptake of these nutrients varies by cooking and eating practice.

Efforts to model cost effective, local food-based solutions for closing the nutrient gaps faced by young children throughout the world have often identified fish as a component of the optimal solution to nutrient gaps[22,23] and as an underutilised solution to micronutrient deficiencies.[5] Fish, like other animal source foods, also contain factors which can enhance the absorption/bioavailability of iron and zinc from other vegetable sources consumed with it in the diet.[24–26] In some cases, however, the health benefits may be tempered by toxins such as mercury or polychlorinated biphenyls.

micronutrients, where fish produced from aquaculture is consumed in place of fish caught from fisheries. For example, in Bangladesh, fish consumption increased by 30% from 1991 to 2010, but due to a decreasing proportion of non-farmed species in the diet, the amounts of dietary calcium and iron obtained from fish declined.[14] This example illustrates the importance of considering fish as a source of food within the context of diets as a whole, and fish from both aquaculture and capture fisheries within wider food systems. Options to enhance the micronutrient value of farmed fish include species selection and enhanced feeds (see Section 5.2).[14]

Figure 2. **Contribution of locally available fish species to the recommended nutrient intakes (RNIs) for pregnant and lactating women (PLW) and young children in Bangladesh**



Arrows represent contribution that exceed 100% of RNI. Contributions calculated for a standard portion (50g/day for PLW and 25 g/day for infants) of each species.
Source: Thilsted et al. (2016)[3] and Bogard (2015)[15]

“Africa has huge potential to develop and benefit from a strong aquaculture sector. In terms of employment, for example, the number of jobs linked to aquaculture in Africa has more than tripled since 2000, but remains very small compared with Asia. Much more is possible for the future including for food security and nutrition.”

Agnes Kalibata, Global Panel Member and President of Alliance for a Green Revolution in Africa (AGRA)

3. The case for aquaculture: the need to go beyond capture fisheries to increase the sustainable production of fish

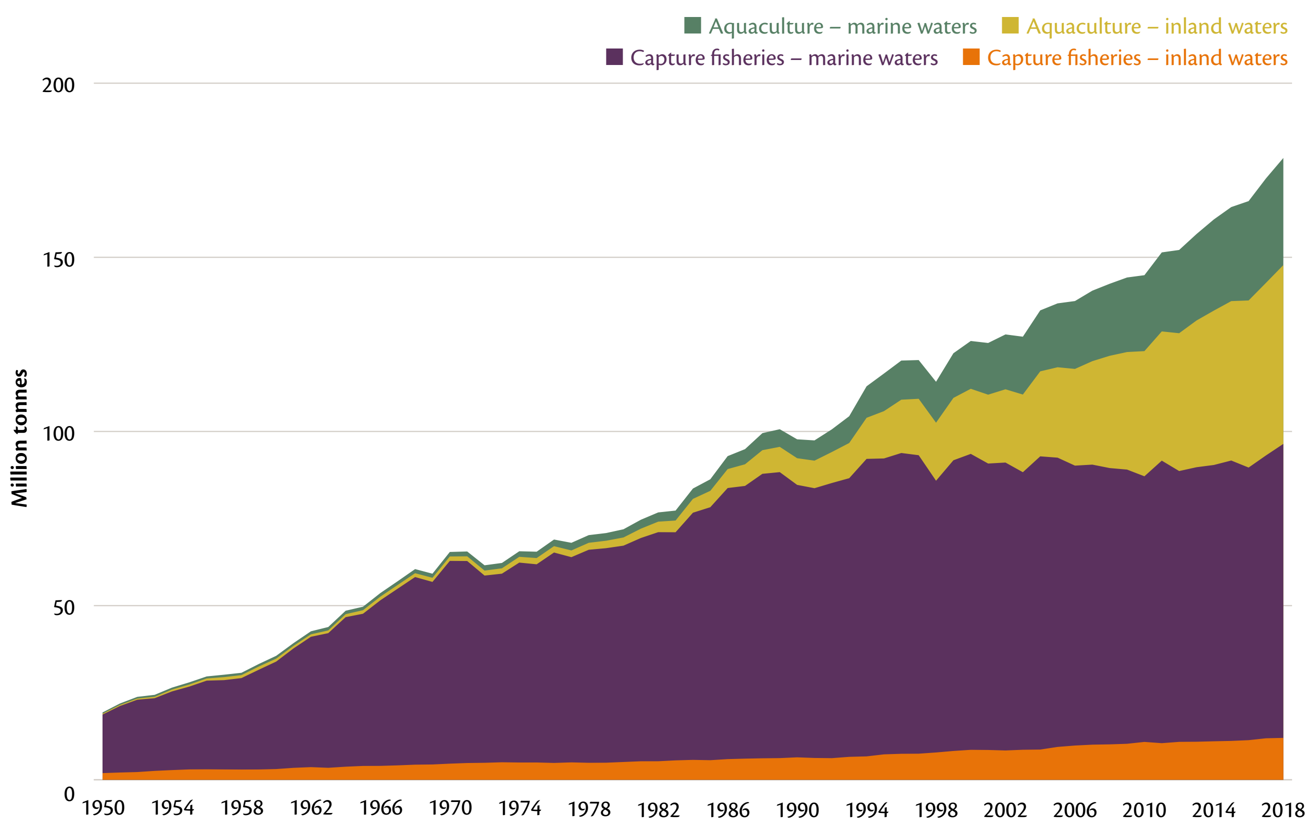
The future of capture fisheries is currently under threat from overfishing and from the impacts of climate change which include changes in water temperature and ocean acidification. It is therefore vital to explore alternative approaches to secure a sustainable supply of fish in the future. Aquaculture, if implemented and managed sustainably, presents many opportunities to help achieve this goal, and to help satisfy the future demand.

The productivity of capture fisheries depends on both the natural productivity of aquatic ecosystems and the degree to which they are fished and managed.[27] About half of the world's supply of fish comes from capture fisheries, and while the number of wild-caught fish increased steadily from the 1950s-1990s, since then it has levelled off (see Figure 3).

In 2017, over one third of fish stocks were being fished beyond biologically sustainable levels, rising from 10% in 1974. However, estimates of fish stocks are often subject to selection bias, as the areas in which monitoring of stocks occurs regularly are the same areas where fisheries management is in place.[28] The extent of overfishing may be higher than reported in fisheries lacking proper assessment and management.

Sustainable Development Goal Target 14.4 aims to end overfishing by 2030. While there has been progress towards this target, and the rate of decline of fish stocks below sustainable levels has decreased in recent years, it may be insufficient to prevent the collapse of some marine fisheries unless further measures are more widely adopted. Doing so requires stronger political will at the national level, and concerted global action including enhanced governance, technology transfer of best management practices, and shifts in consumer perceptions and demand. However, the high cost of enforcing regulations, policing illegal catch, and monitoring legal catch can act as barriers to implementing further measures, particularly in LMICs. In this context, action to expand the capacity of sustainable aquaculture could have the important benefit of reducing the pressures on marine fisheries and help in their recovery.

Figure 3. World capture fisheries and aquaculture production



Note: Excludes aquatic mammals, crocodiles, alligators, caimans, seaweed and other aquatic plants
Source: FAO (2020)[9]

4. Aquaculture: one of the fastest growing food sectors

4.1 Diverse systems of aquaculture

Global aquaculture encompasses the production of more than 580 species farmed in many different types of production systems, with vastly different environmental impacts, profit margins, consumers, and nutritional value.[29] Examples of aquaculture range from households practicing polyculture of carp and small indigenous fish in small homestead ponds in Bangladesh, to rice field fisheries in Cambodia, to large scale tilapia farms in the lakes of Honduras.

Considerable variation exists in the approaches used to produce food through aquaculture (see Box 4). A key distinction is often made between intensive, highly productive systems that require large amounts of feed and care to enhance productivity and those that are more extensive, requiring little to no external inputs aside from fish seed (spawn). In LMICs, the scale and goals of aquaculture in different systems vary widely. For example, small and medium tilapia farms using earthen pond production systems may try to produce fish that weigh from 200-500g targeting local markets, while larger tilapia farms focused on export and which use aeration or cages in lakes may produce bigger fish of 800g.[43]

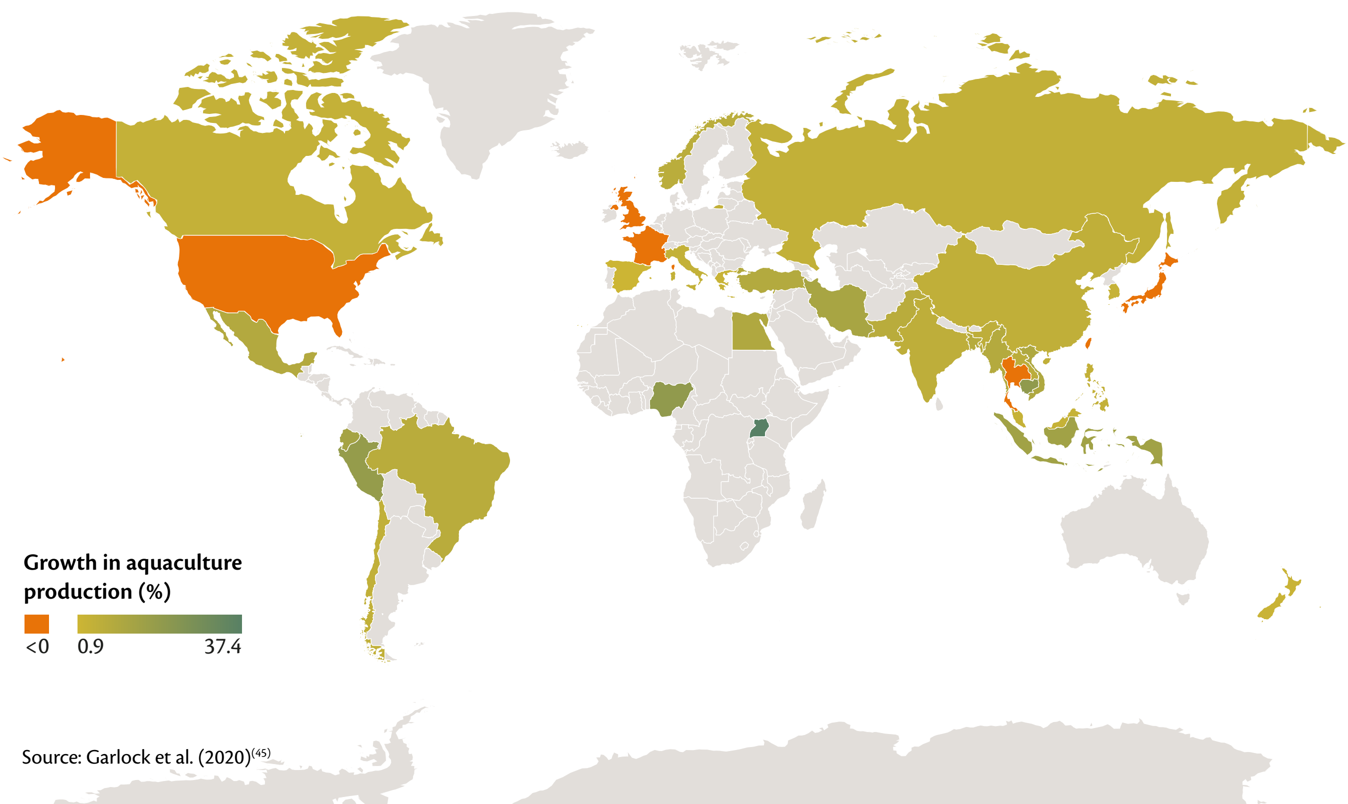
Ultimately, productivity is a function of growth, survival, and feed efficiency, and it is therefore essential that the scale of aquaculture and capacity is considered when planning local or regional investment and policies. Smaller farmers are often not able to optimise productivity using intensive methods due to the high cost or lack of availability of inputs. They may also lack access to markets, or other infrastructure to be able to support profitable activity.

4.2 Global patterns of aquaculture

Aquaculture has been one of the most rapidly growing food production sectors over the past two decades. From 2001 to 2018, global aquaculture production grew by an average of 5.3% per year with much of this growth occurring in Asia (see Figures 4 and 5). This rate of growth is expected to decline slightly due to the enactment of policies designed to enhance longer term sustainability of production in China.[9,44]

Global growth rates from aquaculture between 1990 and 2009 exceeded those of most other food commodities (see Figure 6). Estimates from the OECD and FAO suggest that while the annual

Figure 4. Growth in aquaculture production quantity (%) between 2006 and 2016 for countries with production greater than 100,000 metric tonnes per year



Source: Garlock et al. (2020)[45]

Box 4. The heterogeneity of aquaculture systems

The systems used to produce fish vary considerably by factors such as their inputs and intensity, the technologies used, where they are located (freshwater or marine), the scale at which they are implemented and the species farmed. Examples of different systems of relevance to LMICs are provided below:[30]

- **Traditional aquaculture systems:** Asia has a particularly rich tradition of low intensity, integrated agriculture/aquaculture systems (IAAS) in which locally available agricultural by-products including manure, vegetation, and rice and other brans are used to feed fish. Prior to 30 years ago, this was the most common form of aquaculture being practiced.[30] Due to the low profits per unit of farmed area compared with modern, pellet-fed aquaculture and lower availability of local inputs, this form of aquaculture tends to be practiced by households with few other livelihood options, those that cannot afford inputs, or those that cannot take the risk of intensifying production due to potential disease outbreaks.

- **Pond aquaculture:** Different forms of intensive or semi-intensive aquaculture are practiced around the world. In China and Vietnam, intensive pellet-fed monoculture of species such as carp in commercial fish farms is commonly practiced, although carp is also part of polyculture models, for example in China and Bangladesh.[30,31] However, the integrated systems which also involve livestock and farming of vegetables on dykes are less common today in these countries, although they are re-emergent in both Bangladesh and in Myanmar.[32] Semi-intensive, backyard earthen ponds are common in Bangladesh and often involve polyculture of different species. Nutrition-sensitive aquaculture programmes have aimed to promote vegetable production on dykes and integration of nutrient-dense, small indigenous fish species into ponds.[12,33,34]

- **Aquaculture in freshwater lakes and rivers including cage-based aquaculture:** Caged-based aquaculture occurs throughout Southeast Asia, Africa and Latin America, and is often intensive, involving the feeding of relatively cheap wild-caught fish and pelleted feed to various species of farmed fish.[30] Commercial cage culture of tilapia has been introduced in Lake Malawi and other large lakes in Africa, such as Lake Volta in Ghana.[30] Eutrophication of water bodies is an issue which arises from high cage density and insufficient water flow. It has led to massive fish kills in lakes in Asia where systems have been poorly planned.

- **Rice field culture:** The practice of integrated rice-fish farming dates back at least a thousand years in China, but is not widely prevalent today with estimates indicating that only 1% of the world's rice fields are stocked with fish.[30,35] Development projects implemented in Bangladesh and Cambodia have developed different models for cultivating various species in rice fields and improving the management of rice field fisheries, with 'fish-friendly' irrigation and water management practices and infrastructure an important component and challenge along with issues of ownership and fishing access.[30,36] In the Tonlé Sap region of Cambodia, the rice field fishery catch provides around 60% of the fish and aquatic animals consumed.[37] The establishment of 'community fish refuges' in the country is important in supporting reproduction of fish stock in vulnerable environments.[38,39]

- **Mariculture:** In contrast to freshwater aquaculture, mariculture has not grown as quickly, increasing in production by only 9.3% globally since 1990.[40] Excluding seaweed, the main species cultured through marine and coastal aquaculture include molluscs (56%), finfish (23.8%) and crustaceans (18.5%).[9] The environmental footprint of animal species farmed through mariculture also shows considerable variation, with molluscs requiring few inputs, but finfish having a high environmental footprint. Mariculture for finfish requires substantial up-front investments and is relatively uncommon in LMICs, particularly those in Africa. A global scoping study of areas suitable for mariculture farming of more than 100 commonly farmed marine species identified the Atlantic coast of South America and West Africa to be the most under-utilised for farming.[40]

- **Deep water cages:** this is a type of offshore mariculture in which cages are submerged deep in the ocean and fish are fed automatically by cage-mounted machines. This method was designed in response to criticism about the potential environmental degradation linked with nearshore fish farming, and competition for coastal sea space.[41]

- **Aquaponics and recirculating aquaculture systems (RAS):** In recirculating aquaculture systems, fish are farmed in tanks at high densities and water is treated to remove waste. Aquaponics and RAS have gained attention as potentially more sustainable ways of producing foods in areas with limited water availability such as peri-urban and urban environments. An international survey found that aquaponics was practiced on every continent and in 43 countries, but mostly in high-income nations, and that small-scale hobby production tended to be more common. Findings that only about a third of aquaponics producers returned profits in the past 12 months raise the question of commercial viability. The main issue here is the high start-up costs and the cost of inputs, such as electricity and complete feeds, needed for these systems.[42,42]

growth rate of aquaculture may slow over the coming decade, from 4.3% per annum to 2.3% from 2020 to 2029,[44] fish production from aquaculture is expected to surpass that of capture fisheries by 2024, and exceed 105 million tons in 2029.[44] Whether this is realised depends on the extent to which nations support aquaculture production through policy enablement, investments in value chains, and promotion of jobs in the sector.

Asia has been at the heart of global aquaculture production over the past two decades, and has held an 89% share of the global aquaculture market.[9] While a large volume of farmed fish (and shrimp) is destined for local consumption, exports have grown. Indeed, fish was one of the most traded food commodities globally in terms of financial value (US$ 153 billion in 2017), growing at 4% per annum.[48] China accounted for 58% of total global aquaculture production in 2018 (producing 47.6 million tonnes)[9] while about 30% came from the rest of Asia, with India (8.6%), Indonesia (6.6%) and Vietnam (5.0%) being the next three largest producers.

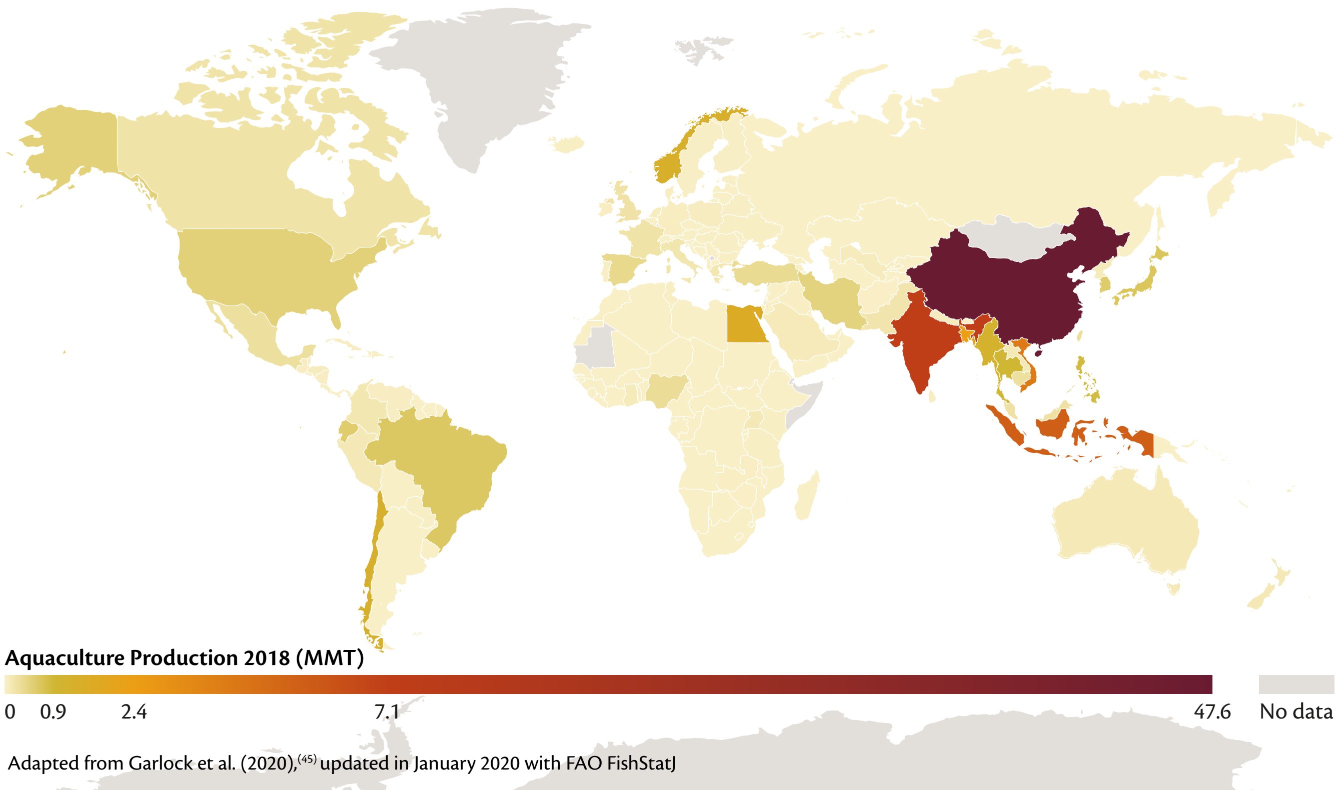
In contrast, aquaculture at scale in Africa remains largely confined to a few countries and has a small share of the global market (2.7% of the world's production in 2018). However, it is growing rapidly in Egypt, Nigeria, Uganda, Ghana, Kenya, Zambia and South Africa. Nigeria is the second largest producer in Africa, after Egypt, having grown more than ten-fold from 2000 to 2018, (from 25.7 thousand tonnes to 291.3 thousand tonnes).[9] The scale of production in Nigeria in 2018 was comparable to the rest of sub-Saharan Africa combined.

4.3 Aquaculture and trade

The intensification of aquaculture in Asia for export was initially driven by growth in the shrimp sector for export to Europe and then expanded to white fish including pangasius (catfish), carp and tilapia.[49] Shrimp production expanded rapidly in the mid-late 1980s in both China and Southeast Asia and in the 1990s, in Vietnam.[49] Asia remains an important exporter of farmed food products to high-income countries.[49] Increasingly it is also supplying farmed fish to emerging economies including those in Latin America and Africa. While in some countries however, the transformation of value chains for certain products, notably shrimp in both Vietnam and Bangladesh, has been driven by opportunities for export, in others, value chains have been transformed primarily to feed domestic and regional consumers.

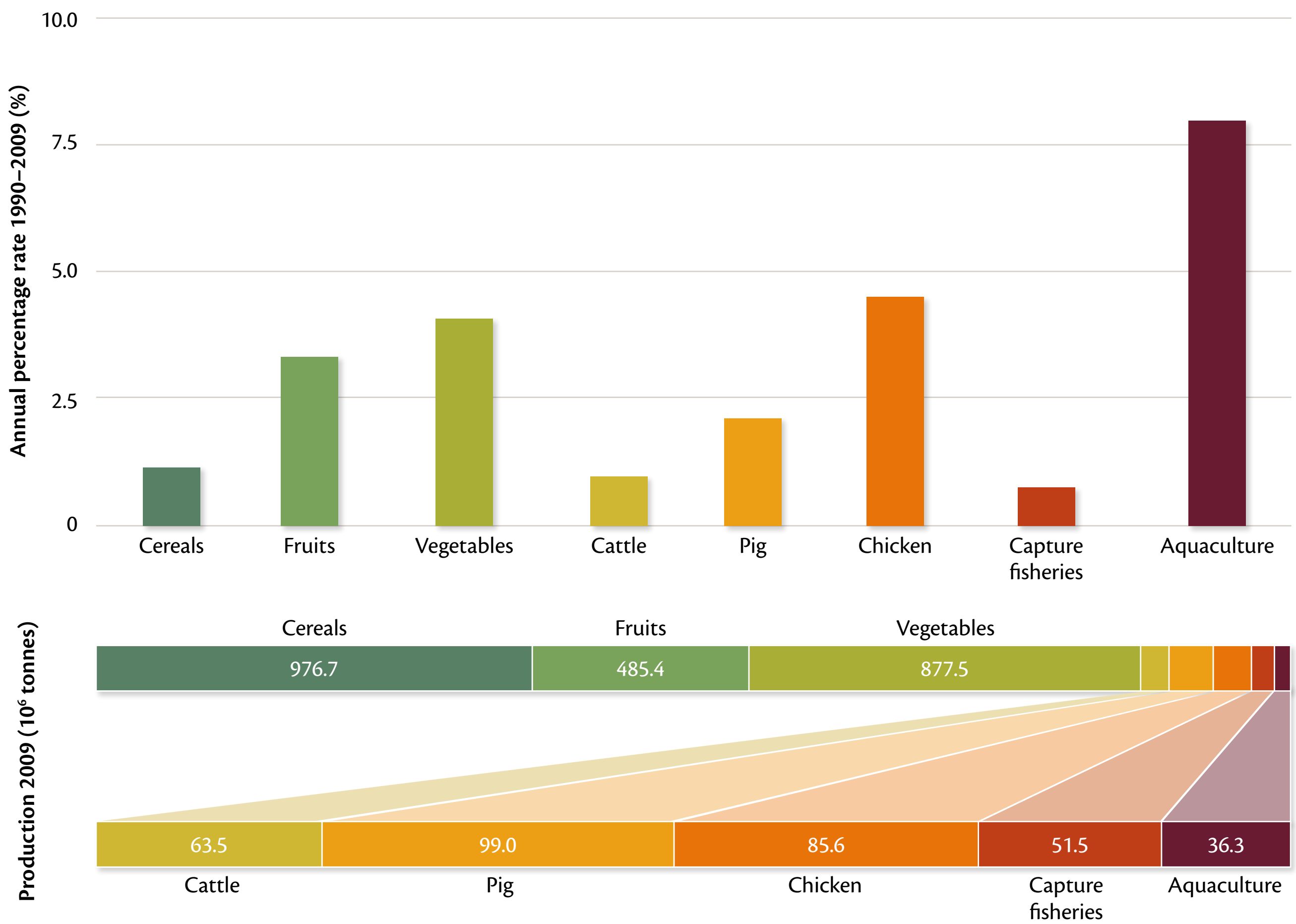
In many of the largest producing countries in the world, most fish reared through aquaculture is ultimately consumed domestically rather than exported. For example, in China, Indonesia, the Philippines, India, Egypt, Brazil and Bangladesh, more than 90% of production is consumed domestically.[50] With domestic demand continuing to grow in line with falling poverty, an important question is whether production can be expanded to meet rising local demand, and demand from foreign markets. Increased demand will also need to be met sustainably. The resilience of the sector in the context of greater demand is also a key issue: the COVID-19 pandemic has disrupted aquaculture value chains worldwide (see Box 5).

Figure 5. Aquaculture production in million metric tons (excluding aquatic plants, 2018)



Adapted from Garlock et al. (2020),[45] updated in January 2020 with FAO FishStatJ

Figure 6. Growth in aquaculture compared to major food commodities



Source: Troell et al. (2014)[48] Original data source: Tacon and Metian (2012)[47] and FAOSTAT and FishStatJ

Box 5. The impact of the COVID-19 pandemic on aquaculture

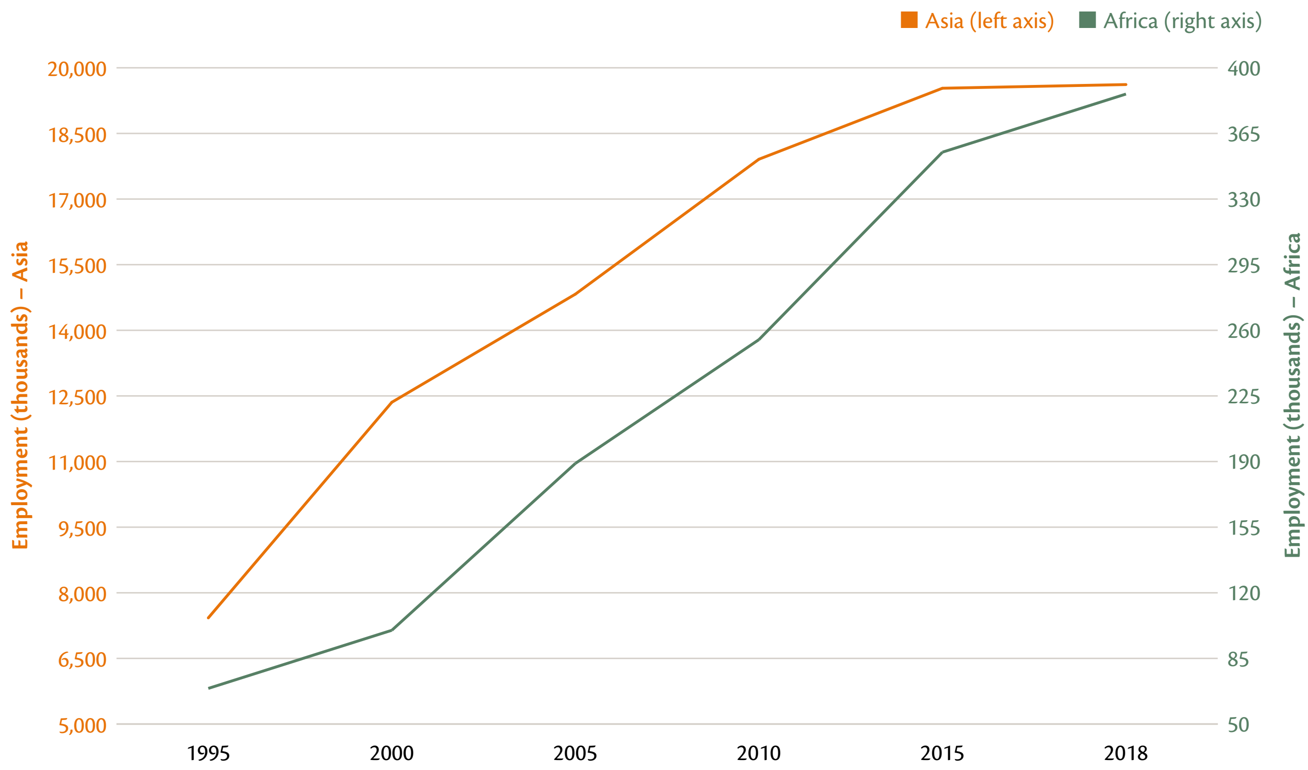
The aquaculture sector, like other sectors in the food system, was significantly affected by the social distancing and lockdown measures imposed in early 2020. Fresh fish is highly perishable and is therefore extremely sensitive to delays in supply chains. Frozen fish, however, could be diverted to alternative markets. There has also been reduced demand for fish products due to changes in household consumption, and restaurant closures and restrictions in tourism. In Latin America and the Caribbean, demand for fish fell by 40-75% from March to September.[53]

In Bangladesh, transport disruptions interfered with the transport of both aquaculture outputs and inputs. Fish farmers were unable to sell their fish due to lockdown measures, and instead kept fish in their ponds and reduced their feed. This led to increased production costs: labour increased by 10% and the cost of feed increased by 5%.[54] There was also a drop in the demand for fresh fish, which may have been partly due to fears that handling raw fish was linked with coronavirus infection. Consequently, farm gate prices were 30% lower in March than normal, leading to fish farmers having to operate at a loss.[54]

While some of the immediate impacts of the COVID-19 pandemic have lessened since March 2020, the aquaculture sector continues to be affected. Ongoing restrictions on international tourism and restaurant closures, even in high-income countries, are affecting those LMICs which export large quantities of fish. In India and Thailand, shrimp exports have been most affected by reduced, delayed or cancelled orders from major markets such as China, the EU, Japan and the USA. The drop in demand has forced processing plants to scale down, leading to an oversupply of raw materials.[55]

The United Nations has suggested that this drop in demand may provide an opportunity to help fish stocks rebuild in the short term,[56] for example by implementing measures to improve the sustainability of the sector. The FAO and United Nations Economic Commission for Latin America has also suggested that new policies for aquaculture should focus on "building local value chains capable of absorbing external impacts".[53]

Figure 7. Employment in aquaculture in Africa and Asia



Source: FAO (2020)[9]

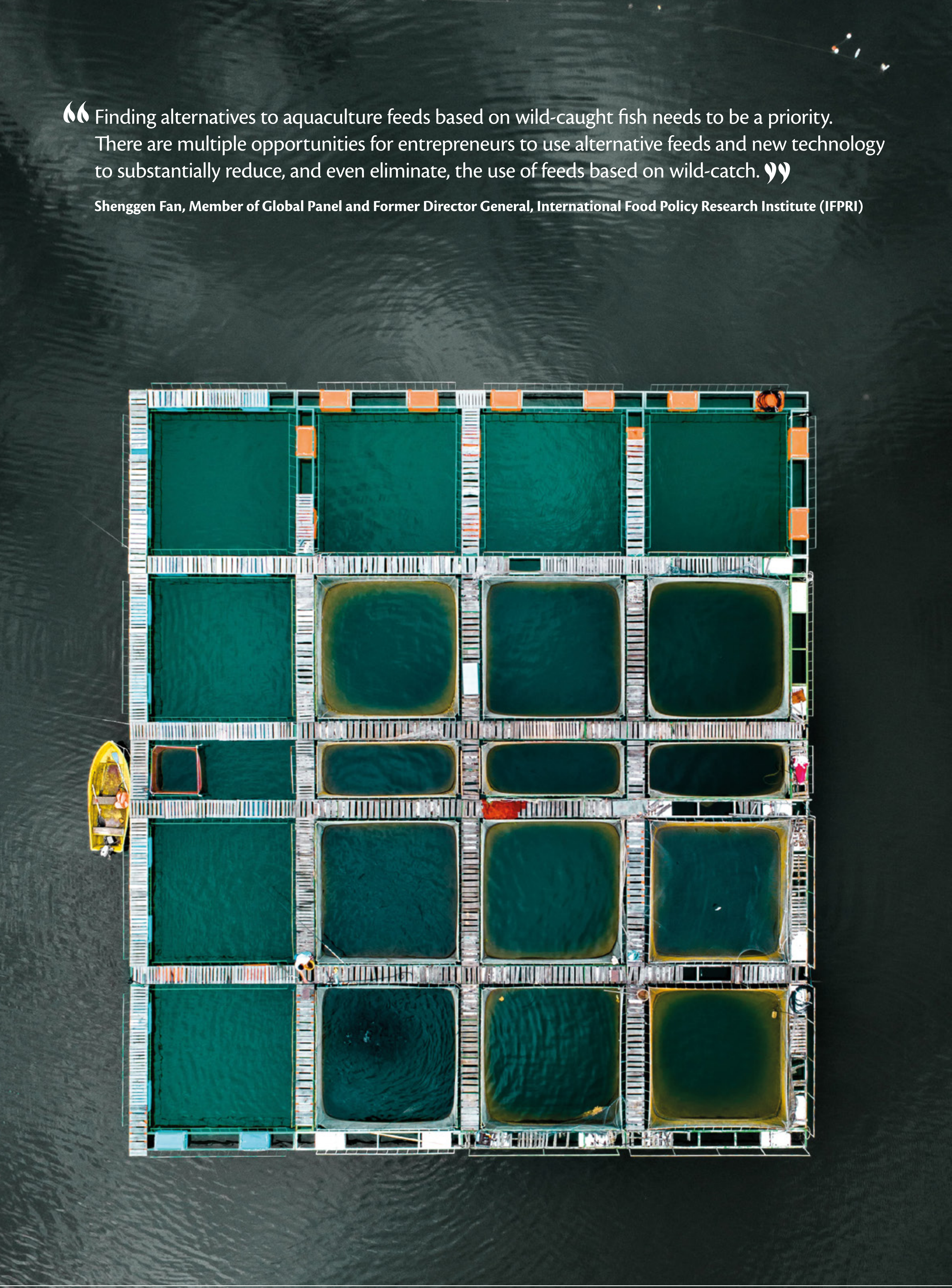
4.4 Aquaculture as a source of employment and food security

Estimates based on incomplete data suggest that around 20.5 million people globally were employed in the primary sector of aquaculture in 2018 (see Figure 7), with about 95% located in Asia and 2% in Africa.[9] In Asia, the number of people employed in aquaculture has grown from around 12.3 million people in 2000 to 19.6 million in 2018.

The scale of employment in aquaculture in Africa is small compared with Asia, but it is experiencing rapid growth: since 2000, the number of jobs linked to aquaculture in Africa has more than tripled (from 100,000 to 386,000). Secondary employment is also very important as truck drivers, ice makers, food stalls, and port handling all rely heavily on the fish value chains. A study from Egypt found that aquaculture generated significant levels of employment, creating 19.5 full-time equivalent (FTE) jobs per 100 tonnes of produced fish,[51] about half of which were in the retail part of the value chain, including transport.

Women are an important part of the aquaculture workforce, with FAO estimating that they account for about a fifth of those employed (19%). However, their roles are often relegated to the lowest paid and lowest grade work,[52] and pay inequalities for the same work are common. However, most workers (58%) in the post-harvest value-addition and marketing activities of fish value chains tend to be women.[9] This is particularly the case in small scale businesses for fish processing and preservation in many LMICs where many are owned and run by women. For example, on the coast of Senegal and other countries in West Africa and around the Great Lakes, small-scale businesses have been built up around processing, smoking and drying of wild-caught fish, which are then traded inland. Increasingly these and businesses elsewhere in Africa and Asia are under threat from larger-scale processing plants, often built using foreign investment, and from reduced local availability of fish due to a combination of poaching by large trawlers and climate change.[7]

Photo courtesy of GIAHS (Dong's Rice Fish Duck System). Editorial use only



> “Finding alternatives to aquaculture feeds based on wild-caught fish needs to be a priority. There are multiple opportunities for entrepreneurs to use alternative feeds and new technology to substantially reduce, and even eliminate, the use of feeds based on wild-catch.”

Shenggen Fan, Member of Global Panel and Former Director General, International Food Policy Research Institute (IFPRI)

5. Opportunities and challenges for aquaculture

The many forms of aquaculture embody very different technical, economic and environmental challenges, impacts and opportunities. This section examines some of these issues, identifies trade-offs and describes some of the approaches being taken to maximise benefits and minimise adverse effects.

5.1 Genetic improvement

Unlike terrestrial animals (chickens, cows, and pigs) or crops which have been selectively bred for productivity improvements over millennia, most species of fish are genetically unimproved, leaving considerable scope for productivity increases through breeding. Some species such as tilapia have been genetically improved through conventional breeding for desired traits, such as growth and disease resistance, but even in these species productivity gains can still be made. For example, over six generations into the Genetically Improved Farmed Tilapia (GIFT) breeding programme initiated by WorldFish, the improved strain of tilapia sustained 10-15% gains in growth per generation compared with fish used at the start of the breeding programme.(57) Genetic improvement programmes have focused primarily on commercial species of interest to consumers in high-income countries, such as salmon, but in the GIFT programme tilapia was chosen because of its popularity as a species grown in LMICs, particularly by poor farmers. Now in its 18th generation, the GIFT strain of tilapia has been disseminated to at least 16 countries, 15 of which are LMICs, where it is the foundation for many national tilapia industries.

While much of the focus of breeding is on selecting traits related to growth, there is also potential to breed for other traits including disease resistance. In a fortuitous development, certain tilapia involved in breeding experiments for the GIFT project recently proved resistant to the tilapia lake virus, which emerged a decade ago in Israel and for which there is no treatment.(58) Selective breeding offers hope against a virus that could devastate aquaculture in the global South.

Greater investment is needed in genetic improvement involving the selective breeding of fish species of relevance to LMICs. Programmes such as GIFT have illustrated their potential to increase the productivity of commercial and non-commercial farms on a scale that surpasses crop breeding programmes for terrestrial agriculture.

5.2 Fish feed improvements

About half of total aquaculture production uses external feed inputs.(9) Traditional fish feeds have relied heavily on fishmeal and oil sourced from small pelagic forage fish such as sardines, anchovies and herrings to supply protein and oil. Even though the amount of forage fish supplies (small wild-caught prey or bait fish used as feed in aquaculture) has remained relatively constant since the 1980s, an increasing proportion – estimated to be around 17 million tons per year in 2015(59) – is used for aquaculture feed.

With growing competition for this feed from the poultry, pig and pet food sectors, aquatic feed producers have developed new formulations that rely on soy, corn, canola, wheat and other sources of protein and fat to replace fish-derived inputs. For carp and tilapia, formulations based almost entirely on vegetable sources have been developed, along with technologies which substantially reduce and even eliminate fish inputs in feeds for salmon and shrimp.(59) New technologies using algae, fungi, bacteria, and single-cell organisms and insects offer novel ways of filling some of the more challenging gaps in amino acids, fatty acids and other nutrients without the need for fish inputs.(59)

While new technologies are emerging, fish by-products remain common in pelleted feed, and fish is an important contributor to the protein content in many livestock and pet feeds.(60) Much of this fish is caught from capture fisheries off the coasts of LMICs including Peru and countries in West Africa. The question of whether novel feed ingredients could support the expansion of aquaculture growth if the forage fish catch were to remain the same has been explored in scenarios which are shown in Box 6.

The findings suggest huge potential to decouple the fish feed industry from reliance on wild catch inputs from capture fisheries. This could have both ecological benefits and make more nutrient-dense fish available for consumption by populations in LMICs, assuming that fisheries management investments and improvements are also made.

The development of local feed industries can also help to create jobs in addition to enhancing productivity. For example, a recent analysis in Egypt estimated that each feed mill under study was directly responsible for 13.8 FTE jobs, or 0.39 FTE jobs per 150 tonnes of produced feed (or 100 tonnes of produced fish), in addition to jobs in other parts of the value chain (e.g. transportation and retail).(61)

However, important challenges remain, including:

1. **How to make feed-related technologies available to farmers in LMICs.** In some cases, licensing agreements have enabled free use of new technologies for use in low-income countries, but efforts are also needed to facilitate, for example, technology transfer, private sector investment in local feed companies and production, loans to farmers, and adapting technologies to local realities and inputs. Tropical climates may be favourable to certain technologies such as algae and insect production as sources of non-fish protein for aquaculture feed.

2. **Much of the research on feed innovation has not been proven at scale.** Large-scale commercial adoption and implementation is needed to assess costs and benefits.

3. **Greater understanding of the environmental trade-offs associated with the adoption of feeds is needed.** For example, the introduction of algal oils can replace the need for fish oils but may involve fossil fuel use associated with production and transportation.

4. **Research is needed on policy measures that governments can take to best stimulate the expansion of sustainable feed industries.** This is essential to support growth in aquaculture in LMICs.

5. **There is a need for continued innovation and research on the use of locally available feed ingredients to enhance the nutritional value of fish.** This is particularly the case for carp and tilapia, but also for other breeds.

5.3 Addressing loss and waste in fish value chains[b]

An estimated 35% of the global fisheries and aquaculture harvest is lost or wasted every year. Once fish enters food value chains, whether from capture fisheries or from aquaculture, it will be at risk of loss and waste during processing and transportation.[9] Estimates range from 30% post-harvest loss and waste in the Latin America region, to 50% in the North America and Oceanic region.[9] In Africa and Latin America, this is mainly due to inadequate preservation infrastructure, practices and lack of expertise.[9] Different forms of loss identified in aquaculture value chains include physical loss[58]

[b] Data on food loss and waste includes fish from multiple sources, i.e. both aquaculture and capture fisheries

Box 6. Potential forage fish savings using novel feeds under three growth scenarios

The potential savings in forage fish when replaced by novel feeds such as algae, bacteria and yeast, were modelled under three different growth scenarios (see Figure 8):

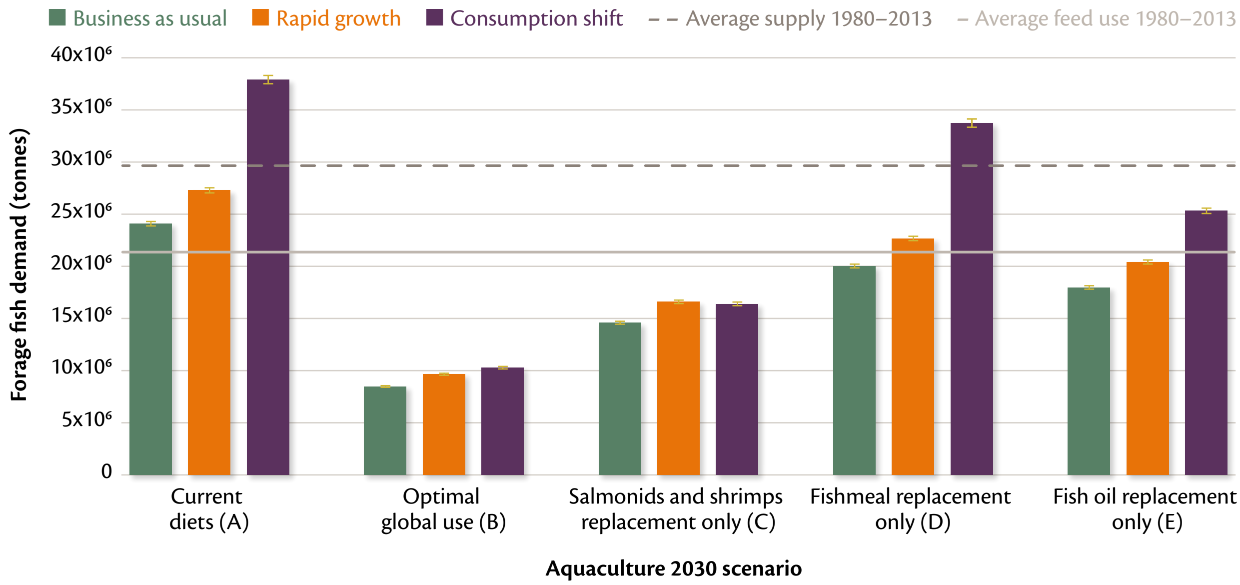
1. A business-as-usual scenario in which production increased at current FAO estimates of 28% by 2030. (BAU)

2. A faster growth scenario aligned with World Bank projections of 50% greater than business as usual. (Rap Gr)

3. A scenario of greater consumption of certain species such as salmon and shrimps in China. (Cons.Shift)

Under any of the three scenarios, replacement of the highest thresholds of plausible fishmeal and fish oil with novel feeds could lead to a reduction of global forage fish demand by 8-10 million tonnes.

Figure 8. Projected demand for forage fish with and without the use of novel feed ingredients under three scenarios



Source: Adapted from Cottrell (2020)[59]

Global forage fish demand is shown for (A) no substitution of feed with novel ingredients, (B) optimal use of novel feed (see Cottrell (2020) for more details), (C) novel feed use constrained to salmonids and shrimp only, (D) use of novel feed limited to reducing fishmeal use only, (E) use of novel feed limited to reducing fish oil use only.

(for example from pests or spoilage), quality loss (involving the loss of value as a product deteriorates), nutritional loss (changes in nutritional content due to spoilage or processing), and loss in economic value (decreases in price that can result from consumer perceptions of low food safety and quality, or periodic over-supply to a market).[62]

Actions that help to reduce losses in fish value chains would be in line with the Sustainable Development Goal Target 12.3 of halving per capita global food loss (on and near the source of production) and waste (down-stream in the value chain) by 2030, and would have multiple benefits.[63] These include enhancing the supply of fish available to consumers, making certain that producers and other value chain actors receive maximum value for money, retaining the maximum nutritional value of fish, ensuring it is safe for consumers, and creating new jobs associated with food processing and transportation.

While there is a major research gap regarding the causes of and solutions to food loss and waste specific to aquaculture, there are many measures that help reduce loss and waste across the overall fish value chain.[62] Improving cold storage, the production and availability of ice, upgrading transport infrastructure, and using preservation techniques such as drying, salting and smoking fish are useful ways of preventing spoilage.[62] While the high costs of cold storage can often hinder development in this area, there can be lower cost options which strengthen the livelihoods of those working in fish value chains. In 2018 West Are'are Rokotanikeni Women's Association in combination with WorldFish provided solar powered freezers to nine villages in the Solomon Islands. Women were able to rent out freezer space for fish and other perishable foods which they sold for profit in the villages. A committee of women recorded the earnings of each freezer, with the aim of earning enough to keep the freezer running by covering repair costs. After one year, 487 people had used the freezers and 1000 kg of fish had been stored, and the women had saved over US$ 3,000.[64]

Systematic assessment mechanisms to capture the multiple dimensions of loss and guide efforts aimed at reducing waste and loss in fish value chains are required. These need to go beyond assessments of physical loss to also document how processing and transportation affect the nutritional value of aquaculture products, how value is lost, and to identify actions to prevent loss.

“Compared to other parts of the food system, aquaculture research and development has not received the attention it deserves. There is a real opportunity to improve the quality of fish stocks, increase productivity and disease resistance, enhance nutritional value, and develop new fish-feeding practices.”

Celso Moretti, Member of Global Panel and President of Brazilian Agricultural Research Corporation (Embrapa)

5.4 Land-water interrelationships

In many contexts, aquaculture competes with other forms of landuse. In China, Vietnam, Thailand and Bangladesh, for example, much of the expansion of inland aquaculture ponds has come from the conversion and/or incorporation (i.e. dual purposing) of rice fields. This has raised concerns in some countries where there are challenges around self-sufficiency of staple food production. For example, in Myanmar, laws prohibit the conversion of rice fields to fish farms, with varying levels of enforcement, and are likely to have restricted growth in the sector.[32] In contrast, Vietnam has actively encouraged the conversion of less productive land to fishponds as a measure to enhance farmer earnings, alongside a policy of maintaining a minimum of four million ha of rice fields for the country.[30]

Many LMIC governments struggle with the decision of whether to pursue land policies that prioritise grain production and self-sufficiency of staple foods over agricultural diversification, economic growth and nutritional benefits that could accompany diversification into aquaculture or other crops.[65] Context-specific studies of the trade-offs can help inform policymakers in making policy choices. For example, in Myanmar it has been estimated that fish farming generates twice as much employment for a given area of land, compared with paddy rice farming, despite the regulations against this conversion.[32]

Similar debates occur with respect to the use of fresh water since this is an increasingly limited resource, particularly in parts of Africa. Innovative solutions which integrate agriculture with aquaculture can produce multiple benefits here. For example, fish farms in Egypt producing tilapia and catfish use the water in which the fish were farmed to grow lettuce, basil and mint. Not only does this help to conserve water, the water from aquaculture is fertilised by fish waste and therefore reduces the need to add further fertilisers.[66]

5.5 Antimicrobial use and resistance

Growth in global aquaculture is constrained by aquatic diseases (including bacteria, viruses, and parasites), which, as on land, increase in risk with farming intensification.[67] There are numerous examples of disease outbreaks in settings throughout the world, adversely impacting productivity in aquaculture.[68] Some producers use antimicrobials to control pathogens, but drug use can lead to drug residues and the spread of antimicrobial resistant (AMR) bacteria in the food supply and environment. This introduces a risk to the production of fish from aquaculture in the future, and to the health of other animals and humans: an estimated 700,000 people died in 2016 from unsuccessful antimicrobial therapy and this figure is projected to grow rapidly.[69]

The status of antimicrobial use and antimicrobial resistance in resource limited settings is generally uncertain.[68] Assessing the extent of antimicrobial use in aquaculture practiced in LMICs is particularly challenging due to the scale and geographic spread of the industry, the large number of species involved, variability in the type of proprietorship, and lack of regulations and information systems to collect data.[70] Despite these shortcomings, there is evidence of misuse and/or overuse of antimicrobials in settings where information is available. There appears to be considerable heterogeneity in the practice of antimicrobial use from farm to farm, country to country and in the classes of antimicrobials being used, with use in salmon

production tending to be better documented.[70] Improved information systems are needed to assess accurately the types and amounts of antimicrobials used in aquaculture throughout the world. This would help guide efforts to better understand their impact on the environment and on public health.

Up to 80% of antibiotics consumed by farmed fish are excreted with their activity intact.[70] The use of antibiotics in net pens or ponds means that residual antibiotics are released into the surrounding environment. The only solution to reduce contamination in such settings is to replace antimicrobials with other therapies, such as vaccines, probiotics, and the use of best management practices (BMPs). If antimicrobials are used, they should be used judiciously and from drug classes that are not used in human medicine.[71] A One Health approach, which involves communication, cooperation and collaboration across disciplines including human, animal and environmental health is now seen as essential to the control of AMR and should involve international efforts to standardise surveillance of antimicrobial use.[72] This requires better stakeholder education, along with implementation of existing voluntary and obligatory agreements, international certification, government regulations, and evaluation of adherence where such measures exist.

5.6 The potential for income growth through aquaculture

Aquaculture is commonly believed to have considerable poverty reduction potential both directly (through increased income and fish consumption by producers) and indirectly (through greater availability of fish, lower prices, and on-farm employment of the poor, and multiplier effects).[73] However, few studies have evaluated the direct contributions of different forms of aquaculture to poverty alleviation[74,75] and those which focus on the indirect effects of aquaculture are complex and inconsistent.[75] An important debate concerns the extent to which the activities of small-scale producers or commercial small and medium enterprises (SMEs) can help to reduce poverty and improve food security and nutrition (see Box 7).[76–78]

Findings from Ghana in Box 7 reinforce the view that small aquaculture producers have limited ability to contribute substantially to national fish production or to poverty alleviation. However, support in the form of access to inputs or coordinated value chain development could facilitate greater impacts towards both goals. By contrast, SMEs have the potential to increase availability and lower the cost of fish for domestic consumption, but not necessarily to reduce poverty. This finding is aligned with the 'quiet revolution' experienced in Asia. A potential concern is competition with low-cost imported fish, which can sometimes be more affordable than fish produced by local SMEs. Low-income households may opt for imported fish if it is cheaper, despite potentially being of a lower quality due to transportation.

5.7 Moving towards sustainable aquaculture

As with any type of food production, producing fish and related products through aquaculture entails multiple impacts on the environment. In LMICs the potential for aquaculture to deliver an affordable and steady source of protein for domestic consumption has been the primary concern and consumer demand that the product be 'sustainable' has been secondary compared with cost. It is, however, important to many consumers that food is safe.

Box 7. Potential impacts of SMEs vs. small pond farms for poverty alleviation in Ghana[73]

Ghana stands out as a country with rapidly growing aquaculture on a continent where the growth of the sector has traditionally lagged. Ghana has many small-scale farmers growing tilapia and catfish under semi-intensive polyculture conditions, and there are over 4700 small ponds with an average area of 0.15 ha. Ghana also has an emerging industry of 70-100 cage farms practicing intensive farming of tilapia on Lake Volta, most of which are commercial in nature and small (<50 tonnes/year) to medium (50-1,000 tonnes/year) in scale (SMEs).

The poverty and food insecurity reduction potential of four different types of cage aquaculture in Ghana was evaluated through a comparative assessment.[73] The study concluded that:

- Start-up and capital costs of aquaculture (especially feed) are often too high for low-income households to engage with. Poor farmers often used local ingredients for feed such as maize bran, groundnut peel, and organic fertilisers including chicken droppings.
- A threshold effect was seen between asset ownership and income from aquaculture: those with more assets to invest had much greater potential for income. Fish farmers who were not classed as poor harvested four times more fish and sold five times as much compared with poor fish farmers, and received five times the revenue from the sale of fish.
- Poor fish farmers sold an average of 60% of their harvest (eating and gifting the rest) while non-poor farmers sold 80%. Most fish sold was directly to local consumers.
- In contrast, SMEs intensively farming tilapia tended to be owned by investors from Accra or expatriates for whom aquaculture was not their primary livelihood and therefore were considered base investments.[73] Many small-scale cage farms sell directly to retailers including stores, hotels and restaurants, but most SMEs sell directly to traders and wholesalers and a growing network of traders and fish processers (largely women from local communities).

Fish produced from aquaculture differs markedly in its environmental footprint depending on *how* it is produced against a background of increasing prevalence of capture fish stocks being overfished. Aquaculture has considerable potential to contribute to meeting the rising global demand for fish. However, it will need to do so sustainably, learning lessons from past mistakes. For example, the expansion of shrimp farming has resulted in an estimated loss of nearly 240,000 ha of mangroves over the last two decades in key producing countries. The outcome has been reduced coastal protection against sea level rise, storms and coastal erosion and reduced habitat for a wide range of aquatic species.(79,80) It has also caused increased greenhouse gas emissions from mangrove soils due to waste from the shrimp farms.(81)

The feed conversion ratio for many types of fish ranks favourably against most terrestrial animals, with conversion ratios for fish and shrimp being similar to that of chicken, and lower than pigs and cattle.(48) However, it is important to also evaluate other dimensions such as water use, carbon footprint, etc. which are more complicated to assess given the heterogeneity of the sector. Climate change is likely to affect aquaculture in several ways. Mariculture, in particular, will be impacted by rising sea levels, changes in salinity, water temperature and ocean acidification (specifically for shellfish).(82) Increases in water temperature can also impact land-based aquaculture by interfering with the delicate balance of ecosystems in freshwater lakes and ponds, and by affecting growth rates of some fish species.(83) Cold water fish may be particularly affected and suffer from thermal stress.(84) Land-based aquaculture is also at risk from rising sea levels as it increases the occurrence of flooding. Floodwaters can intrude on land-based aquaculture, possibly resulting in escapes, or contaminating the culture water.(82)

Globally in 2017, aquaculture was responsible for an estimated 0.49% of anthropogenic greenhouse gas emissions.(85) Certain practices can also lead to environmental damage. For example, overstocking fishponds can increase fish waste and reduce water quality.(83) Eutrophication as a result of aquaculture is also increasing(83) which can be harmful for many fish populations.(86) Regulation of nitrogen and phosphorus is being incorporated into aquaculture certification, but it is difficult to determine the maximum permissible concentration of these nutrients, as they vary based on the type of water body.(87) Integrated aquaculture

systems, such as rice field culture (see Box 4), as well as sustainable intensification (discussed in more detail in Box 8) and recirculating aquaculture systems have been suggested as approaches to increase the productivity of aquaculture while reducing its environmental impact.[83]

Future global demand for fish will continue to grow due to a combination of population growth, urbanisation, and rising incomes. Much of the growth in production that occurred over the past three decades in Asia has come from both expansion of the area devoted to aquaculture and from using more intensive production methods. In the future, growth will largely come from the latter, particularly from greater use of pelleted feed.

One challenge in applying concepts of sustainability to aquaculture and other agricultural production systems in LMICs is that they are heterogeneous, ranging from extensive to intensive, with most somewhere in between. Access to technology varies widely. There is also relatively little regulation or enforcement, and limited traceability along the value chains, which tend to be fragmented, leading to concerns about food safety and nutrient content.

Box 8. Sustainable intensification

The concept of sustainable intensification (SI) – increasing productivity to achieve greater yields while minimising environmental impact – is driven by four premises:[49,88]

- Growing consumer demand for food means that production and/or productivity need to increase;
- To avoid additional conversion of land/water to food production there is a need to intensify production or improve output per unit of input;
- Food security should be prioritised at the same time as environmental sustainability and productivity increases;
- SI should be a goal alongside conserving biodiversity, and the promotion of animal and human welfare, good nutrition, and sustainable development.

> “Aquaculture has real potential to accelerate economic growth, provide employment opportunities, improve food security, and deliver an environmentally sustainable source of good nutrition for millions of people, especially in low- and middle-income countries.”
>
> **Sir John Beddington, Co-Chair of Global Panel and Former United Kingdom Government Chief Scientific Adviser**

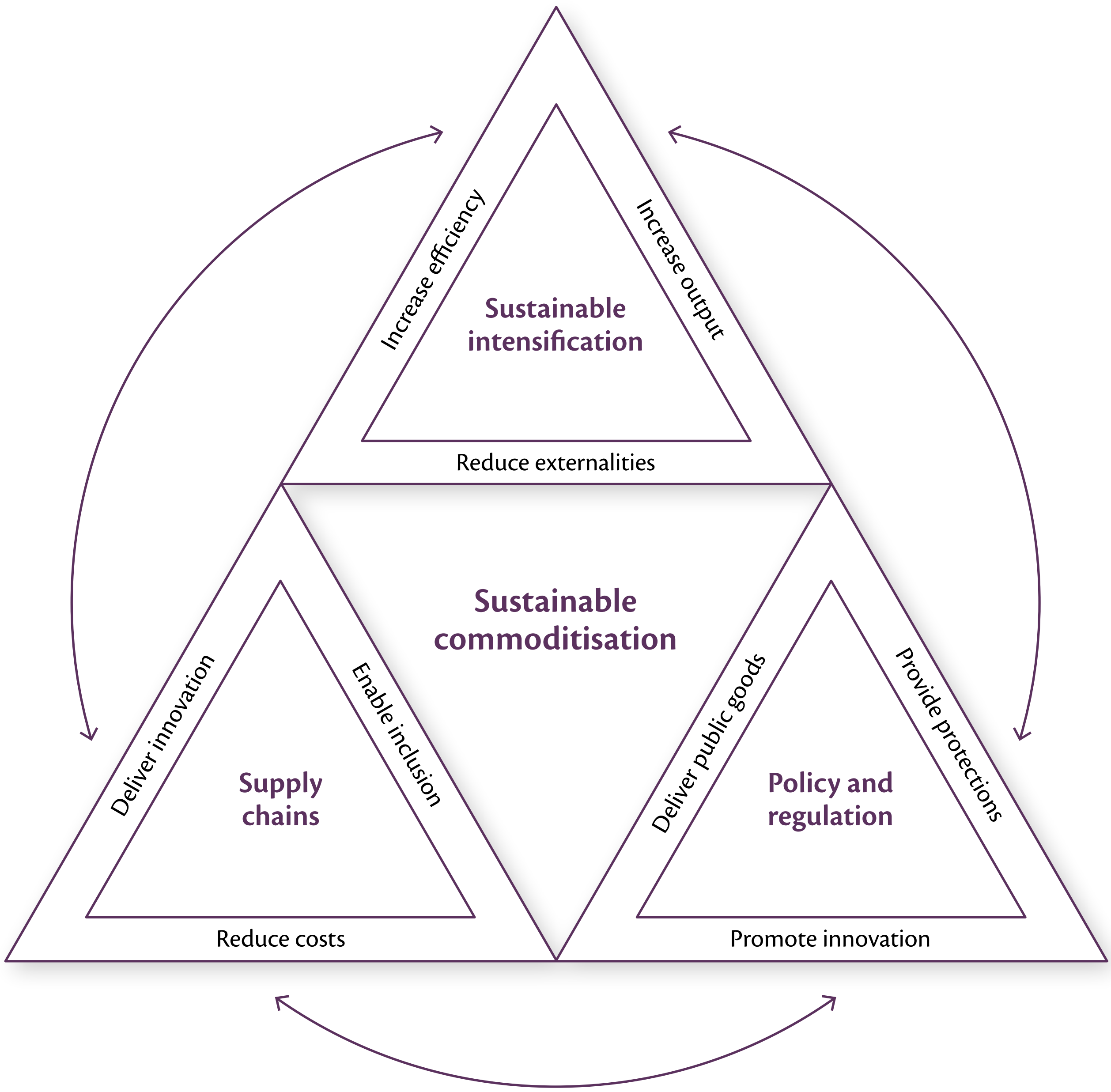
Box 9. Future scenarios for aquaculture in Indonesia: an analysis of fish supply and demand (based on Tran et al., (2017)[90] and Henriksson et al., (2018)[91]

Fish is an important part of the diet in Indonesia, accounting for more than half of all per capita intake of animal protein.[9] Fish production is also economically important to the country: in 2018, Indonesia was responsible for 8% of the world's marine captures, lagging only behind China and Peru.[9] Indonesia has also seen remarkable growth in its aquaculture sector. Between 2009-2018, production of fish grew by 12.4%, and in 2018 aquaculture accounted for 42.9% of all fish produced by the country.[9]

Demand for fish is expected to grow in response to rising incomes, population growth, and shifting consumer preferences due to health concerns. To continue to support the growth of the sector and consumer demand, the government had set ambitious production targets for aquaculture of 11.8 million tonnes per year by 2019. At the same time the government adopted a blue growth policy emphasising the need to minimise environmental impact and unsustainable use of aquatic resources.[92]

In a scenario planning exercise, future supply-demand scenarios and their environmental impacts from 2012 to 2030 were modelled to help guide policy.[90,91] This exercise led to an important conclusion: under a business as usual scenario, more wild fish and land would be required than is manageable using current production practices, and the future growth targets set by the Indonesian government would still not be achieved.[91] The exercise revealed the need to re-evaluate production goals, the relative balance of different species and to identify more sustainable aquaculture production practices including lower feed use, lower inclusion of fishmeal in feeds, and practices of sustainable intensification. Additionally, even with substantial aquaculture growth, Indonesia still needs to transform capture fisheries by enacting policies which limit illegal, underreported, and unregulated fishing, and habitat destruction. This example illustrates a process that other countries can use to plan for growth and policies which support domestic and/or export orientation. As supplies of fish come from both fisheries and aquaculture, scenario planning involving both sectors can be an important planning tool.

Figure 9. The triangle of sustainable commoditisation



Source: Belton (2020)[89]

The concept of 'sustainable commoditisation' of fish as a whole has recently been proposed as a way of harmonising concepts of sustainability with the development of systems oriented towards increasing the availability of food.[89] When applied to aquaculture, the concept recognises three interlinked concepts: sustainable intensification, policy and regulation, and supply chains (see Figure 9).[89] Sustainable intensification aimed at increasing fish production from aquaculture seeks to increase output while at the same time increasing efficiency of production and reducing negative externalities, which often accompany greater intensification and particularly greater feed use. Policies are needed to help put in place infrastructure, education and a favourable climate for growth and innovation, while regulation can help ensure food safety, working and environmental conditions. Supply chain transformation can also create efficiencies leading to lower prices and reduced risk, and helps to create employment and inclusive growth, which benefits both businesses and workers.

6. Recommendations

Aquaculture can deliver diverse benefits to LMICs. It contributes to food security, and its outputs can enhance the quality of diets and the health of populations through improved nutrition. It is a major source of employment throughout the value chain, reaching 20.5 million globally in 2018. It can provide a major source of exports, evidenced by Asia's exports to high-income countries. And if implemented and managed sustainably, it can provide an alternative to wild-caught fish, thereby reducing pressure on fisheries under threat from overfishing and climate change.

However, despite the many opportunities presented, aquaculture, together with capture fisheries, is too often sidelined in policies and dialogues relating to nutrition and food systems. These tend to focus much more on land-based food production. Over the next decade, as food systems strive to meet the demands of a growing world population, policy makers need to take much greater account of the aquatic dimension in their food-system policies and strategies.

There is considerable potential for many African countries in particular to capitalise much more on the opportunities and benefits presented by aquaculture. While Asia is at the heart of global aquaculture production and its growth, employing 19.6 million in 2018, Africa only employs around 400,000. At present a relatively small number of countries in Africa are expanding their activities substantially.

Worldwide, the production of fish from aquaculture could surpass that of capture fisheries by 2024. But the extent to which this is achieved will depend on policymakers taking action to create the right enabling policy environment, and to promote investment in value chains. Further expansion of the aquaculture sector also needs to address major challenges, relating in particular to sustainability and antimicrobial resistance. Using new practices and technology will be key to avoiding the mistakes that have beset the sector in the past. The priority actions for different classes of stakeholder are as follows:

Governments:

- **Incorporating fish and related products into agriculture and trade policies, updated national food-based dietary guidelines, and nutrition and health policies and strategies.** Policymakers should also support scenario planning exercises to explore an expansion of aquaculture and to guide fisheries policies. Such exercises can help plan for sustainable growth, ensure that targets are realistic, help set targets for domestic consumption vs. export and facilitate contingency planning for events such as disease outbreaks and climate change impacts.

- **Integrating food security and nutrition issues into policy decisions relating to fisheries and aquaculture.** Too often decisions focus on economic considerations, neglecting the nutrition and health implications of policies in this sector. This means that communities often miss out on the potential of fish for solving nutritional deficiencies in populations.

- **Encouraging entrepreneurship by SMEs involved in aquaculture.** Many of the actions that support the growth of small business can also help support the growth of aquaculture. Governments should encourage access to loans and financial markets to enable capital investments that can help overcome the barriers faced by businesses starting up, or increasing production. Access to inputs and coordination of value chain development should also be supported to enable SMEs to play a bigger role in national fish production and poverty alleviation.

- **Promoting inclusive growth.** This should be a priority as value chains are upgraded. Women and local communities should benefit from opportunities for aquaculture value chain development. Women already play a major role throughout the value chain, but are often relegated to the lowest paid and lowest grade work.

- **Resolving competition for land.** Policy choices relating to inland aquaculture projects should be informed by studies of the trade-offs which take a wide perspective of costs and benefits. This may be important when there are competing priorities, for example relating to the need for self-sufficiency in the production of staples. Important considerations should include: the nutritional and health benefits of aquaculture products, diversification of food production, enhanced earnings when relatively unproductive land is repurposed, and possible increases in employment.

Multiple stakeholders working together:

- **Encouraging investment to enhance the diversity and profitability of feed options across LMIC markets.** Governments, their development partners, and private sector entities all have a role to play. The goals should include: increasing human capital, skill development, and wider adoption of existing feed-related technologies in LMICs. Policymakers should also consider implementing pro-business policies: for example reducing import taxes on machinery and raw materials for feed.

- **Addressing the growing threat of antimicrobial resistant bacteria.** This needs to be a priority for all countries in view of the threat to commercial growth, animal and human health, and contamination of the environment and food chain. A 'One Health' approach is essential. This involves the international standardisation of surveillance of antimicrobial use, as well as measures such as improved stakeholder education, international certification, and voluntary as well as regulatory measures.

- **Prioritising the goal of sustainability.** Sustainability in new and existing aquaculture systems needs to be a priority, not least in view of the threat of climate change, and the relentless degradation of so many environmental resources. Tools and approaches that should be considered include: life cycle assessment tools to guide sustainability decisions; sustainable intensification; integrated aquaculture systems and recirculating aquaculture systems. 'Sustainable commoditisation' is a further approach which seeks to deliver sustainability while simultaneously increasing food availability.

- **Addressing loss and waste in fish value chains.** Systematic assessment tools need to be developed to capture the multiple dimensions of loss, and used to inform actions to prevent loss. These need to go beyond assessment of physical loss to include the effects of processing and transportation on the nutritional value of aquaculture products, and how value is lost throughout the value chain. The potential benefits are many: improving consumer choice, enhancing value for money for producers and other value chain actors; preserving nutritional value as products move through the value chain; and creating new jobs associated with food processing and transportation.

Researchers:

- **Identifying alternatives to meal and fish oil from capture fisheries.** Research has highlighted the potential to decouple the fish feed industry from reliance on wild catch inputs from capture fisheries, with both ecological and nutrition benefits. Further research and development are needed to find replacements that make use of local inputs and which are scalable in LMICs. Existing technologies and solutions also need wider dissemination and scaling up.

- **Genetic improvement of fish species.** Increased investment is needed to target the genetic improvement of fish species, particularly those that are widely consumed in LMICs such as tilapia, carp, and catfish. Through selective breeding, there is considerable scope to increase productivity, enhance nutritional value, and improve disease resistance. Further objectives should be to increase feed efficiency, and also to reduce reliance on fishmeal and fish oil.

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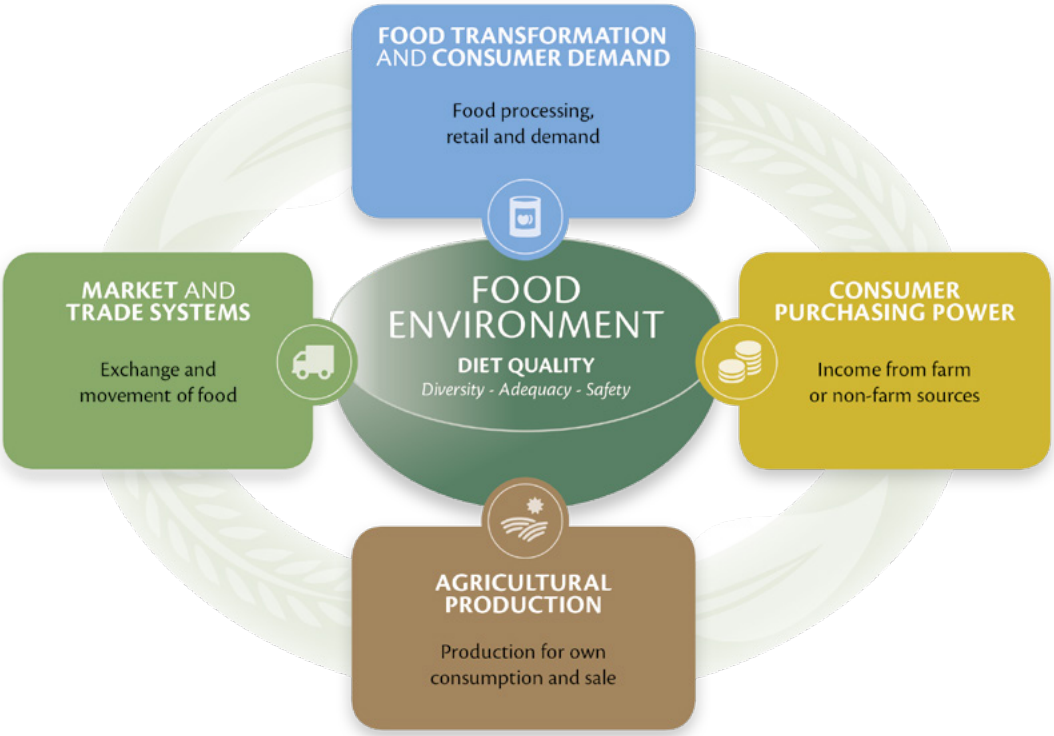
How can Agriculture and Food System Policies Improve Nutrition?

The multiple burdens on health in low- and middle-income countries due to food-related nutrition problems include not only persistent undernutrition and stunting but also widespread vitamin and mineral deficiencies and a growing prevalence of overweight, obesity and non-communicable diseases. These different forms of malnutrition limit people's opportunity to live healthy and productive lives, and impede the growth of economies and whole societies.

The food environment from which consumers should be able to create healthy diets is influenced by four domains of economic activity:



In each of these domains, there is a range of policies that can have enormous influence on nutritional outcomes. In the Global Panel's first Technical Brief, we explain how these policies can influence nutrition, both positively and negatively. We make an argument for an integrated approach, drawing on policies from across these domains, and the need for more empirical evidence to identify successful approaches.

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Rethinking trade policies to support healthier diets makes recommendations for policymakers to consider concerning all domains of the food system in order to improve diets.

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