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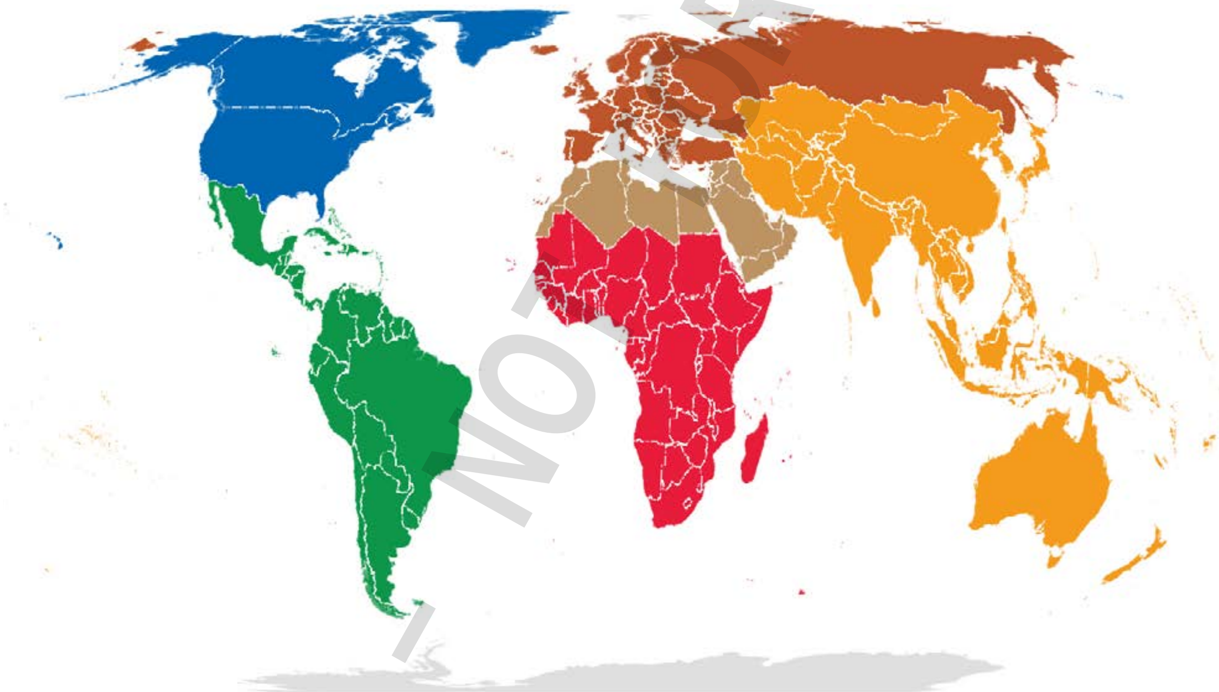
WORLD AQUACULTURE 2020: A BRIEF OVERVIEW



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WORLD AQUACULTURE 2020: A BRIEF OVERVIEW

by

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Preparation of this document

The FAO Fisheries and Aquaculture Division is pleased to present *World aquaculture 2020: a brief overview*. Continuing the FAO's traditional aquaculture regional and global review process, six regional reviews on aquaculture were compiled in 2020 and were published in 2021. This document, *World aquaculture 2020: a brief overview*, attempts to synthesize the information presented in the six regional reviews into a global overview, with the view to examine how the aquaculture sector has grown and performed over the past five years and what lessons could be learned from the past to ensure sustainable growth and expansion of the sector in the coming years. Additional FAO documents and published literature were reviewed and incorporated into the overview. The aquaculture production data used in this review are 2018 data from the FAO Fisheries and Aquaculture Database – FishStatJ. This is the fourth review in the series, the first, second and third having been published in 2006, 2011 and 2017.[1] Similar global and regional aquaculture reviews were developed in 1997 and 2000. This volume has been titled as a brief overview, considering that most information provided in the last review is still valid. This volume updates the global status and trends in aquaculture development and provides some insights on prospects and forecasts of global aquaculture development especially in light of the 2030 Agenda and its Sustainable Development Goals.

Data used in this global aquaculture overview, as well as in the regional aquaculture reviews, derive mainly from the different FAO fisheries and aquaculture statistics (FishStat), accessible through different tools, including the FAO Yearbook Fishery and Aquaculture Statistics, online query panels and FishStatJ. A discussion of FAO data is included in Appendix 1.

In continuing the global efforts to achieve aquaculture sustainability through dissemination of up-to-date information on the status and trends of the sector, FAO publishes Aquaculture Regional Reviews and a Global Synthesis about every 5 years, starting in 1997. Previous reviews, along with recordings of virtual webinars held 26–29 October 2020, can be found on the dedicated website here: www.fao.org/fishery/regional-aquaculture-reviews/aquaculturereviews-home/en/

[1] www.fao.org/fishery/regional-aquaculture-reviews/en/

Abstract

This document provides a synthesis of six regional aquaculture reviews: Asia-Pacific, Europe, Latin America and the Caribbean, Near East and North Africa, North America and sub-Saharan Africa. Global aquaculture production, including aquatic plants, in 2018 was 114.5 million tonnes, with an estimated value of USD 263 billion. The Asia-Pacific region continued to be the major producer. Globally, aquaculture provides over 50 percent of fish for human consumption. In 2018, aquaculturists were reported to farm about 622 species or species items including 387 finfishes, 111 molluscs, 64 crustaceans, seven frogs and reptiles, ten miscellaneous aquatic invertebrates and 43 aquatic plants. From 2000-2018, aquaculture production in freshwater, brackish water and marine water increased at a compound annual growth rate of 5.7 percent, 7.7 percent and 5.2 percent respectively while total aquaculture production grew at an annual growth rate of 5.6 percent. Global food supply and per capita consumption of fish and fish products continued to increase faster than human population growth. However, in parts of Africa the apparent fish consumption has decreased. In 2018, 20.53 million people were employed in aquaculture and a higher proportion of women worked in the aquaculture industry than in the fishing industry. Aquaculture is striving to innovate in order to increase production and sustainability. Progress in biosecurity and fish health management, feed formulation and utilization, and genetic resource management are showing good, but uneven progress. Globally aquaculture has used over the last decades about 18 million tonnes of forage fish in the formulation of fish and animal feeds. Although domestication and genetic improvement have played a large role in the increased production in some species, the most widely cultured farmed-type is the wild type. In 2018, 37 percent of total fisheries and aquaculture production were traded internationally, with a total export value of USD 165 billion. The aquaculture sector faces challenges including competition for land and water resources, as well as external factors such as climate change, conflict, economic uncertainties and most recently the COVID-19 pandemic. The pandemic and other stresses such as droughts and tsunamis, revealed that the aquaculture industry has not engaged sufficiently in disaster preparedness. International and national mechanisms are being put in place to increase the sustainability, good governance and social license of the sector to address these challenges. The diversity of the sector, the opportunities for good jobs and commitments by governments to good governance will help the sector meet these challenges. Aquaculture is, and will be, instrumental in helping countries implement the 2030 Agenda and to meet nearly all of the UN Sustainable Development Goals and other international instruments, particularly through contributions to food security and nutrition.

Key words: aquaculture, global and regional status, trends and challenges, aquatic food production, sustainable development.

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Key words: aquaculture, global and regional status, trends and challenges, aquatic food production, sustainable development.

Abbreviations and acronyms

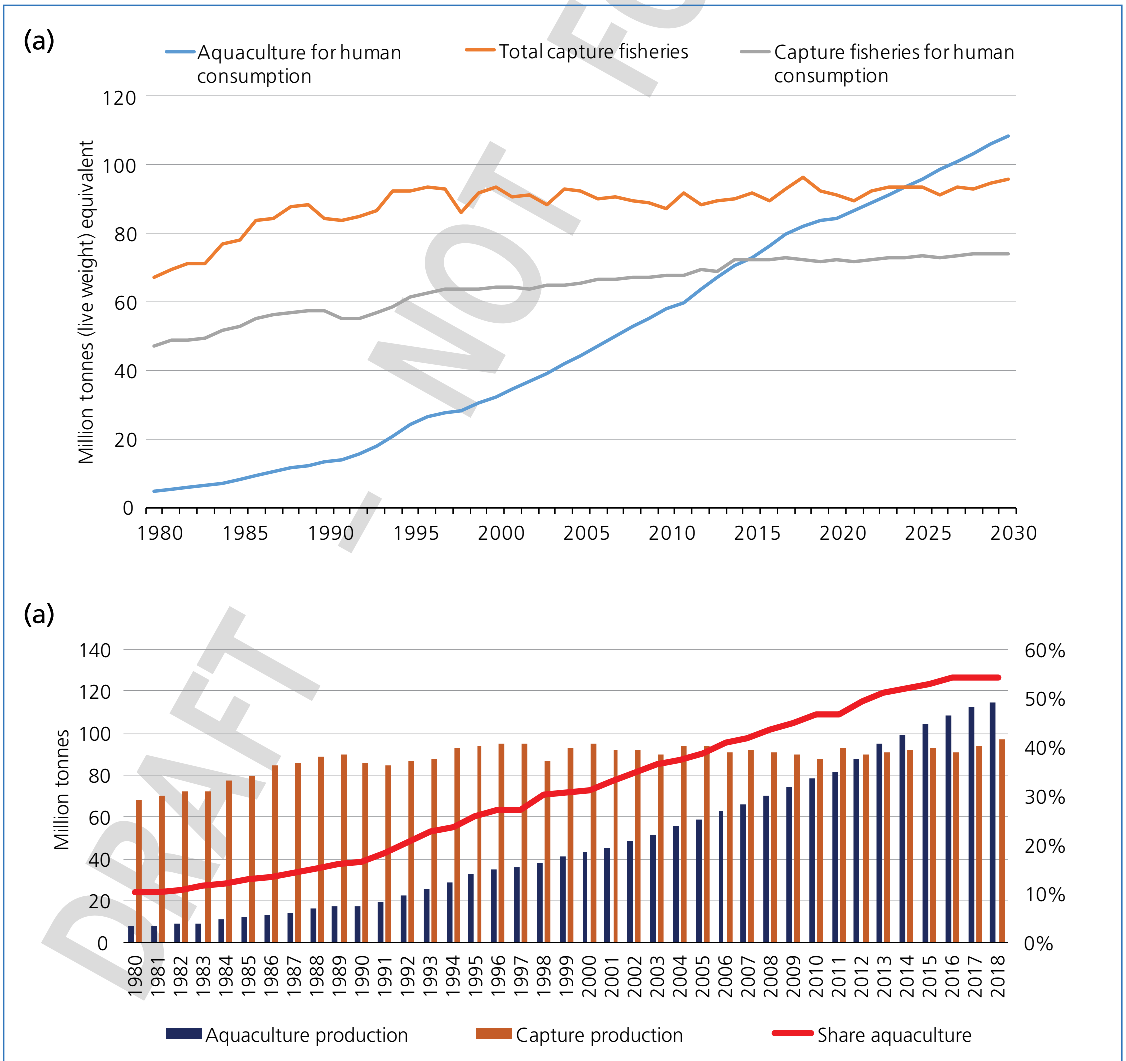
BGI	The Blue Growth Initiative
CAGR	Compound annual growth rate
DNA	Deoxyribonucleic acid
EAA	Ecosystem approach to aquaculture
EATiP	European Aquaculture Technology and Innovation Platform
FAO	Food and Agriculture Organization of the United Nations
IMTA	Integrated multi-trophic aquaculture
ISSCAAP	International standard statistical classification of aquatic animals and plants
LAC	Latin America and the Caribbean
NEI	Not elsewhere included
NENA	Near East and North Africa
SAR	Special Administrative Region
SSA	sub-Saharan Africa
USD	United States Dollar

1. Background and objectives

Aquaculture is now, and is expected to be in the future, an increasingly important and necessary component of the global food system providing the world with high quality and affordable aquatic food for human consumption. Aquaculture is already the main source of aquatic food globally (Figure 1) and is expected to continue to be the major source of additional aquatic food production as the world's human population continues to grow while global capture fisheries harvests have stabilized at a plateau of about 90 million tonnes since the 1990s (FAO, 2020a). This increased aquaculture production will need to be carried out in a responsible manner with due regard for the environment, the welfare of farmed animals, human rights and decent work for the people employed in the sector and for society in general.

The Food and Agriculture Organization of the United Nations (FAO), as the major intergovernmental organization with a global mandate for aquaculture and fisheries has recognized the significant role that the sector plays in providing the world with high quality and affordable aquatic food. FAO has routinely prepared a series of regional reviews and flagship publications on aquaculture since 1995, most recently covering the period up to

FIGURE 1. Global capture fisheries and aquaculture production (a) historic and projected production excluding aquatic plants 1980–2030 and (b) production including aquatic plants 1980–2018



Source: FAO, 2020a; FAO, 2020b.

2015 (FAO, 2017a) demonstrating that the development and management of aquaculture is not homogenous around the world. Aquaculture management practices vary considerably in different regions and countries. In some areas the sector is very well developed while in others it is in its infancy. In some areas it has declined, while in others it is growing rapidly. A regional approach highlights these differences, but there may well be significant differences also within regions.

The present document – *World Aquaculture 2020: A brief overview* – follows from FAO (2017a) with the objective of synthesizing six new regional reviews in order to examine how the sector has grown and performed over the past five years and what lessons might be learned to best enable its sustainable growth in the coming years. Considering the amount of information and data provided in the previous syntheses and in the current regional reviews, this 2020 overview often refers to those earlier documents to avoid repetition and focuses instead on new developments while citations in this review refer readers to the earlier reviews rather than listing primary sources. All statistical data on aquaculture production and value presented in this review originate from 1950–2018 (FAO, 2020b).

The review takes into consideration the same regional breakdown as in the six regional reviews which include Asia-Pacific (FAO, 2021a), Europe (FAO, 2021b), Latin America and Caribbean (LAC) (FAO, 2021c), Near East and North Africa (NENA) (FAO, 2021d), North America (FAO, 2021e) and sub-Saharan Africa (SSA) (FAO, 2021f). For some of the regions, in particular Europe, Asia and Africa, slight differences occur with the continental breakdown of UN M49. More information on the country composition of each of the regions is available online at http://www.fao.org/fishery/regional-aquaculture-reviews/aquaculture-reviews-home/en/.

The regional reviews and global syntheses have served to focus discussions and recommendations in the past (FAO/NACA, 2012; FAO, 2017b) and are also expected to provide the basis for discussions and recommendations at the forthcoming Global Conference on Aquaculture Millennium + 20 (FAO/MARA/NACA, 2021) and for the declaration emerging from that conference.

2. Farming systems and practices

2.1 BACKGROUND

Aquaculture continues to grow in most regions of the world with most growth coming from Asia, and primarily from China. Aquaculture production, including aquatic plants, has risen from 7.8 million tonnes in 1980 to 114.5 million tonnes in 2018 or from 4.7 million tonnes to 82.1 million tonnes if aquatic plants are excluded (Figure 1). Aquaculture production is increasing globally, and at a regional level its contribution to total fish supplies (excluding aquatic plants) is greater than capture fisheries in Asia-Pacific where it accounts for about 60 percent of the regional production of fish (Table 1). At country level, 39 countries located across all regions except Oceania now produce more aquatic animals from farming than from fishing (FAO, 2020a). Aquaculture in Asia contributed the most to global production of aquatic animals by far, while the contributions of aquaculture in North America and sub-Saharan Africa regions were 10.1 percent and 7 percent, respectively (Table 1).

TABLE 1. Fisheries and aquaculture production, excluding aquatic plants, in 2018 (million tonnes/year, live weight equivalent)

	Asia-Pacific	SSA	North America	NENA**	LAC**	Europe	World*
Aquaculture production	72 581 989	606 399	659 557	1 696 236	3 139 634	3 411 239	82 095 054
Capture production	49 771 569	8 073 640	5 876 787	2 905 807	14 447 000	15 344 697	96 433 763
Total	**122 353 558**	**8 680 038**	**6 536 344**	**4 602 043**	**17 586 634**	**18 755 936**	**178 528 817**
Share of fish production from aquaculture (percent)	*59.3%*	*7.0%*	*10.1%*	*36.9%*	*17.9%*	*18.2%*	*46.0%*

* The World aggregate includes 14 263 tonnes of capture fisheries production of Others nei, 'not elsewhere included' in any of the regions.

** SSA : sub-Saharan Africa. NENA : Near East and North Africa. LAC : Latin America and Caribbean.

Source: FAO, 2020b.

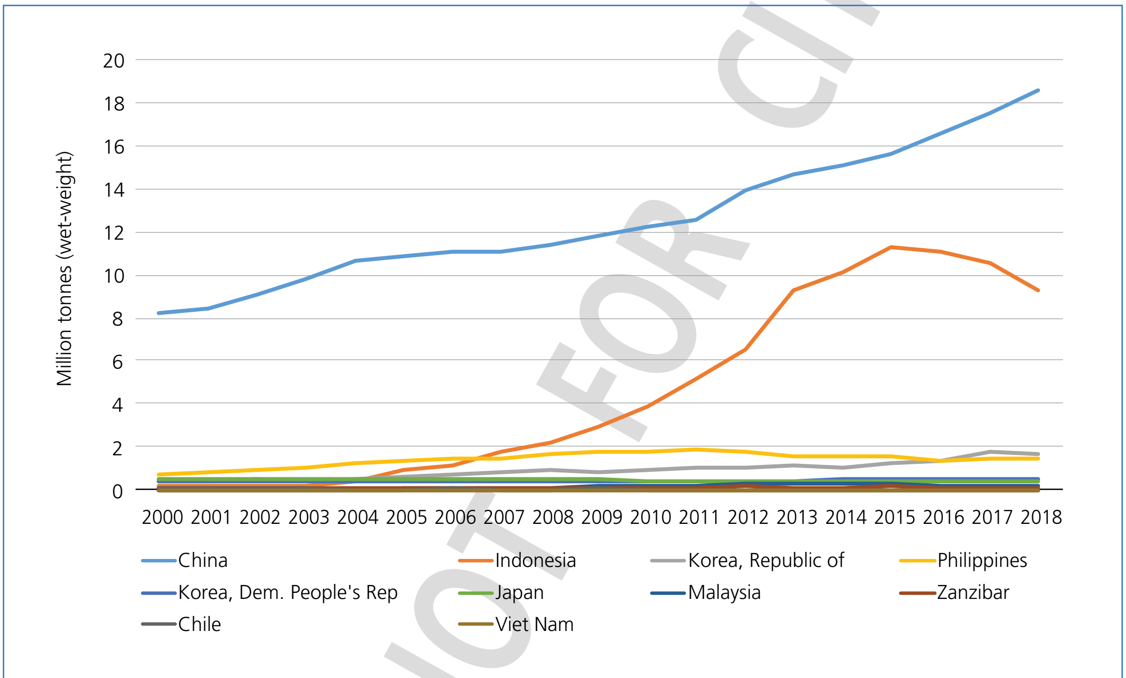
2.2 SPECIES

Aquaculture producers farm about 622 species and species items, a term that includes groups of organisms not identified to species level such as family or 'not elsewhere included' (nei) groups such as tilapia nei or freshwater fishes nei. This total includes 387 finfish species or species items (including hybrids), 111 molluscs, 64 crustaceans, seven frogs and reptiles, ten miscellaneous aquatic invertebrates, and 43 aquatic plants (FAO, 2020b). This contrasts with terrestrial (land-based) agriculture where only about 38 species of livestock and 173 species of crops are farmed. However, the terrestrial agriculture sector farms many more farmed types, including breeds and varieties. For example, there are over 100 000 varieties of rice curated by the International Rice Research Institute in the Philippines and around 8 800 livestock breeds (FAO, 2021g; FAO, 2021h).

The total number of commercially farmed aquaculture species items recorded by FAO has increased by 31.8 percent, from 472 in 2006 to 622 in 2018 (FAO, 2020b) while recent studies have revealed about 250 more species being farmed that are not being reported to FAO during routine data reporting of aquaculture production (FAO, 2019a). Terrestrial agriculture has created hundreds of genetically improved breeds and varieties while there has been relatively little genetic improvement for most farmed aquatic species meaning that the wild type is still the most often farmed type (FAO, 2019a). Notable exceptions are the numerous strains of common carp, tilapia, channel catfish, and the hybrids and polyploids used in aquaculture (FAO, 2019a).

Farmed aquatic plants accounted for 32.4 million tonnes (wet weight) in 2018 or about 28 percent of total aquaculture production (FAO, 2020b). Marine algae is the main group and they are being farmed in over 50 countries. Asia also leads the world in aquatic plant production although Chile and United Republic of Tanzania, Zanzibar also feature among the top ten producing countries while Indonesia, the second highest global aquatic plants producer, where production grew rapidly between 2004 and 2014 (FAO, 2017a), has recently experienced declining aquatic plant production (Figure 2).

FIGURE 2. Top producers of aquatic plants 2000–2018 (million tonnes/year)



Source: FAO, 2020a; FAO, 2020b.

2.3 SYSTEMS AND PRACTICES

Aquaculture is the most diverse food-producing sector (Metian *et al.*, 2019). In addition to context-specific economic, social and governance factors, the growth of aquaculture has been possible also due to a diversity of farming systems and species which allows aquaculture to be practiced in a range of environments and habitats from Arctic oceans to tropical rice fields (FAO, 2021a; FAO, 2021b; FAO, 2021c; FAO, 2021d). The intensity of aquaculture practices also varies from highly intensive, recirculating systems to low input, extensive systems that depend largely on the environment for feed and maintaining water quality (FAO, 2017a). Traditional pond and cage-based systems continue to provide the bulk of aquaculture production (FAO, 2017a; FAO, 2021e). Newer systems such as aquaponics, although still with low levels of production, are expanding in some areas where water and land are scarce, such as in sub-Saharan Africa and the Near East and North Africa (NENA) while innovative systems using biofloc also show promising results in tilapia and shrimp farming in these regions (FAO, 2021d; FAO, 2021f).

There is a move towards sustainable intensification of aquaculture in order to meet increased demands for aquatic foods (FAO, 2016a). Sustainable intensification in this context is defined as aquaculture production systems or technologies or management practices that improve production and resource use efficiency of land, water, feed, and energy, result in improved environmental benefits, strengthen the economic viability and resilience of farmers and improve social acceptance and equality while not compromise the other factors. However, the regions will differ in their ability to intensify. For example, FAO (2021e) stated "Moving forward as a technology-based, intensive production model in all sectors and species will differentiate North America from other aquaculture regions, and will play on its educational and workforce strengths and limitations." The NENA region with limited water resources is also looking toward more intensification (FAO 2021d). However, there are significant trade-offs that need to be considered with intensification (Waite *et al.,* 2014).

Aquaculture is usually an intensive technology-based industry in North America where, "efforts to increase production within the constraints of the current regulatory burden have focused on development of new production technologies, diversification of production in support of new sustainable (ecological) production models" (FAO 2021e). In arid areas, for example in NENA region, recirculating systems and aquaponics are becoming popular (FAO, 2021d). In SSA, high operational costs and unreliable electricity supplies sometimes hinder intensification (FAO, 2021f), while in Chile larger farms for salmon are importing technologies that can be used to intensify tilapia farming (FAO, 2021c).

Integrated multi-trophic aquaculture (IMTA) is seen as a technology to increase efficiency, re-use and reduce waste, and provide additional products from a farming system. North America and Europe (FAO 2021b; FAO 2021e) are moving towards IMTA in the marine environment, whereas Asia has been practicing it in inland waters for decades in the form of polyculture systems where different species of fish feed on different trophic levels. Although it is a promising approach, technical, legal and marketing constraints need to be overcome before there is wider acceptance of IMTA in North America and Europe (FAO, 2021b).

Aquaculture businesses in Asia-Pacific, as in many parts of the world, are mostly small-scale and family-owned, with some exceptions such as large-scale shrimp farms in Indonesia (FAO, 2017a; FAO, 2021a). Small-scale farms are often clustered together where farm conditions are suitable, for example, where there are available water resources and the gains to the communities where these are located are often not explicit. Community benefits may be indirect and occur through providing goods and services, including labour when and if needed, to these aquaculture farms.

Aquaculture often provides juvenile aquatic animals for release into the wild to rebuild, enhance or create capture fisheries or depleted natural aquatic populations. In many areas this stocking or stock enhancement may be substantial in both marine (Bell *et al.,* 2006) and inland areas (FAO, 2015a). However, the level of stocking and actual enhancement is often unclear due to inconsistent reporting, lack of standard definitions and marketing preferences (Bartley *et al.,* 2015). Although some countries do report numbers of fish stocked, many with significant stocking programmes often do not report this information to FAO (X. Zhou, personal communication). Most of the regional aquaculture reviews did not report on stock enhancement, the main exception being the Asia and Pacific review (FAO, 2021a). Culture-based fisheries, is a type of enhancement that is usually a community managed, extensive aquaculture practice conducted primarily in inland water bodies that provides direct benefits to the communities involved in monetary terms as well as providing food fish for household consumption, thereby improving the nutritional status of those households (FAO 2021a).

The lack of reporting to FAO on stocking programmes has been noted by the Committee on Fisheries' Sub-Committee on Aquaculture (FAO, 2014a), but the problem still remains. Reasons for the lack of reporting are unclear but could be related to the different reporting obligations of hatchery managers and fishery managers, the difficulties in identifying hatchery fish in fish catches and the inconsistencies in how countries report information to FAO (FAO, 2019a).

The aquaculture sector needs innovation across the entire aquaculture value chain to meet its role in providing sustainably produced, aquatic foods. The Latin America and the Caribbean regional review (FAO, 2021c) stated:

> *Large-scale producers are the vehicle through which technology and competitiveness strategies are usually introduced, allowing countries to compete globally. These large operations are also required by supermarkets and other merchants that need stability, uniformity, predictability, cost efficiency and sanitary assurances. Large operations, if vertically integrated, can also achieve diversification of supplies, through new products and/or preservation alternatives (value-added, ready-to-eat preparations; fresh, frozen products, etc.). While the large-scale producers may drive export and innovation, small-scale producers are more likely to supply local communities and need access to land and water resources.*

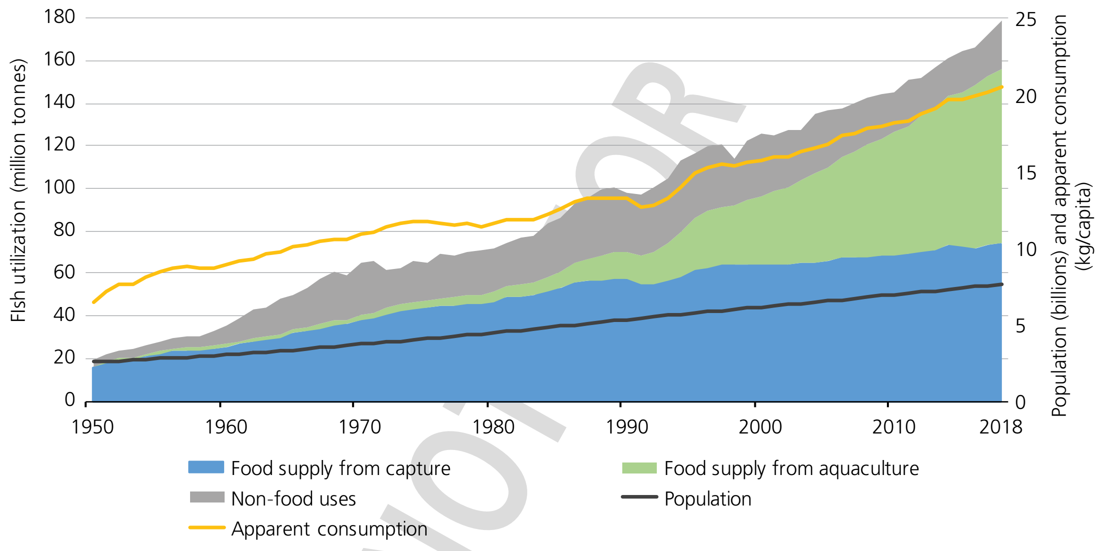
In areas with large and small-scale aquaculture, for example Chile, small-scale aquaculture may be challenged by aquatic food imports because they cannot compete with the prices of large-scale aquaculture, the inability to deliver standardized products that large-scale farms deliver and the large quantities required by supermarkets and other outlets in urban areas that large farms could deliver (FAO 2021c).

3. Production and value

3.1 OVERALL TRENDS

Overall, the world has seen an increase in human population as well as an increase in overall wealth (UN, 2019a; UN, 2019b). Aquaculture production of aquatic animals (excluding aquatic plants), has steadily increased over the last few years from 72.8 million tonnes in 2015 to 82.1 million tonnes in 2018. Global food supply and per capita consumption of fish and fish products have continued to increase faster than human population growth (Figure 3). However, parts of Africa appear to be exceptions to this general trend as per capita fish consumption rates have decreased.

FIGURE 3. World fish utilization and apparent per capita consumption, 1950–2018



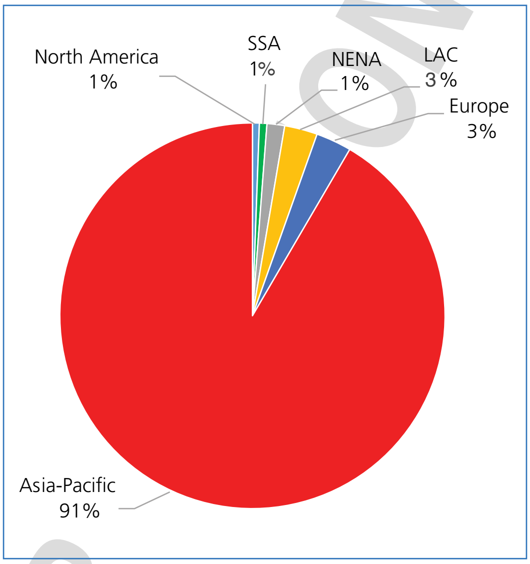
Source: FAO, 2020c.

The global aquaculture industry is estimated to use about 18 million tonnes of fish that has been used or processed in the formulation of fish feeds (FAO, 2020a). However, this value has fluctuated over recent years primarily based on varying levels of anchoveta production. Although aquaculture is sometimes criticized as it can involve feeding fish to fish and not to people, the harvest of forage fish (fish caught and rendered into animal feeds) has remained relatively constant over several decades (Figure 3) while production from aquaculture and production from livestock that also uses fish in animal feeds, has increased dramatically. At the same time, the proportion of total fishmeal production derived from fish processing by-products has increased to 25–35 percent (FAO, 2020a). Improved feed technology, viable replacement raw materials for fish in diets and improved farming practices have permitted aquaculture to produce more fish with the same total amount of fish in feeds.

3.2 REGIONAL TRENDS

Aquaculture production is unevenly distributed across the regions of the world (Table 1 and Figure 4) with Asia being the main producer by far while growth rates in the top 15 producing countries have also varied (Table 2). Overall aquaculture growth rates in terms of quantity have been slowing, but several of the top producing countries have shown recent increases in growth rates, for example India, Japan, Republic of Korea, and Democratic People's Republic of Korea, while Thailand and Philippines have recently shown declining growth rates.

FIGURE 4. Regional distribution of total aquaculture production in 2018 (percent, including aquatic plants)



Source: FAO, 2020b.

In 2018, only four of the top 15 producing countries were not in Asia (Norway, Egypt, Chile and Brazil). Some areas, such as Canada and the United States of America have prioritized environmental impact, regulatory frameworks, sustainability, partnerships, marketing and access to investment as key influencing factors determining aquaculture development rather than focussing on absolute growth of the sector (FAO, 2021e). Aquaculture production growth rates in the major producing countries have had a strong influence on global aquaculture growth rates and had very similar values throughout the period from 2003 to 2018. Percentage changes are always influenced by initial starting values and should be judged accordingly. It is encouraging to see that several countries, including Chile and Republic of Korea that had negative growth rates in 2014–2015 (FAO, 2017a) had positive growth rates overall in 2013–2018 (FAO, 2020b).

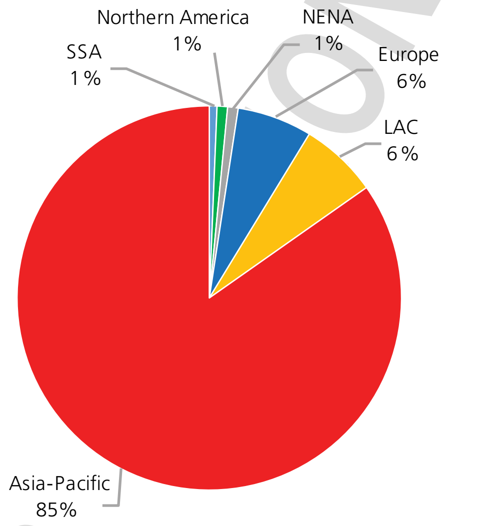
TABLE 2. Aquaculture production and growth rates for the top fifteen producing countries (including aquatic plants)

Country	Production per year (× 1 000 tonnes)						Compound Annual Growth Rate (%)		
Year or time period	**2000**	**2003**	**2008**	**2010**	**2013**	**2018**	**2003-2008**	**2008-2013**	**2013-2018**
China	29 750	34 892	44 068	47 787	55 027	66 134	4.8%	4.5%	3.7%
Indonesia	994	1 226	3 835	6 220	13 272	14 747	25.6%	28.2%	2.1%
India	1 943	2 317	3 856	3 790	4 555	7 071	10.7%	3.4%	9.2%
Viet Nam	514	953	2 477	2 701	3 221	4 153	21.1%	5.4%	5.2%
Bangladesh	657	857	1 006	1 309	1 860	2 405	3.2%	13.1%	5.3%
Philippines	1 101	1 449	2 408	2 546	2 373	2 304	10.7%	-0.3%	-0.6%
Korea, Republic of	668	840	1 395	1 377	1 533	2 279	10.7%	1.9%	8.2%
Egypt	340	445	694	920	1 098	1 561	9.3%	9.6%	7.3%
Norway	491	584	848	1 020	1 248	1 355	7.7%	8.0%	1.7%
Chile	425	607	871	713	1 046	1 287	7.5%	3.7%	4.2%
Myanmar	99	252	675	853	931	1 132	21.8%	6.6%	4.0%
Japan	1 292	1 302	1 187	1 151	1 028	1 033	-1.8%	-2.8%	0.1%
Thailand	738	1 064	1 331	1 286	998	891	4.6%	-5.6%	-2.2%
Korea, Dem. People's Rep	468	508	509	510	512	629	0.0%	0.1%	4.2%
Brazil	172	273	332	412	478	606	3.9%	7.6%	4.9%
Total top 15	**39 651**	**47 569**	**65 491**	**72 594**	**89 179**	**107 589**	**6.6%**	**6.4%**	**3.8%**
Others	3 362	3 959	4 687	5 324	5 767	6 893	3.4%	4.2%	3.6%
Total	**43 013**	**51 528**	**70 177**	**77 918**	**94 946**	**114 481**	**6.4%**	**6.2%**	**3.8%**

Source: FAO, 2020b.

The value of aquaculture products has risen dramatically from USD 53.7 billion in 2000 to over USD 263 billion in 2018. Aquaculture production value reflects the quantity and variety produced, in addition to highlighting differences in the cost of production. The distribution of production value was uneven among regions, with Asia-Pacific dominating (Figure 5).

FIGURE 5. Regional distribution of the value of total aquaculture production in 2018 (percent, including aquatic plants)



Source: FAO, 2020b.

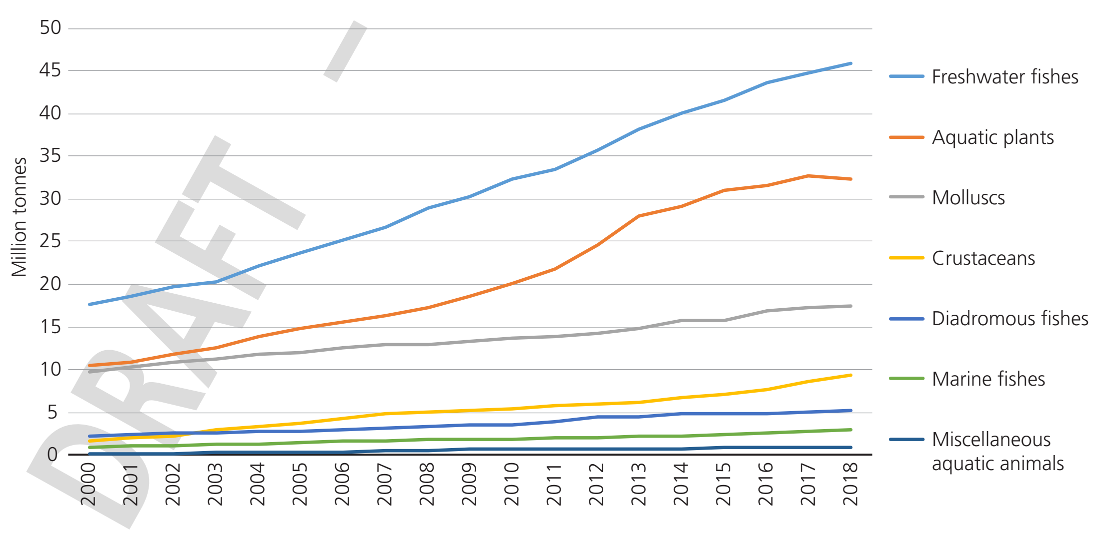
3.3 SPECIES

Freshwater fishes continue to lead aquaculture production (Figure 6) and were the most valuable group of aquaculture species (Figure 7).

In 2018, the top two species and five of the top 20 by production volume were seaweeds (Table 3) while four of the top 20 by volume were invertebrates. In contrast, only one seaweed was in the top 20 in terms of value and the most valuable farmed species was whiteleg shrimp, while 11 of the top 20 species were finfish and seven of the top 20 most valuable species were invertebrates (Table 4).

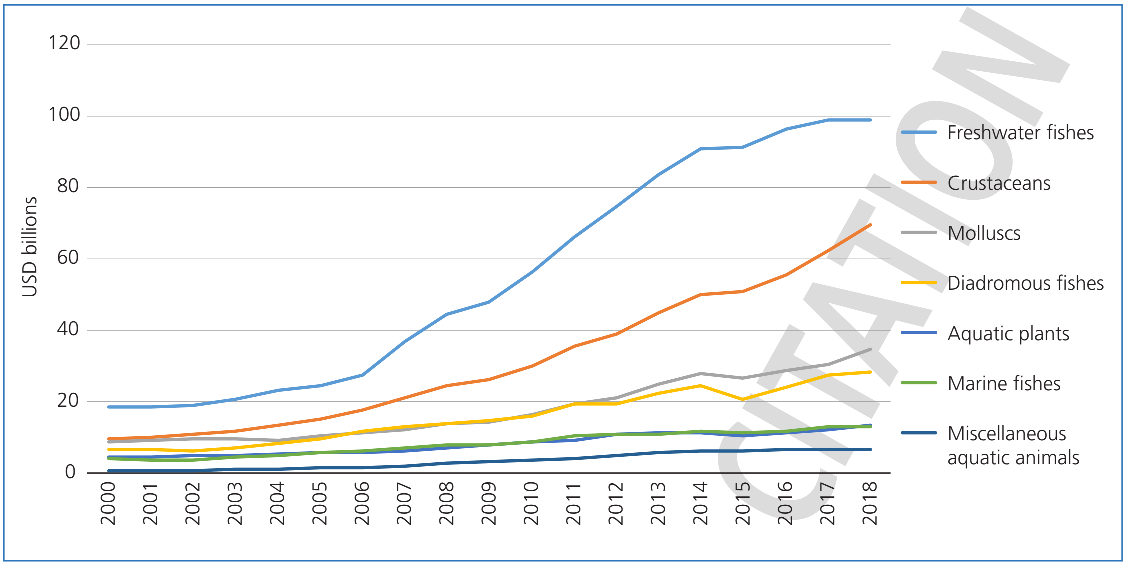
The regions differed in the aquatic species they produced (Table 5), probably reflecting a combination of opportunity and local advantages with regard to environment, capacity and target markets. The top five species in terms of quantity in Asia-Pacific, the world's top aquaculture producing region, are all species that feed low on the food chain and need very little or no external feed to raise them. FAO and other organizations are looking carefully at the productivity and relative advantages of 'fed' and 'non-fed' aquaculture especially with regard to support for small-scale producers in developing countries (FAO, 2016b).

FIGURE 6. Production from main aquaculture species groups, 2000–2018 (million tonnes/year)
ISSCAAP - International standard statistical classification of aquatic animals and plants



Source: FAO, 2020b.

FIGURE 7. Value of major aquaculture species groups, 2000–2018 (USD billion/year)



Source: FAO, 2020b.

TABLE 3. Aquaculture production volumes (wet weight, tonnes × 1000) and share of total production (percent) for top 20 species items in 2018

Species item	Production volume (× 1 000 tonnes)	Share of total production (percent)
Japanese kelp (*Laminaria japonica*)	11 448	10.0%
Eucheuma seaweeds nei	9 238	8.1%
Grass carp (=White amur) (*Ctenopharyngodon idella*)	5 704	5.0%
Cupped oysters nei	5 171	4.5%
Whiteleg shrimp (*Penaeus vannamei*)	4 966	4.3%
Silver carp (*Hypophthalmichthys molitrix*)	4 788	4.2%
Nile tilapia (*Oreochromis niloticus*)	4 525	4.0%
Common carp (*Cyprinus carpio*)	4 190	3.7%
Japanese carpet shell (*Ruditapes philippinarum*)	4 139	3.6%
Gracilaria seaweeds	3 455	3.0%
Bighead carp (*Hypophthalmichthys nobilis*)	3 144	2.7%
Catla (*Catla catla*)	3 041	2.7%
[*Carassius* spp]	2 772	2.4%
Freshwater fishes nei	2 545	2.2%
Atlantic salmon (*Salmo salar*)	2 436	2.1%
Striped catfish (*Pangasius hypophthalmus*)	2 360	2.1%
Wakame (*Undaria pinnatifida*)	2 320	2.0%
Nori nei	2 018	1.8%
Roho labeo (*Labeo rohita*)	2 017	1.8%
Scallops nei	1 918	1.7%
Total top 20	**82 195**	**71.8%**
Others	32 286	28.2%
Total	**114 481**	**100.0%**

Source: FAO, 2020b.

In 2018, freshwater finfish production was led by cyprinids (63 percent of total freshwater fish production), cichlids (13 percent) and pangasid catfishes (six percent). Production of molluscs was dominated by oysters (34 percent of total molluscan aquaculture), clams (24 percent), scallops (12 percent) and mussels (12 percent). The main groups of crustaceans farmed were

TABLE 4. Aquaculture production value (USD x million) and share of total value (percent) for top 20 species items in 2018

Species item	USD x million	Share of total value (percent)
Whiteleg shrimp	30 222	11.5%
Atlantic salmon	17 143	6.5%
Red swamp crawfish (*Procambarus clarkii*)	14 456	5.5%
Grass carp (=White amur)	13 046	5.0%
Silver carp	10 365	3.9%
Chinese mitten crab (*Eriocheir sinensis*)	9 617	3.7%
Common carp	8 729	3.3%
Nile tilapia	8 226	3.1%
Bighead carp	7 316	2.8%
Japanese carpet shell	6 914	2.6%
Giant tiger prawn (*Penaeus vannamei*)	6 294	2.4%
Cupped oysters nei	5 593	2.1%
[*Carassius* spp]	5 514	2.1%
Mandarin fish (*Siniperca chuatsi*)	5 367	2.0%
Catla	5 012	1.9%
Scallops nei	4 970	1.9%
Marine molluscs nei	4 471	1.7%
Japanese kelp	4 310	1.6%
Freshwater fishes nei	4 269	1.6%
Rainbow trout (*Oncorhynchus mykiss*)	3 878	1.5%
Top 20	**175 712**	**66.7%**
Others	87 685	33.3%
Total	**263 396**	**100.0%**

Source: FAO, 2020b.

TABLE 5. Top five species items in terms of quantity in each region in 2018

SSA	NENA	Asia - Pacific	Europe	North America	LAC
North African catfish	Nile tilapia	Japanese kelp	Atlantic salmon	Channel catfish	Whiteleg shrimp
Nile tilapia	Mullets nei	Eucheuma seaweeds nei	Rainbow trout	Atlantic salmon	Atlantic salmon
Spiny eucheuma	Common carp	Grass carp	Sea mussels nei	American cupped oyster	Nile tilapia
Tilapias nei	Cyprinids nei	Cupped oysters nei	European seabass	Red swamp crawfish	Chilean mussel, *Mytilus platensis*
Torpedo-shaped catfishes nei	Silver, bighead carps nei	Silver carp	Common carp	Rainbow trout	Rainbow trout

Source: FAO, 2020b.

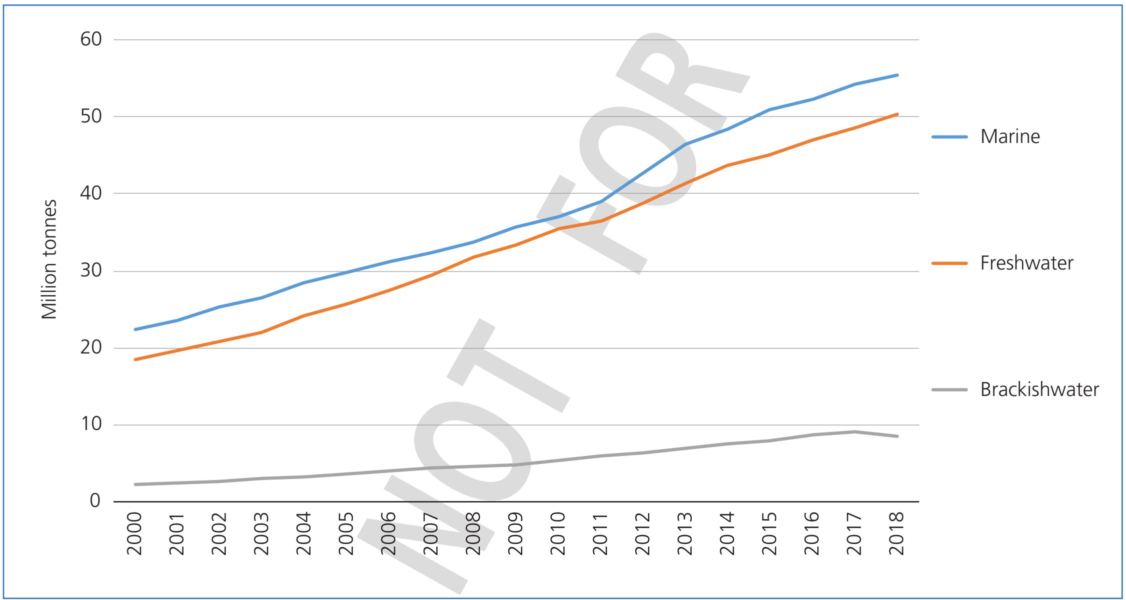
penaeid shrimps (64 percent), crayfish (18 percent), crabs (12 percent) and freshwater prawns, for example *Macrobrachium* spp. (five percent). There has been a significant increase in global crayfish production from just over 720 000 tonnes in 2015, to more than 1.7 million tonnes in 2018, primarily from China farming red swamp crayfish, *P. clarkii* (Cai *et al.*, 2020). This increased production comes mainly (>70 percent) from a rotational model based on an integrated crayfish-rice system (FAO, 2019b). Production of farmed diadromous fishes were dominated by Atlantic salmon (46 percent), milkfish *Chanos chanos* (25 percent), rainbow trout (16 percent), Japanese eel, *Anguilla japonica* (five percent), coho salmon, *Oncorhynchus kisutch* (three percent) and sturgeon (two percent). Marine fish production was led by marine fishes nei

(25 percent), mullets nei (nine percent), European seabass *Dicentrarchus labrax* (eight percent), gilthead seabream *Sparus aurata* (eight percent) and groupers nei (seven percent).

3.4 PRODUCTION BY ENVIRONMENT

From 2000 to 2018 growth of aquaculture in all environments, including freshwater, marine and brackish waters, and in most regions increased, although at a lower level for brackish-water aquaculture (Figure 8, Table 6). High growth rates were seen in freshwater and brackish water aquaculture in sub-Saharan Africa, and in brackish water aquaculture in Asia and LAC. Slight decreases were seen in European brackish water and North American freshwater aquaculture. The large increase in sub-Saharan African freshwater aquaculture reflects initial low production values, but also demonstrates the efforts expended in the region to increase aquaculture production.

FIGURE 8. Global aquaculture production by environment, 2000–2018 (million tonnes/year, including aquatic plants)



Source: FAO, 2020b.

TABLE 6. Production (× 1000 tonnes per year, including aquatic plants) by farming environment in 2000, 2009, 2010 and 2018 and average annual growth rate 2000–2018 (Compound annual growth rate (CAGR), percent) by farming environment

		Production (× 1000 tonnes per year)				CAGR 2000-2018
Region	**Environment**	**2000**	**2009**	**2010**	**2018**	
SSA	Brackish-water	1	0	0	2	5.1%
	Freshwater	49	269	350	593	14.9%
	Marine	58	121	146	125	4.3%
	Sub-total	**108**	**390**	**496**	**720**	11.12%
NENA	Brackish-water	305	602	751	1 315	8.5%
	Freshwater	52	144	211	314	10.6%
	Marine	3	23	23	68	18.8%
	Sub-total	**360**	**769**	**985**	**1 697**	9.00%
Asia-Pacific	Brackish-water	1 683	3 840	4 281	6 549	7.8%
	Freshwater	17 252	31 544	33 369	47 630	5.8%
	Marine	19 997	32 015	33 541	50 649	5.3%
	Sub-total	**38 932**	**35 384**	**71 191**	**104 828**	5.66%
Europe	Brackish-water	124	61	66	68	-3.3%
	Freshwater	515	566	566	628	1.1%
	Marine	1 518	2 074	2 084	2 721	3.3%
	Sub-total	**2 157**	**2 701**	**2 716**	**3 417**	2.59%
North America*	Brackish-water	0	-	-	-	N/A
	Freshwater	338	309	309	275	-1.1%
	Marine	246	328	350	385	2.5%
	Sub-total	**584**	**637**	**659**	**660**	0.68%
LAC	Brackish-water	126	278	325	643	9.5%
	Freshwater	271	549	601	938	7.1%
	Marine	476	1 091	943	1 580	6.9%
	Sub-total	**873**	**1 918**	**1 869**	**3 161**	7.41%
Total	**Brackish-water**	**2 239**	**4 781**	**5 424**	**8 577**	**7.7%**
	Freshwater	**18 476**	**33 381**	**35 407**	**50 377**	**5.7%**
	Marine	**22 298**	**35 651**	**37 087**	**55 527**	**5.2%**
Total		**43 013**	**73 814**	**77 918**	**114 481**	**5.6%**

* Canada and the USA did not report separate brackish-water aquaculture data.

Source: FAO, 2020b

4. Employment and social development

Numerous regions and countries have identified aquaculture as one of the most sustainable options for increasing production of fish and for economic development (FAO, 2021f). The UN estimates that population growth in sub-Saharan Africa will account for more than half of world population growth between 2019 and 2050 (UN, 2019a), while populations in many parts of Asia, Latin America and the Caribbean, Europe and North America are projected to peak and to begin to decline before the end of this century. According to the UN (2019a), "the 47 least developed countries are among the world's fastest growing – many are projected to double in population between 2019 and 2050 – putting pressure on already strained resources". The increased population as well as economic and regional differences will present both opportunities and challenges for aquaculture.

In 2018, an estimated 59.51 million people were engaged in the primary activity of fishing or fish farming and of these, 20.53 million were fish farmers (FAO, 2020a). Although more people are involved in capture fisheries worldwide, there is a higher percentage of women involved in aquaculture (19 percent) than in capture fisheries (12 percent) (FAO, 2020a). Aquaculture is being promoted as an activity that can provide opportunities and empower women, notably when it facilitates women's decision-making and participation in leadership. It also plays a critical role for women by supporting the consumption and provision of nutritious food (FAO, 2017c). Although the role of women and youth has not been fully documented nor recognized, there is a general increase in their direct involvement in the sector, particularly in small-scale production and in the feeding and post-harvest sectors (FAO, 2021f). De Graaf and Garibaldi (2014) stated that women make up 34 percent of those employed in aquaculture in sub-Saharan Africa (FAO, 2021f).

The active workforce in the sector is different across the regions both quantitatively, in terms of numbers of people working, and qualitatively for example, in terms of gender, age and capacity level. In 2018, Asia-Pacific again had the most people involved in fish farming representing 90 percent of the global aquaculture workforce while the remaining regions each had around five percent or less (FAO, 2020a). Regions such as Oceania and sub-Saharan Africa show increased participation in aquaculture, although starting at a low level. North American and European aquaculture sectors are increasingly technology- based requiring an educated and technical workforce to run and maintain the systems (FAO, 2020e). However, the social importance and contribution of micro-enterprises (less than ten employees), often engaging family members, is high in several European Union countries and comprise 90 percent of the European Union aquaculture sector (FAO, 2021b).

The rural nature of some aquaculture facilities makes it difficult to attract today's youth into the sector, for example, in Canada (FAO, 2021e). However, the rural nature also presents economic opportunities for aquaculture to contribute to livelihoods in those rural areas where there are limited opportunities for other types of employment. In Latin America, apart from a few exceptions, aquaculture needs to demonstrate that it will have a meaningful impact on society (FAO, 2021c) in order to gain social license and grow sustainably. In North America, aquaculture plays a relatively minor role as an employer although the economic value of aquaculture is growing (FAO, 2021e).

Due to the many factors involved, aquaculture may not always be able to alleviate poverty, especially with respect to small communities due to lack of resources, markets and capacity, so research results on the effects of aquaculture on poverty alleviation have been mixed (FAO, 2020a; Nguyen *et al.*, 2016). In addition to direct employment and food provisioning, in sub-Saharan Africa the aquaculture sector is active in corporate social responsibility initiatives, and vocational and academic training opportunities (FAO, 2021f).

Human rights and labour rights issues in agriculture, fisheries and aquaculture value chains are increasingly being discussed at international levels (FAO-ILO, 2013; FAO, 2016c; OECD-FAO, 2016; FAO, 2017b; FAO, 2017d; FAO Committee on Fisheries, 2017; ILO, 2016; DIHR, Rafto Foundation and IHRB, 2020; Kittinger *et al.*, 2017). These issues include decent work conditions which are also being considered for aquaculture workers (FAO, 2015b). Occupational health and safety in aquaculture also needs special attention (Cavalli *et al.*, 2019; Watterson *et al.*, 2019; Ngajilo and Jeebhay, 2019; Mitchell and Lystad, 2019; Cavalli, Watterson and Marques, 2019; Holmen and Thorvaldsen, 2018; Fry *et al.*, 2019; Kaustell *et al.*, 2019).

5. Resource use, services and technologies

5.1 BACKGROUND

Aquaculture is dependent on a variety of resources and ecosystem services. While inadequate supplies of quality feed and seed have been the main constraints to aquaculture development, improvements in feed manufacturing, replacement of fish in aquafeeds with plant-based material, microbial and single cell proteins, and insects are being researched and show promise to help alleviate feed constraints. Meanwhile, genetic improvement and husbandry are addressing seed constraints (FAO, 2021b).

5.2 LAND AND WATER

As reported earlier (FAO, 2017a), the aquaculture sector is in competition for resources with other users of land and water. Aquaculture often involves the conversion of land or imposes a new use of land and water, for example, shrimp ponds on the coast and cage farming in reservoirs. Spatial planning and designating specific areas for aquaculture development, including zoning, as well as following an ecosystem approach to aquaculture (EAA) are being used to address this issue (Aguilar-Manjarrez, Soto and Brummett, 2017; Meaden *at al.* 2016). Spatial planning will be important for the growth and sustainability of aquaculture, but will only be effective if applied by other sectors as well (FAO, 2021c). After facing global criticism for destroying mangroves, coastal shrimp farming has learned to farm in other areas and mangrove destruction has not increased in critical areas (FAO, 2021c) while mangroves are even being restored in some (FAO, 2021a). Furthermore, farming of species such as bivalves and seaweeds can help restore coastal areas through the provision of a wide range of regulating, provisioning, habitat, and cultural ecosystem services (Theuerkauf, *et al.*, 2019). On the other hand, an increase in reservoirs in South America has led to an increase in cage-based aquaculture systems and often there has been no environmental monitoring of their impact (FAO, 2021c).

Many parts of the world are water scarce, for example in NENA region and parts of sub-Saharan Africa. Efforts are being made to access new water sources, including geothermal water, underground aquifers and groundwater (FAO, 2021d). The re-use of irrigation water such as channelling water designated for crops to fish farms after being used for irrigation, has been a successful strategy in NENA region (FAO, 2021d). Competition for land and water between aquaculture and other sectors has impacted aquaculture development in parts of Latin America and elsewhere (FAO, 2021c). FAO (2017e) reported on efforts to follow appropriate zoning procedures for aquaculture and to use freshwater more efficiently, especially in drought and water scarce areas such as sub-Saharan Africa and NENA. Droughts in sub-Saharan Africa have been a regular feature of the climate for the past 20 years and farmers have had serious loss of production (FAO, 2021f). Droughts have also recently affected European production of carp and trout, for example in eastern European fish ponds, and the drying of small water courses, although recent increases in rainfall may help alleviate this situation (FAO, 2021b).

5.3 FEED

Feed is often the most expensive component of an aquaculture budget and the majority of farmed species require the addition of feed (FAO, 2020a). Fed aquaculture's share of overall aquatic animal production increased from 56.1 percent in 2000 to 69 percent in 2018. Although the relative proportion of global production resulting from non-fed aquaculture declined, the total volume of aquatic animal production in these systems increased in 2018 to 25 million tonnes. This comprised eight million tonnes of filter-feeding finfish (mainly silver carp, *Hypophthalmichthys molitrix*, and bighead carp, *H. nobilis*) and 17 million tonnes of aquatic invertebrates, mainly marine bivalves raised in seas, lagoons and coastal ponds (FAO, 2020b).

Commercial aquaculture feeds often include fishmeal and fish oil in their formulations, as do many feeds for terrestrial livestock and the pet food sector. In 2018, the aquaculture industry used about 18 million tonnes of fish in aquafeeds (FAO, 2020a). The use of fish for feed has remained fairly constant over recent decades while aquaculture production has increased significantly (FAO, 2020b). The industry is looking for alternatives to fish in commercial aquafeeds and has found viable alternatives for fish meal in the form of terrestrial plant-based proteins. In general soybeans seem to be the most widely used plant-based material used in aquafeeds to replace fish proteins (FAO, 2021b) and their use is increasing (FAO, 2021c). Successful research in Norway has led to reductions in fishmeal and fish oil inclusion rates in the formulation of salmon diets from 50 percent and 30 percent, respectively, to under 10 percent for each (FAO, 2021b).

According to the IFFO (the Marine Ingredients Organization), processed animal proteins, krill and fermented ingredients are recent additions to the list of high-protein, aquafeed raw materials while the use of by-product raw materials from aquaculture and fisheries has increased significantly and now represents between 25 percent and 35 percent of world fishmeal production (FAO, 2020a). Finding a substitute for fish oil appears to provide a greater challenge than that for alternative sources of protein. Algae or fermented organisms appear to have most potential in Europe. Genetically modified algae could provide protein but this is problematic in some regions because of opposition to the use of genetically modified organisms (FAO, 2021b).

Africa is a net importer of aquafeed (FAO, 2021f) while in other regions locally-produced feeds are more common. The aquaculture sector in NENA has seen significant investment in feed production capacity and facilities that has resulted in improved growth and economic returns (FAO, 2021d). In countries that have embarked on high quality aquafeed manufacturing, local aquaculture production has increased thus motivating similar investment in other countries (FAO, 2021d; FAO, 2021f).

5.4 SEED

The majority of farmed aquatic species rely on seed produced in hatcheries or other controlled or semi-controlled environments and this ‘closing of the life cycle’ has been a major reason for the success of aquaculture (FAO, 2021b). Domestication and genetic improvement have played significant roles in the increased production of species such as Atlantic salmon, whiteleg shrimp, channel catfish (*Ictalurus punctatus*), Nile tilapia and common carp. Selective breeding programmes in most regions have successfully developed fish with desirable traits including faster growth, better disease resistance, more attractive colour and later sexual maturity (FAO, 2021a; FAO, 2021b; FAO, 2021c; FAO, 2021e). For example, modern genetic techniques for improving growth have been established for rainbow trout in Denmark, the United Kingdom of Great Britain and Northern Ireland, and France, and for common carp in Belarus (FAO, 2021b) while Norwegian genetic improvement of Atlantic salmon for yield and disease resistance has been an important factor in making the sector productive and profitable (FAO, 2021b). However, the most widely cultured farmed-type (a general term for a strain, variety, hybrid, triploid, monosex group, other genetically altered form or wild type) for all farmed aquatic species is still the ‘wild type’, in other words, an organism that is nearly identical to the same species found in the wild (FAO, 2019a).

There are still species that rely on wild-caught early life history stages for on-growing under culture conditions, including bluefin tuna *(Thunnus thynnus)* and anguillid eels. In the past, milkfish culture relied on wild-caught juveniles (FAO, 2021a), but now hatcheries supply the bulk of seed (Xiaowei Zhou, personal communication). In Europe, the only species currently caught in the wild for on-growing in aquaculture are European eel *(Anguilla anguilla)* and bluefin tuna (FAO, 2021b). Whiteleg shrimp has surpassed other penaeid shrimps in production primarily due to the ease with which it can be reproduced in aquaculture facilities, its disease resistance and the resulting high yields (Alday-Sanz *et al.*, 2020). Sub-Saharan African countries have embarked on genetic improvement programmes for a variety of species, including giant tiger prawn in the Madagascar, abalone (*Haliotis* spp.) in the South Africa, Nile tilapia from Lake Volta in Ghana, Nile tilapia in Uganda sourced from local lakes, and African catfish in Kenya and Nigeria. Lack of hatchery facilities and feed manufacturing facilities constrain development in areas such as NENA (FAO, 2020d) and parts of sub-Saharan Africa (FAO, 2021f) as feed and seed must be imported with associated high costs and often poor quality.

5.5 HEALTH MANAGEMENT AND BIOSECURITY

Diseases, pathogens and parasites have consistently been a challenge to aquaculture and the movement of aquatic species for trade and aquatic animal health issues continue to be important considerations for aquaculture facilities. Recently several countries have been placing special emphasis on strengthening national veterinary capacity for aquatic animal disease management diagnosis, control and surveillance. This follows the emergence of aquatic diseases such as epizootic ulcerative syndrome, white spot syndrome virus and recent, suspected cases of Tilapia Lake Virus (FAO, 2021f).

There are often disease concerns specific to particular species and regions including sea lice in salmonid culture in Northern America (FAO, 2021e) and Europe (FAO, 2021b), oyster diseases in Europe (FAO, 2021b), shrimp viruses in Asia (FAO, 2021a) and Latin America (FAO, 2021c) and tilapia lake virus in Asia (FAO, 2021a) and Africa (FAO, 2021f). Species that are disease resistant or may be farmed in more biosecure systems may be preferred, as is the case with the switch to farming whiteleg shrimp in many parts of the world (Alday-Sanz, 2020; FAO, 2021a, FAO, 2021d). Egyptian fish farmers have suffered significant losses from 'summer mortality' of tilapia since 2013. Although this may be more related to poor husbandry, further research may confirm an infectious agent as the primary cause (FAO, 2021d). Vaccines have now been produced that confer resistance to a variety of bacteria (Shefat, 2018) in response to pressure to reduce use of antibiotics and the increased prevalence of antibiotic resistance occurring in many pathogens. The aquaculture industry along with regulatory agencies and the international community are developing novel means to address these issues, such as biological control of sea lice (FAO, 2021b).

5.6 TECHNOLOGIES

FAO (2019c) reviewed general areas for technological improvements in aquaculture and recommended, among others, the following areas for development:

- Optimizing resource use through integrated multi-trophic aquaculture (IMTA), multi-trophic level aquaculture, integrated aquaculture agriculture, and aquaculture zoning.
- Improving aquaculture engineering and the use of recirculating aquaculture systems.
- The use of biology and genetics, nutrition and feeding including bacterial fermentation of feeds and recycling methane.
- Application of biotechnology including nanotechnology, bioremediation and probiotics in environmental management of effluents, toxicants and pathogens.

- The use of digital and information and communication technology using modern environmental sensors and computer-assisted aquaculture decision making system that can help determine proper culture cycles with input-based growth performance under climate and environment changes.

Technologies for spatial planning, breeding, disease diagnosis and treatment, are continuing to advance (FAO, 2017a; Aguilar-Manjarrez, Wickliffe and Dean, 2018). The use of modern molecular genetic technologies in disease diagnosis, breed improvement and tracing aquatic species in nature and in supply chains is becoming more common and less expensive. The first transgenic animal for human consumption, AquaAdvantage Atlantic salmon was approved for sale in 2015. However, it is unclear how this salmon is performing in the market as some consumers and regulators are trying to prevent distribution in the USA (Alison Van Eenennaam, personal communication)

New gene editing technologies, although still not at a commercial level in aquatic organisms, have the potential to revolutionize the speed and accuracy of genetic manipulation (Houston *et al.*, 2020). Through the analysis of environmental DNA (the DNA an organism sloughs off into the water including waste, skin and scales), the presence of aquatic animals or pathogens can be detected merely by sampling the surrounding water (Rees *et al.*, 2014). However, these technologies have not yet become part of mainstream aquaculture.

Although a range of innovative technologies are in theory available to the aquaculture industry, it is often only the larger companies and aquaculture facilities that are able to utilize them (FAO, 2021c). With the increased use of digital information aquaculturists are now challenged with how to access and interpret large amounts of data, often provided in real time (FAO, 2020a).

6. Aquaculture and the environment

The aquaculture sector has learned that environmental sustainability, along with economic viability and social responsibility are key to a successful industry. The impact of aquaculture on the environment depends on the species farmed, the farming system and the environmental characteristics of a given location and adjacent areas. Thus, an ecosystem approach to aquaculture (EAA) is crucial (FAO, 2010). Brugere *et al.* (2018) suggested that mainstreaming the EAA in planning processes raised awareness of the usefulness of holistic and participatory approaches in aquaculture and helped steer the sector towards greater sustainability. However, the approach has had varying degrees of resonance and uptake with different user groups. For example, the aquaculture industry may focus more on production whereas government resource managers focus more at the ecosystem level.

Use of fish in aquafeeds is seen as a major environmental impact of aquaculture. Production of salmon, shrimp and other marine fishes use the largest amounts of wild fish-based feed per unit of farmed fish produced (Froehlich *et al.*, 2018) while species feeding lower in the food chain, such as carp, tilapia and catfish tend to have lower inclusion rates of wild fish in their diets and might be expected to have less impact on wild fish populations (Waite *et al.*, 2014). However, due to the large quantities of fish farmed, the total amount of fish used in the feed for low trophic-level species could still be significant. Extensive farming of bivalve molluscs, such as oysters and clams as well as seaweeds have overall some of the lowest impacts on the environment. Other ingredients in aquafeeds can also adversely impact the environment, such as antibiotics and hormones, and the industry is taking steps to reduce or eliminate harmful ingredients. For example, Norwegian salmon farming has reduced antibiotic use by 90 percent in the last 30 years (FAO, 2021b).

Intensive aquaculture facilities with contained, recirculating systems have the potential to reduce the environmental footprint of aquaculture by using less land and water per unit of fish produced. However, intensification may also come with higher energy costs, increased greenhouse gas production and water pollution (Waite *et al.*, 2014).

Environmental concerns are at the forefront of aquaculture development in Asia, North America and Europe (FAO, 2021a; FAO, 2021b; FAO, 2021e) while they are becoming more important in other areas as well. In Brazil, Colombia and other parts of the LAC region, for example, aquaculture is sometimes considered a threat to globally significant biodiversity (FAO, 2021c). There are a wide range of legislations and policies regulating aquaculture and the environment in North America (FAO, 2021e) and Europe (FAO, 2021b) but also other areas (FAO, 2009; FAO, 2021a; FAO, 2021c; FAO, 2021d; FAO, 2021f). These policies and laws cover a variety of subjects including aquaculture zoning, environmental impact assessment, nutrient loading, water quality and use of non-native species (FAO, 2021d). The African Union has recently developed a framework on environmental management for sustainable aquaculture development in Africa to facilitate implementation of international and regional environmental strategies and guidelines for Africa (FAO, 2021f). In arid regions availability of water and water quality are major environmental impact concerns (FAO, 2021d; FAO, 2021f).

There is a movement to make aquaculture 'land-based' in North America in response to environmental concerns in coastal areas. However, estimates of a three-fold increase in costs for more land and freshwater as well as increased of greenhouse gas emission from land-based systems compared to coastal cage-based systems may constrain the movement (FAO, 2021e). Disease outbreaks and large escapes of non-native Atlantic salmon have contributed to legislation banning ocean rearing of this species in Washington State on the west coast of the United States of America (FAO, 2020e). In Canada, the government mandated the Department of Fisheries and Oceans to "create a responsible plan to transition (away) from open net-pen salmon farming in coastal British Columbia waters by 2025 and begin work to introduce Canada's first-ever Aquaculture Act". The Global Aquaculture Alliance responded that this move would be, "detrimental not only to the region's thriving aquaculture sector but also to the push for responsible aquaculture globally" (FAO, 2021e).

Aquaculture is the primary reason for the deliberate introduction of non-native species beyond their natural range (Bartley, 2006). Aquaculture development in many areas is based on non-native species, for example whiteleg shrimp and tilapia farming in Asia, Atlantic salmon and rainbow trout farming in the southern hemisphere, and Pacific cupped oyster culture in North America and Europe. Environmental impacts from these species must be weighed against their social and economic gains. In Latin America, non-native species dominate production in many areas, and while there have been efforts to diversify with native species, they have not been very successful, despite the number of species potentially available (FAO, 2021c). A global analysis of the number of reported cases of the use of non-native species revealed that overall there have been more cases of negative environmental impacts than positive social and economic impacts (Bartley and Funge-Smith, 2018). However, the magnitude of the impacts was not assessed and countries seem to be willing to accept some negative impacts if they perceive positive economic impacts as well. Sub-Saharan African countries adopted the Nairobi declaration on conservation of aquatic biodiversity and use of genetically improved and alien species for aquaculture in Africa, in principle (FAO, 2008). In 2003, the African Union added political weight to this position by requesting that member states strictly control the intentional and as far as possible, the accidental introduction of species not native to a particular area (FAO, 2021f).

As noted by FAO (2017a), aquaculture has been criticized for creating environmental harm and that concern continues in all regions to differing degrees. What is often not realized is that aquaculture has clear advantages over many other forms of food production, including efficient feed conversion rates, the opportunity to use non-fed aquaculture systems and the integration of aquaculture with other farming systems. Certainly aquaculture, and practically any other form of food production, will have an impact on the environment at some level. Whether that impact is judged as negative will depend on the environment and the priorities of each society. In NENA and other arid areas where water is a scarce resource, impacts on water quality are important (FAO, 2021d), whereas in North America water quality concerns are secondary to the impacts of non-native species (FAO, 2021e) and in parts of Latin America where there are areas with globally significant biodiversity as well as in many developed regions of the world, biodiversity protection is the paramount environmental challenge (FAO, 2021b; FAO, 2021c). This reinforces the call for an ecosystem approach to aquaculture (FAO, 2010) where stakeholders and policy makers come together to help make aquaculture more environmentally and socially sustainable.

7. Markets and trade

Fish and fish products remain one of the most traded food commodities in the world. In 2018, 66 million tonnes equal to 37 percent of total fisheries and aquaculture production were traded internationally (FAO, 2020d). The total 2018 export value for fish and fish products of USD 165 billion represented 11 percent of the export value of agricultural products (excluding forest products) and almost one percent of the value of total merchandise traded (FAO, 2020d).

The level of international trade varies greatly by region. Aquaculture products in NENA are mainly sold in domestic markets (FAO, 2021d) with little international trade. South American countries rely heavily on exports of fish products to generate foreign income (FAO, 2021c). European markets for fish and fish products can only be satisfied by imports and about 25 percent of the supply of fish and fish products came from aquaculture (FAO, 2021b). In sub-Saharan Africa there is limited trade outside of the region (FAO, 2021f). However, it is often difficult to distinguish farmed exports from capture fisheries exports. The United States of America leads the world in the import of fish and fish products, resulting in a 2018 trade deficit of USD 18 billion. By value, nearly 90 percent of the fish eaten in the United States of America comes from abroad, over half of it from aquaculture (FAO, 2021e). Sub-Saharan Africa also imports aquaculture products from outside the region, including mussels from New Zealand, Atlantic salmon from the EU, striped catfish from Viet Nam and shrimp from South East Asia (FAO, 2021f). Ironically, tilapia, a native fish of Africa, is imported frozen from Asia to many countries in the region (FAO, 2021f). Aquaculture products are increasingly entering African regional trade routes for fish and fish products as processed or fresh products. In most cases regional bilateral trade arrangements are facilitating and promoting this trade (FAO, 2021f).

Asia, and primarily China, is the main global exporter of fish and fish products. In several South American economies including Chile and Brazil, the exports of fish and fish products generates hard currency, with trade surpluses reaching USD 15.1 billion in 2018 and growing at an average annual growth rate of 6.8 percent since 2000. Just over 50 percent of the value of fish imports to Latin America relate to fresh, chilled or frozen fish, a category that increased by 664 percent in value and 209 percent in volume from 2000 to 2018 (FAO, 2021c). This equates to an average annual growth rate of 11.8 percent by value and 5.6 percent by volume. The global trade in farmed fish products is expected to increase due to limited additional supplies of fish from the world's capture fisheries. Fish and fish product consumption in China is predicted to exceed domestic production by 2030. In order to address this gap in aquatic foods, China "will probably attempt to increase domestic freshwater and offshore aquaculture, increase aquatic foods imports, possibly expand the distant water fishing industry and invest in aquatic foods production abroad." (Crona *et al.*, 2020).

However, information on the level, flow, commodities and value of trade in farmed fish and fish products was reported by all regions and sub-regions to be incomplete and in need of improvement (FAO, 2021a; FAO, 2021b; FAO, 2021c; FAO, 2021d; FAO, 2021e; FAO, 2021f). Information problems included, *inter alia*, disaggregating farmed from captured fish products, recording small scale production, identifying local and intra-regional trade and accurately valuing products. There are mechanisms to help provide more accurate information such as the European Market Observatory for Fisheries and Aquaculture (EUMOFA, 2021), FAO GLOBEFISH, and social media. New information technology, including social media and cell phones, are increasing the flow and accuracy of information on trade and value of fish and fish products (FAO, 2021f).

There is a general increase in demand for convenience, frozen and pre-packaged foods (FAO, 2016b; FAO, 2021e). However, in some regions, such as NENA, aquaculture products are marketed fresh and unprocessed with no value-addition (FAO, 2021d). Globally, live, fresh and frozen products dominate fish utilization and represented 69 percent of total supplies in 2018, compared with 58 percent of total supply in 2000. The remaining product categories lost ground, from 39 percent of total supply in 2000 to 36 percent in 2018. This was mainly driven by lower volumes allocated to non-food purposes. Volumes of fish reduced to fishmeal and fish oils, mainly used to produce animal feeds, decreased by 29 percent over the period 2000–2018 while total fish production rose by 42 percent over the same period, mainly reflecting lower production of fish meal and fish oil in Latin America (FAO, 2020d; FAO, 2021c).

Ecolabelling and certification have become market tools to promote environmental and social sustainability. However, the benefits of certification are difficult to define. Studies in areas such as North America, have shown that the value of certified products is increasing as certified aquaculture products facilitate market access and may command a higher price, while in Asia, certified products were not as readily accepted as in Europe (FAO, 2018a). Similar global studies would be beneficial (FAO, 2021e). In Europe, the extra price commanded by organic certification has been largely successful in salmon markets, but less so for other products where consumers were unwilling to pay higher prices, such as organically-certified carp. In NENA region, Saudi Arabia was the first country to achieve a global aquaculture certification and Morocco has also started taking steps towards organic aquaculture certification (FAO, 2021d). Although a minor contributor to global trade in farmed fish, countries in sub-Saharan Africa are embarking on certification of a variety of species including tilapia and trout, abalone, giant tiger prawn and red drum, *Sciaenops ocellatus* (FAO, 2020f). Expected benefits include more than just increased prices and markets for aquaculture products but also increased employment. However, constraints to small-scale enterprises in meeting certification standards were also identified (FAO, 2018a).

8. Food security and nutrition

FAO (2006) considers food security to have four dimensions:

- Availability. Food of sufficient quantity and quality to meet nutritional and physiological needs.
- Access. People can access food, generally through purchasing it or having it provided to them, or in some cases through subsistence farming, harvesting, barter, and trade.
- Utilization. People are healthy and knowledgeable enough to utilize it.
- Stability. Food is accessible on a regular or stable basis.

Fish is a nutrient-rich commodity that is usually low in saturated fats, carbohydrates and cholesterol. It is a source of high quality protein and contains a wide range of essential micronutrients, such as vitamins, minerals, and polyunsaturated omega-3 fatty acids (Thilsted *et al.*, 2016). Global fish consumption (capture and culture) has increased at a greater rate than human population and accounts for about 17 percent of total animal protein and 7 percent of all protein consumed (FAO, 2020c). Fish provided about 3.3 billion people with almost 20 percent of their average per capita intake of animal protein. In several developing countries in Asia, Africa and in small island developing states, fish contributed 50 percent or more of total animal protein intake (FAO, 2020c).

However, FAO (2018b) and others (Tacon *et al.*, 2020) have reported that the global food system is not providing food security and good nutrition to many parts of the world. Food systems were designed to maximize profits and not to deliver good nutrition. Highly processed foods with preservatives and sugar are becoming a huge part of the global food chain, but these commodities contribute significantly to the burden of malnutrition, including obesity and diabetes. Willet *et al.* (2019) stated, "Food systems have the potential to nurture human health and support environmental sustainability. However, they are currently threatening both". FAO (2018c) and Willet *et al.* (2019) also stated that "business as usual is not an option".

The complexity of the global aquaculture food system, including production, processing, distribution, marketing and consumption, plus the awareness that a food system should deliver good nutrition, necessitate a holistic approach to the development and management of the aquaculture sector. It has been argued that maintaining diversity of particular systems, such as integrated rice and fish production, confers adaptability of food systems to global change (Freed *et al.*, 2020, Hu *et al.*, 2015) as well as providing two important elements of a nutritious food basket, rice and fish. The international development and scientific communities are beginning to embrace a holistic approach through *inter alia* the Common Vision on Sustainable Food and Agriculture (FAO, 2014b) and the One Health initiative (Stentiford *et al.*, 2020). The 2030 Agenda including the SDGs, the Blue Growth Initiative as well as the Strategic Objectives of FAO (FAO, 2021j) fully encompass this complexity and provide the holistic framework needed to ensure that aquaculture continues to provide food, economic opportunities and high-quality nutrition to an ever-growing human population.

Aquaculture has been recognized as playing an important role in food security, good nutrition and in social development (FAO, 2017c; FAO, 2017f; FAO, 2019d). Fish is seen as a nutritious, available, and affordable commodity (Thilsted *et al.*, 2016). Farmed fish, in particular, can help to stabilize overall supplies of fish and fish products when capture fisheries are unable to meet demand and they can offer safe food less affected by pollution (Tacon, Lemos and Metian, 2020). Tacon, Lemos and Metian (2020) also noted that in many instances, marine capture fisheries provide higher concentrations of key nutrients than those in farmed freshwater fish, and stressed the need to take advantage of the opportunity to improve the nutritional profile of farmed fish through their feed, something that is not possible with fish from capture fisheries.

Overall, consumption of fish and fish products from all sources (aquaculture and fisheries) continues to increase (FAO, 2020c). In 1974, aquaculture provided only 7 percent of fish for human consumption and this proportion has risen to over 50 percent in 2018 (FAO, 2020c). The apparent per capita fish consumption rate varies by area with Oceania consuming the most and South America consuming the least (Table 7). Some areas, including Africa, have shown declines in fish consumption over the last few years. Growth in fish consumption was observed in North America region while it remained level or decreased in some countries in sub-Saharan Africa. According to FAO (2020a), "Low fish consumption in sub-Saharan Africa is the result of a number of interconnected factors, including among others: population increasing at a higher rate than food fish supply; stagnation of fish production because of pressure on capture fisheries resources; and a poorly developed aquaculture sector'.

TABLE 7. Regional fish consumption rates in 2017 (kg per capita per year)

Area	Per capita supply (kg)
Africa	9.9
North America	22.4
Central America	12.4
Caribbean	9.4
South America	9.8
Asia	24.1
Europe	21.5
Oceania	25.0
Least Developed Countries	12.6
Low Income Food Deficit Countries	9.3
World	**20.3**

Source: FAO. 2020c

However, regional and national statistics often obscure local differences in fish consumption. For example, annual per capita figures for South America range from less than 3 kg to over 30 kg (FAO, 2020c) and Brazil's national average of around 9 kg is much lower than the consumption rate of nearly 170 kg per capita per year reported for communities along the Brazilian Amazon, although this is unlikely to be from aquaculture (Begossia *et al.*, 2018). Some Asian countries have among the highest per capita fish consumption values in the world. For example, the Maldives ranked as the highest at 166 kg followed by Iceland and China, Hong Kong SAR (FAO, 2021a).

Any analysis of the contribution that aquaculture makes to fish consumption is complicated by the failure to disaggregate captured fish from aquaculture-produced fish and fish products. For example, while only two percent of Africa's total fish supply comes from aquaculture, it could make a much larger contribution if suitable land and water were devoted to aquaculture (FAO, 2021f). However, the regional reviews revealed that data to accurately assess the contribution of aquaculture to food security are incomplete. Efforts have been made to disaggregate the sources of fish availability, towards consumption, for example, through household surveys and in-depth examination of national statistics and trade data (Funge-Smith and Bennett, 2019). In the European Union, Member States must submit data on aquaculture under the Data Collection Framework which requires recording information on a number of variables (European Union, 2010). However, its data structure does not include any category for nutrition or for food security components of aquaculture products (FAO, 2020b).

There are a number of factors influencing the decisions consumers make to purchase aquatic foods, including price, date of production and best-before calendars, organic production, food miles, sustainability, local or geographic indication, perceptions on animal welfare and whether the product is farmed or captured (FAO, 2021b). Looking only at the farmed versus captured criterion, in Europe, 'wild fish' was significantly preferred by purchasers, but with different values by age, and with younger people preferring farmed product (FAO, 2021b). Public perception of aquaculture in general also plays a role. In developing countries, aquaculture is viewed more favourably than in developed countries (Froehlich *et al.*, 2017). In many Latin American countries, aquaculture has a negative image (FAO, 2021c). In the United States of America and New Zealand, marine and offshore aquaculture was perceived to be less desirable than inland aquaculture or capture fisheries (Froehlich *et al.,* 2017).

FAO (2017b) highlighted the problem of aquaculture meeting the needs of nutritionally vulnerable nations and food systems while analyses have only recently started to focus on the nutritional content of aquaculture products (Stentiford, *et al.*, 2020). Aquaculture has traditionally produced larger fish with high quality fillets while discarding nutrient-rich bones (calcium), liver and eyes (vitamin A) and the carcass (zinc). An alternative to marketing larger fish for fillets is to market smaller fish that can be consumed whole. Many wild-caught, small, indigenous species are consumed whole and thus provide higher nutrient levels to diets (Mitra *et al.*, 2013, Halwart, 2013). Although more research is needed on farming small indigenous species, Beveridge *et al.* (2013) stated, “There are many good economic and environmental reasons to produce smaller-sized, herbivorous and omnivorous fishes or fish products for poorer consumers”. Producing smaller fish, more quickly, more cheaply and with better availability for the poor could contribute significantly to the SDGs.

9. Governance and management

Governance is a complex term that includes planning, managing, regulating and governing aquaculture and associated stakeholders (FAO, 2017d; FAO, 2017e). Good governance includes accountability, effectiveness and efficiency of governments, equity and predictability of the rule of law (Hishamunda, Ridler and Martone, 2014).

While each region is striving towards good governance in the aquaculture sector there are specific challenges and opportunities. To strengthen governance in the Asia-Pacific region, FAO and NACA stated, "administrative, legislative and regulatory frameworks for aquaculture development have been established in major aquaculture producing countries in the region, with relevant policies, laws, regulations and standards being formed and institutional mechanisms developed for implementation and enforcement" (FAO, 2021a). In Europe, the Common Fisheries Policy of the European Union (OJ L, 2013) is the main regulatory framework for aquaculture (FAO, 2020b). The African Union established the African Union Aquaculture Action Plan for Africa 2016–2025 (AU-IBAR, 2016) and the Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa (FAO, 2021f). In the LAC region in general, aquaculture has a low political and institutional profile resulting in a lack of strong policies and limited allocation of funds to the sector, although exceptions exist, including Mexico and Chile (FAO, 2021c). Regulations on aquaculture are well established in many parts of Asia-Pacific region (FAO, 2021a), North America (FAO, 2021e) and Europe (FAO, 2021b) but slowly being developed in NENA region (FAO, 2021d), LAC region (FAO, 2021c) and sub-Saharan Africa (FAO, 2021f).

In Europe, the allocation of licences to operate is the main challenge to the growth of the sector as it falls within geographic conditions where there is intense competition for space. This was confirmed by an international workshop on aquaculture in the Mediterranean and Black Sea that concluded the major constraints to the industry were related to administrative issues and a lack of knowledge about the sector by administrators (FAO, 2017e). Extensive delays for the approval of farm licences are well known and without authoritative national aquaculture plans, application of a precautionary principle retards the permit agreement process (FAO, 2021b). Guidance documents were developed on how the European Union Water Framework Directive and the Marine Strategy Framework Directive link to aquaculture and large sums of money were set aside for the development of European Union aquaculture, principally for investments in modernisation, providing environmental services, improving the environmental footprint and productivity. However, very little of this money was utilized due to complex application processes and national regulations which can be overly restrictive (V. Chomo, personal communication). For many European aquaculture operators, regional or local administrators and researchers, local policies are preferred to broad European-level policies. Thus, the European Aquaculture Technology and Innovation Platform (EATiP) promoted the concept of Mirror Platforms which follow the recommendations developed by EATiP at local, regional or national levels (FAO, 2021b). Fish farming associations have been shown to be an effective mechanism for the aquaculture sector to interact with the government and take advantage of group buying and influence (FAO, 2021a; FAO, 2021b). However, farmer associations are notably weak in NENA region (FAO, 2021d).

Transboundary governance mechanisms have been established in most regions, such as the Volta Basin Authority, the Indian Ocean Commission, the East African Community, the Regional Organization for the Protection of the Marine Environment (Sea of Oman) and the Great Lakes Fisheries Commission. Fisheries and aquaculture specific mechanisms also exist

(FAO, 2021i), including the Benguela Current Large Marine Ecosystem, the Lake Victoria Fisheries Organization, the East African Community Fisheries and Aquaculture Policy (FAO, 2021f), the General Fisheries Commission of the Mediterranean, the Regional Commission for Fisheries (FAO, 2021d), the European Inland Fisheries and Aquaculture Advisory Commission (FAO, 2021b) as well as the Central Asian and Caucasus Regional Fisheries and Aquaculture Commission, and the Network of Aquaculture Centres in Asia-Pacific .

International mechanisms and instruments exist that lay out a framework for good governance and management, including the Code of Conduct for Responsible Fisheries (FAO, 1995) and the Convention on Biological Diversity (UN, 1992). National policies supporting good governance also exist in many, but not all areas (FAO, 2019d). However, even where policies exist, their implementation and enforcement are often lacking (FAO, 2021d).

10. External pressures and resilience

The global economy and the aquaculture sector must respond to a variety of external factors. Four main categories of external pressures were identified by the regional reviews (FAO, 2021d; FAO, 2021e) and were associated with the environment, society, politics and the economy. Although FAO (2017a) noted that global aquaculture faced several major natural, technological, and complex disasters in the previous decade, the current series of reviews cited climate change as one of the primary external pressures on the sector and the COVID-19 pandemic has now been identified as a more immediate pressure.

In early 2020, the COVID-19 pandemic began to severely impact nearly every region of the world. Besides the tragic loss of life of over 4 million people as of 9 July, 2021, work places closed, supply chains collapsed and governments were inconsistent in their response to the pandemic (OECD, 2020). Although the long-term impacts on the aquaculture industry are unknown, short-term impacts are already visible. China, the world's largest aquaculture producer, saw markets collapse and production decrease (FAO, 2021a) while sub-Saharan Africa is experiencing its first recession in 25 years (FAO, 2021f). Countries that rely on export markets, including Chile, Brazil and Norway, witnessed reduced demand and faced difficulty selling their aquaculture products (FAO, 2021b; FAO, 2021c) while imports of feed and seed also were disrupted (FAO, 2021c). Misinformation on alleged contamination of fish and shrimp with COVID-19 in China markets has also had a negative impact on demand for imports. While aquaculture industries have improved measures and traceability to deal with this issue (Bondad-Reantaso *et al.*, 2020), the problem still remains.

Most aquaculture systems rely on the ambient environment thus making the sector vulnerable to the impacts of climate change (Reid *et al.*, 2019). Recent reports from the United Nations indicate that current efforts to slow climate change are insufficient so we can expect impacts on aquaculture to continue (United Nations Environment Programme, 2020). For inland aquaculture there are at least two pressing climate change related threats; increasing water temperatures and decreasing water availability, while marine and coastal aquaculture will need to address ocean acidification and sea level rise as well as warmer water temperatures (Barange *et al.*, 2018). In addition, the adaptation measures taken by other sectors, such as increased energy generation and irrigation, will further impact aquaculture (Barange *et al.*, 2018; FAO, 2021c).

In NENA region the warmer temperatures will impact pond-based aquaculture and cage aquaculture through increased disease, red tides and invasive species (FAO, 2021d). However, warmer temperatures could extend the growing season for many species in NENA and elsewhere thus allowing for more production.

Different regions of the world will have different capacities to adapt and mitigate the impacts of climate change. Tropical ecosystems and poorer communities are thought to be most at risk and these are the areas where aquaculture development is expanding or expected to expand in the future (Barange *et al.*, 2018). Greater capacity for adaptation, including the diversification of livelihoods, as well as adoption of more effective management measures that contribute to the sustainability of aquaculture activities will help to increase resilience of the sector (FAO, 2021c). Unfortunately, in many areas, "the degree of inclusion of climate change adaptation plans was very minimal. This is due to a number of reasons including, lack of capacity among national fisheries authorities, lack of scientific information which authorities can use as evidence for policy formulation and institutional barriers because climate change issues at both national and international levels tend to be championed by the ministries responsible for environment." (FAO, 2021f).

However, there are other significant pressure that will impact the sector. Political instability is currently impacting aquaculture development in NENA region (FAO, 2021d) and economic pressures, such as fluctuations in global markets as well as those economic impacts from climate change and the pandemic (FAO, 2021c) are prevalent globally.

Although planning and preparing for external impacts is preferable to trying to recover from a disaster, FAO (2017d) and the current reviews noted that disaster preparedness was inadequate in all regions (FAO, 2021a; FAO, 2021b; FAO, 2021c; FAO, 2021e, FAO, 2021f).

Better management practices and diversification of aquaculture growing methods and the species farmed has been suggested as a means to address external pressures and increase resilience (FAO, 2021b; FAO, 2021c; FAO, 2021e), and further promote agro-ecological methods in aquaculture (Halwart, Dabbadie and Beveridge, 2019). In North America, the aquaculture industry is moving towards more diversification and production innovation as an adaptation response to changing environmental conditions, including climate change (FAO, 2021e). However, diversification may not be easily achieved by small scale aquaculturists or in areas where aquaculture is developing slowly (FAO, 2021c; FAO, 2021d; FAO, 2021e; FAO, 2021f). A science-based approach is one consideration that strives to address external pressures with evidence and the best available information (FAO, 2021e). Where information is not available, this approach would establish scientifically justifiable means to acquire the evidence. In this way, misinformation, panic and inappropriate government or public responses can be avoided.

11. Contribution of aquaculture to the FAO strategic objectives, the Sustainable Development Goals, and the Blue Growth Initiative

The aquaculture sector, through its production of high quality and nutritious fish products, the creation of employment, the contribution to local and regional trade, its efficient use of natural resources and the opportunities it provides to women and youth has, and will continue to have, a significant role in meeting international goals on sustainable development established by the member nations of the United Nations and FAO. The UN predicts that the global population will reach 8.5 billion in 2030 (UN, 2015a). FAO (2020a) estimates that global fish consumption in 2030 will be 28 million tonnes or 18 percent higher than in 2018. Since production from capture fisheries has plateaued (FAO, 2020b) most of the increase in aquatic foods will need to come from aquaculture. The international community is tasked with assisting governments and industry provide food for this growing population in a sustainable and responsible manner.

In 2015, 193 Member States of the UN adopted the 2030 Agenda for Sustainable Development and the accompanying Sustainable Development Goals (SDGs) (UN, 2015b). There are 17 SDGs that provide targets and indicators for sustainable development with regard to *inter alia* resource use, poverty alleviation, energy, climate change, gender equity, nutrition, and economic and social development (UN, 2021). The SDGs have become a cornerstone for international development.

Sustainable aquaculture will directly contribute to the following SDGs:

- SDG 1. End poverty through the creation of viable employment.
- SDG 2. Zero hunger by providing nutritious fish.
- SDG 3. Good health and well-being from eating more fish.
- SDG 5. Gender equity by empowering women in the workforce.
- SDG 8. Growth, employment through providing jobs, also in areas where few other opportunities exist.
- SDG 12. Production and consumption through sustainable production systems.
- SDG 13. Reduced impacts of climate change through efficient use of resources.
- SDG 14. Conservation and use of marine resources and ecosystems.
- SDG 15. Life on land through an EAA and efficient use of water and other resources.

Indirectly, sustainable aquaculture development will contribute to many other SDGs:

- SDG 4. Quality education when families and women are empowered through employment.
- SDG 6. Clean water when recirculating aquaculture systems and pollution controls are implemented.
- SDG 9. Industry innovation and infrastructure when aquaculture zoning and development enriches an area.
- SDG 10. Reduced inequalities when aquaculture is developed in areas previously marginalized or with few other options for development.
- SDG 11. Sustainable cities when peri-urban aquaculture brings fish products closer to the consumer.

- SDG 17. Partnerships when investors, governments and donors realize the potential for responsible aquaculture.

Clearly aquaculture will have an important role to play in achieving the SDGs. However, to reach its full potential the sector will need to adapt policy frameworks so that they are holistic, especially with regard to nutrition-sensitive appropriateness and social and ethical acceptance. The current narrow focus on producing quantity or generating profits is not sufficient and needs to be expanded to meet local needs for food security, decent work and employment, improved nutrition and gender equity (FAO, 2017f; FAO, 2019d). The sector will also need to increase efforts to better integrate with capture fisheries and other food producing sectors (FAO, 2014b; FAO, 2017f).

In addition, FAO has recently refined its strategic objectives to align with the SDGs (FAO, 2021j) and is now developing a new priority programme area, called Blue Transformation (FAO, 2021k), based on the experiences of the Blue Growth Initiative (BGI) (FAO, 2015c). FAO (2015c) defined Blue Growth as "sustainable growth and development emanating from economic activities using living renewable resources of the oceans, wetlands and coastal zones that minimize environmental degradation, biodiversity loss and unsustainable use of aquatic resources, and maximize economic and social benefits". The BGI is a flagship initiative to support more productive, responsible and sustainable fisheries and aquaculture sectors by improving the governance and management of the aquatic ecosystems, conserving biodiversity and habitats, and empowering communities. The Asia-Pacific Blue Growth Initiative (FAO, 2021k) is a programmatic system of efforts and actions. Its main objective is "the conservation and sustainable contribution of biological resources and environmental services of marine, coastal and continental ecosystems to food and nutritional security and to the alleviation of poverty and global economic growth". Regional initiatives incorporating blue growth are underway such as the high-level meeting on the Blue Growth Initiative for Latin America and the Caribbean, where agreements were generated aimed at increasing the contribution of fisheries and aquaculture to food and nutrition security, poverty alleviation and sustainable use of fisheries and aquaculture resources through South-South Cooperation (FAO, 2021c).

The FAO concept of Blue Growth (FAO, 2017g) is similar in many respects to that of the World Bank's Blue Economy (Patil *et al.*, 2018), a concept that came out of Rio +20 (UN, 2012), in that both are built on the environmental, economic, and social growth pillars of sustainable development. From 2019, the Africa Union began developing Africa's Blue Economy Strategy which will include fisheries, aquaculture, conservation and sustainable aquatic ecosystems. This concept also seeks to promote inclusive economic growth and the preservation or improvement of livelihoods while at the same time ensuring environmental sustainability of the inland waters, oceans and coastal areas. The African Union has also designated 2015-2025 as 'The Decade of African Seas and Oceans'. Observance of these occasions puts Africa's Blue Economy in the spotlight (FAO, 2021f). In 2012, the European Commission (EC) prepared a Communication on Blue Growth opportunities for marine and maritime sustainable growth (FAO, 2021b). The focus areas the EC identified for action were blue energy, aquaculture, maritime, coastal and cruise tourism, marine mineral resources and blue biotechnology.

Progress on the EC Blue Growth Strategy in 2017 was encouraging; while European Union aquaculture had remained relatively constant, its value had increased by 40 percent and virtually all was consumed within the region (FAO, 2021b) giving added value to consumers concerned about fresh, healthy and sustainable choices. While Norway has a global market for Atlantic salmon, it is not a member of the European Union. Actions for marine aquaculture were part of a special strategy in 2017 for the Blue Economy in the western Mediterranean with the goal of sustainable consumption and production through diversification, capacity building and the development of common standards (FAO, 2021b).

The paradigm shift called for by FAO (2017d) from, "aquaculture for development" to "aquaculture for sustainable development" is happening and there is further guidance on this transformation (FAO, 2018c, FAO, 2021k). Blue Growth, One Health, the 2030 Agenda including the SDGs and the Common Vision for Sustainable Food and Agriculture promote sustainability, build on the FAO Code of Conduct for Responsible Fisheries and provide a more holistic framework for the aquaculture sector that the regions are attempting to follow.

12. Conclusions

Aquaculture has an important role to play by providing safe, stable and nutritious sources of food to an ever-growing human population. However, the challenge will be to do so in an environmentally and socially sustainable manner.

The diversity of the aquaculture sector, that is, the diversity of species farmed, from non-fed shellfish and seaweeds to highly domesticated fishes such as Atlantic salmon and Nile tilapia, diversity of environments from temperate seas to tropical rice fields and the diversity of farming systems from extensive ponds to highly intensive recirculating systems has helped create the world's fastest-growing food producing sector.

Additional factors contributing to growth are the ability to satisfy market and consumer demands, improved governance, entrepreneurship and employment opportunities, technology improvements and increased social and cultural capital.

However, regions of the world are also diverse, as are the countries within each region. China is the leading aquaculture producer, but there are other countries within Asia where aquaculture is only starting to be developed. In rural areas, aquaculture can provide job opportunities where few other options exist. Aquaculture can also be implemented to empower women in the work force. Each country within a region will have specific objectives, opportunities and challenges in developing and managing aquaculture. Therefore, regional approaches should be made with caution; what works for one country may not work for others. Nevertheless, there should be an emphasis on regional cooperation and harmonization of policies where appropriate.

Aquaculture has made great strides addressing sustainability issues and each country has different priorities regarding sustainability. Food security may be a priority over conservation in food insecure areas, whereas an economically viable aquaculture industry would be considered sustainable in economic terms. Recirculating systems and aquaponics may be prioritized in water scarce areas where sustainability would imply access to water. Globally, aquaculture has been an efficient user of forage fish in aquafeeds. About the same amount of forage fish has been used in aquafeeds (around 5 million tonnes) for decades whilst aquaculture production has increased dramatically. Replacements for fish in aquafeed are already being used and more research is underway. However, this replacement effort should not unduly impact the use of forage fish and that industry. Thus, sustainability in the case of aquafeeds would include the sustainability of the forage fishing as well as the aquaculture industry.

Innovation in farming systems, disease diagnosis and treatment, genetic improvement and in the use of digital technology has further increased the sustainability of aquaculture. However, there are small-scale enterprises within each region that may not be able to utilize new technologies. There are many traditional technologies that are working well, but are not being fully utilized, such as selective breeding. Technology transfer and capacity building will be required for both innovative and traditional technologies.

Ecolabelling and certification schemes are market tools to promote environmental, economic and social sustainability as well as animal welfare. However, the efficacy of these schemes has been uneven. In certain areas and for certain species, consumers are willing to pay extra for certified products, whereas in other areas this is not the case. More analysis is needed to understand whether such schemes are working to promote sustainability and whether small-scale enterprises can access the schemes.

Trade in fish and fish products from aquaculture is contributing greatly to the economic sustainability of the sector, both at international and local levels. However, trade statistics often do not disaggregate fished from farmed commodities so aquaculture's contribution to the trade in fish and fish products is often unclear and poorly documented. Here too, countries will have different priorities for trade with major producing countries generally concentrating on export markets. Opportunities exist for improvements in aquaculture value chains through increased national and international attention to governance, working conditions, food safety and product quality.

Aquaculture production and the resulting trade in fish and fish products are subject to serious threats from outside the sector and the most obvious current threat is the COVID-19 pandemic. This pandemic and the impacts of climate change were the most cited external factors in the regional reviews. Countries will have different capacities to deal with these impacts depending on their exposure to impacts and their reliance on aquaculture. However, countries are lacking in disaster preparedness, especially in the face of global impacts, and therefore must take action.

With the establishment of the SDGs, the international community is adopting a holistic approach to food production (Stentiford *et al*., 2020). The aquaculture sector needs to do the same and embrace new paradigms for evaluating the sector that goes beyond tonnes and dollars of product (FAO, 2017f). Aquaculture can contribute to sustainable food systems by ensuring a nutritious product that benefits local communities. Governance structures need to embrace this new paradigm and incorporate aquaculture into national policies to ensure that the sector is developed with adequate resources and safeguards for local communities.

13. References

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Annex 1. FAO statistical data

Data used in this global aquaculture overview, as well as in the regional aquaculture reviews, derive mainly from the different FAO fisheries and aquaculture statistics, accessible through different tools, including the FAO Yearbook of Fishery and Aquaculture Statistics, online query panels and FishStatJ[2] (FAO, 2020a; FAO, 2020b; FAO, 2020c). These tools provide free access to fisheries and aquaculture data, including production, trade, consumption and employment for over 245 countries and territories from 1950 to the most recent year available. FAO represents the only global source of fisheries and aquaculture statistics, which are mainly compiled from data submitted by member countries. Statistics received are validated by FAO through adequate quality controls and, in the absence of official reporting, FAO estimates the missing data based on information obtained from alternative sources or standard estimation methods. Estimates also involve disaggregating some of the data received by FAO in aggregated form by species and, in the case of production, also by culture environment.

FAO highlights that data received from countries show different levels of quality in terms of coverage of species, environment and overall national reporting. Inconsistencies may occur in data reported or data are not reported at all. For example, in the case of aquaculture production, FAO has noted that not all the countries have adequate and effective data collection systems set in place. Many countries still do not have a systematically established framework aligned with internationally and regionally accepted standards for data collection from fish farms. In addition, in several countries, the staff responsible for reporting aquaculture production lack the relevant knowledge, support or relevant mechanisms such as specifically designed databases to develop accurate production estimates and improve monitoring and control of the industry. Production data are often estimated through extrapolation by multiplying the area under fish culture by an estimate of average productivity, with adjustments according to advice from key contacts in the industry. Improvements to this problem could, for example, be found by resolving issues related to the fish farm licensing process and devising a system for direct reporting of production, coupled with validation through sample survey by trained enumerators.

Problems occur as well for other typologies of aquaculture statistics. Only a very limited number of countries have a breakdown for farmed vs wild species in their trade statistics and, in addition, many farmed species are often reported in an aggregated form under miscellaneous entries as other fish. The lack of accurate trade data on farmed fish and fish products implies the impossibility to calculate separate consumption statistics on farmed species, with no clear assessment of the nutritional role of farmed species in the countries. In addition, not all the countries have a good collection of employment data in the primary and secondary aquaculture sectors, including insufficient detail on the role of women in the sector, which is captured mainly by ensuring employment data is sex-disaggregated and that all types (part time, full time, occasional time use) are all collected and reported . These data are essential to better assess dependency on the sector and other relevant indicators.

Due to the key role that accurate and timely data play in the management and policy formulation for sustainable aquaculture development, FAO remarks the urgent need for national capacity development in aquaculture statistics systems at several levels, including:

- the legal status, institutionalization and resource allocation;
- development of national statistical standards in line with international standards;

[2] http://www.fao.org/fishery/statistics/en

- adequate and stable staffing plus an effective mechanism for data collection, compilation, storage, dissemination and reporting; (FAO, 2020d)
- improvement in the coverage of farmed species in trade statistics, with the clear separation of farmed vs wild species; and,
- improvement in the coverage and accuracy of employment data, disaggregated by sex, occupational status and age.

In continuing the global efforts to achieve aquaculture sustainability through dissemination of up-to-date information on the status and trends of the sector, FAO publishes Aquaculture Regional Reviews and a Global Synthesis about every 5 years, starting in 1997. This review paper summarizes the status and trends of aquaculture development at the global level.

Relevant aspects of the social and economic background of the region are followed by a description of current and evolving aquaculture practices and the needs of the industry in terms of resources, services and technologies. Impacts of aquaculture practices on the environment are discussed, followed by a consideration of the response by the industry to market demands and opportunities, and its contribution to social and economic development at regional, national and international levels. External pressures on the sector are described, including climate change and economic events, along with associated changes in governance.

The review concludes with an analysis of the contributions of aquaculture to the Sustainable Development Goals, the FAO Strategic Objectives, and the FAO Blue Growth Initiative. Throughout the review, outstanding issues and success stories are identified, and a way forward is suggested for each main topic.