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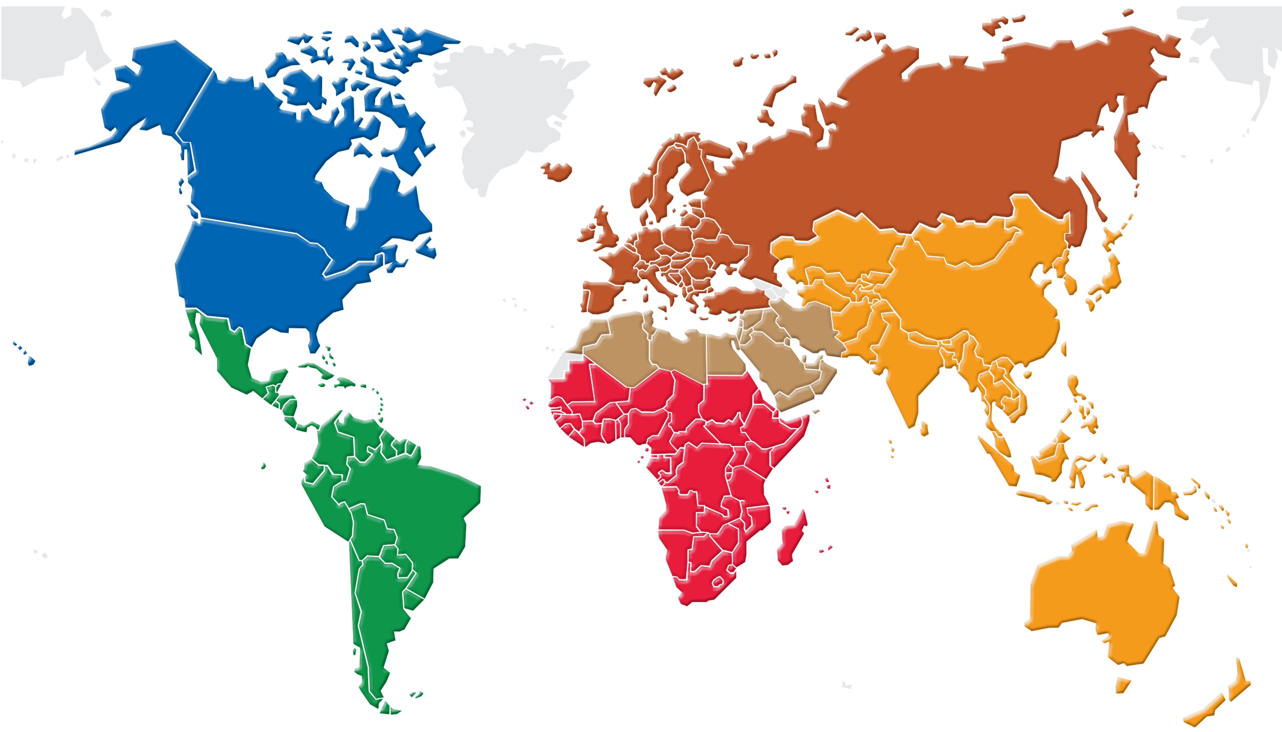
WORLD AQUACULTURE 2015: A BRIEF OVERVIEW



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WORLD AQUACULTURE 2015: A BRIEF OVERVIEW

by
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PREPARATION OF THIS DOCUMENT

The FAO Fisheries and Aquaculture Department is pleased to present *World aquaculture 2015: a brief overview.*

Continuing the FAO's traditional aquaculture regional and global review process, six regional reviews on aquaculture were compiled in 2016 and were published in 2017 (FAO, 2017a, 2017b, 2017c, 2017d, 2017e, 2017f). This document, *World aquaculture 2015: A Brief Overview*, attempts to synthesize the information presented in the six regional reviews into a global review, with the view to examine how the aquaculture sector has grown and performed over the past five years and what lessons could be learnt from the past to ensure sustainable growth and expansion of the sector in the coming years. The aquaculture production data used in this review are the latest 2015 data from the FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

This is the third review in the series, the first and second having been published in 2006 (FAO, 2006) and in 2011 (FAO, 2011). This volume has been titled as a brief overview, considering that most information provided in the last two reviews are still valid. This volume updates the global status and trends in aquaculture development over the past five years, provides some insights on prospects and forecasts of global aquaculture development.

FAO. 2017.
World aquaculture 2015: a brief overview, by Rohana Subasinghe. FAO Fisheries and Aquaculture Circular No. 1140. Rome.

ABSTRACT

Global aquaculture production in 2015 has been recorded as 106 million tonnes, with an estimated value of US$163 billion. The production comprised of farmed aquatic animals, aquatic plants and non-food products (pearls and shells). The average annual percentage growth rate of world aquatic animal production slowed down to 6.4 percent in the period 2001–2015. However, African aquaculture recorded 10.4 percent during the same period, albeit from a comparatively low baseline. By production volume, aquatic animals have been dominated by finfish farming (63–68 percent in the last two decades). Aquatic plants contributed 27.7 percent to the global aquaculture production in 2015. Fish produced by this rapidly growing sector are high-protein, containing essential micronutrients sometimes essential fatty acids, which cannot easily be substituted by other food commodities. The 76.6 million tonnes of aquatic animals produced in 2015 contributed 45 percent to the total global aquatic animal production and little over 53 percent to the total global fish consumption in the same year. Per capita food fish consumption is estimated as 20.3 kg in 2015, compared to 19.7 kg in 2013. An estimated 18.7 million people were employed in global aquaculture in 2015.

The United Nations predicts that the global population will reach 8.5 billion in 2030. This will inevitably increase the pressure on food sectors to maximize production and reduce losses and waste. Production increase must occur in a sustainable way and in a context where key resources, such as land and water, are likely to be scarcer and where climatic change impact will intensify. Aquaculture is no exception. Achieving the long-term goal of economic, social and environmental sustainability of the aquaculture sector, to ensure its continued contribution of nutritious food to keep the world healthy, will depend primarily on continued commitments by governments to provide and support a good governance framework for the sector. As the sector further expands, intensifies and diversifies, it should recognize the relevant environmental and social concerns and make conscious efforts to address them in a transparent manner, backed with scientific evidence. This document provides an overview of global aquaculture status and development trends as a synthesis of such status and trends in six regions of the world: Asia-Pacific, Europe, Latin America and the Caribbean, Near East and North Africa, North America and Sub-Saharan Africa.

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Zhou Xiaowei is acknowledged for his efforts in the timely update of FishStatJ aquaculture production database. Aquaculture production data has been extracted and presented as tables and figures by Lei Chen, and her inputs are also appreciatively acknowledged.

Several staff of the Aquaculture Branch of the FAO Fisheries and Aquaculture Department, namely; Lionel Dabbadie, José Aguilar-Manjarrez, Uwe Barg, Junning Cai and Pongthanapanich; led by Malcolm Beveridge, the acting Branch Head, reviewed the document and provided guidance for improving the drafts. The author is thankful for their invaluable contributions.

The document was edited, proof read and formatted in line with FAO house style by Danielle Rizcallah who also prepared the final layout.

ABBREVIATIONS AND ACRONYMS

AHPND	Acute Hepato-pancreatic Necrosis Disease
ALA	α-Linolenic acid
AMR	Antimicrobial Resistance
APR	annual percentage growth rate
ASEAN	Association of Southeast Asian Nations
BGI	Blue Growth Initiatives
BMP	Better management practices
CBD	Convention on biological diversity
CCRF	Code of Conduct for Responsible Fisheries
CFP	Common Fisheries Policy
COP	Code of practices
CWS	closed water systems
DHA	docosahexaenoic acid
DNA	DeoxyriboNucleic Acid
EAA	Ecosystems approach to aquaculture
EAF	Ecosystem Approach to Fisheries
EHP	*Enterocytozoon hepatopenaei*
EIA	environmental Impact assessment
EU	European Union
EUS	ulcerative syndrome
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed conversion ratio
FDA	United States Food and Drug Administration
GE	genetically engineered
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GPS	global positioning systems
HABs	harmful algal blooms
IAS	invasive alien species
ICN	International Conference on Nutrition
ICT	Information and communication technology
IEE	Initial Environment Examination
IHNv	Infectious hematopoietic necrosis virus
IMTA	integrated multitrophic aquaculture
ISA	Infectious salmon anaemia
LAC	Latin America and the Caribbean
LC-PUFA	long-chain, poly-unsaturated fatty acids
LIFDCs	low-income food-deficit countries
MrNV	Macrobrachium rosenbergii noda virus
MT	methyltestosterone
NENA	North East and North Africa
NGO	non-governmental organization
NVN	nutritionally vulnerable nations
PCR	polymerase chain reaction
R&D	Research and development
RAS	recirculating aquaculture systems

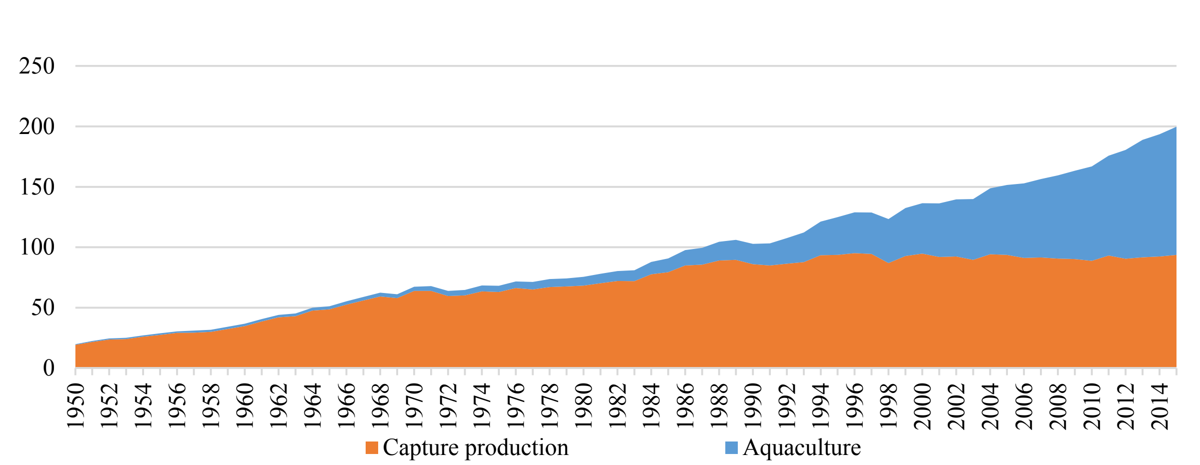
RWS	recirculated water systems
SDGs	sustainable development goals
SPF	Specific Pathogen Free
SPR	Specific Pathogen Resistant
SPS	Sanitary and Phytosanitary Measures
SRS	salmonid rickettsial septicaemia
SSA	sub-Saharan Africa
TiLV	tilapia lake virus
UN	United Nations
WHO	World Health Organization
WTO	World Trade Organization
WSSV	White spot syndrome virus

BACKGROUND AND OBJECTIVES

Realizing the challenge of feeding over 9 billion people in 2050, United Nations (UN) Member States adopted the 2030 Agenda for Sustainable Development, which offers a set of Sustainable Development Goals which include targets that can be aimed for by enhancing the contribution and conduct of fisheries and aquaculture towards food security and nutrition, especially in the use of natural resources. This unprecedented commitment was made in 2015, immediately after a milestone was reached in 2014 when the aquaculture sector's contribution to the supply of fish for human consumption overtook that of wild-caught fish for the first time. Aquaculture is still the fastest growing food producing sector in the world and it is expected to bridge the future global supply-demand gap for aquatic food. However, the challenge is to ensure that meeting this growing demand for fish as food will be met in conformity with the 2030 Agenda.

Since capture fishery production became relatively static in the late 1980s, aquaculture has been responsible for the growth in the supply of fish for human consumption (Figure 1). Aquaculture provided only 7 percent of fish for human consumption in 1974. This share increased to 26 percent in 1994, 39 percent in 2004, and 53 percent in 2015.[1]

Figure 1. World capture fisheries and aquaculture production (including plants) – million tonnes



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Growth in the global supply of fish for human consumption has outpaced population growth in the past five decades, increasing at an average annual rate of 3.2 percent in the period 1961 – 2013, double that of population growth, resulting in increasing average per capita availability. World per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 14.4 kg in the 1990s and 19.7 kg in 2013, with preliminary estimates for 2015 pointing towards further growth beyond 20 kg (FAO, 2016a).

Although annual per capita consumption of fish has grown steadily in developing regions, in low-income food-deficit countries (LIFDCs)[2] the growth has been low (from 3.5 to 7.6 kg). People in industrialized countries consume more fish (26.8 kg per capita in 2013). World Bank (2013) predicted that despite the expected growth in fish consumption in Asia and Latin America, fish consumption in the Africa region might decrease significantly over the coming two decades. In an era where the contribution of fish to global food and nutrition security has been fully recognized, such a prediction is alarming and warrants attention.

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[1] All statistical data on aquaculture production and value presented in this review originate from 1950-2015 (FishstatJ). In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 2017. www.fao.org/fishery/statistics/software/fishstatj/en

[2] Low-Income Food-Deficit Countries (LIFDC) – List for 2016. [online] Rome. [Cited 7 June 2017]. www.fao.org/countryprofiles/lifdc/en/

Sectoral reviews and trends analyses are important to ensure correct decisions are made in support of sustainable development of a sector. Aquaculture is an important global food producing sector. Its performance is not evenly manifested among all regions, thus requiring a regional approach to sectoral reviews and trends analysis. Over the years, FAO has been in the forefront of regional and global sector reviews and trends analysis in aquaculture. The 2000 Bangkok Millennium Conference (NACA/FAO, 2000) reflected on the 25 years of aquaculture development globally and its likely role in past and future development. The Global Conference on Aquaculture 2010 reviewed the status and trends in aquaculture development and evaluated the progress made in the implementation of the Bangkok Declaration (FAO/NACA, 2012), which was agreed at the millennium conference in 2000.

In 2005 and 2010, FAO prepared two series of six regional reviews and published in 2006[3] and 2011.[4] They were synthesized into two flagship publications; *State of World Aquaculture 2006* (FAO, 2006) and the *World Aquaculture 2010* (FAO, 2011), providing a closer look at the state of global aquaculture, with a prospective view to the sustainable growth of the sector. In 2016 similar regional reviews were carried out in six regions and were published in 2017 (FAO, 2017a, 2017b, 2017c, 2017d, 2017e, 2017f). The present document – *World Aquaculture 2015: A brief overview* – also attempts to synthesize the six regional reviews, with the view to examine how the sector has grown and performed over the past five years and what lessons might be learnt to ensure sustainable growth and expansion of the sector in the coming years. Considering the amount of information and data provided in the previous two reviews (FAO, 2006 and FAO, 2011) and their continued validity, this 2015 overview has been made a "brief", simply to avoid repetition.

FARMING SYSTEMS AND PRACTICES

Compared to agriculture and livestock sectors, except for a few countries, aquaculture could still be considered a young food producing sector. However, this young sector has grown rapidly over the past 40 years witnessing an impressive production increase of 4.7 million tonnes of aquatic animals[5] in 1980 to 76.6 million tonnes in 2015. The average annual percentage growth rate (APR) of global aquaculture, including plants, during 2014–2015 was 4.5 percent. This global sectoral growth has only been possible due to the continued high levels of production from China. The average annual percent rate of growth of aquaculture, including plants, during 2014–2015 for China was 3.8 percent.

Species

Unlike the livestock sector, aquaculture farms around 580 species and/or species groups, including 362 finfishes (including hybrids), 104 molluscs, 62 crustaceans, 6 frogs and reptiles, 9 aquatic invertebrates, and 37 aquatic plants (FAO, 2016a). Inland finfish culture in earthen ponds is still by far the largest contributor from aquaculture to food security and nutrition in the developing world. Cage culture of finfish is increasingly being introduced to places where conditions are conducive. Table 1 shows the aquatic animal production in different regions of the world. Asia, including China accounts for 89 percent, while Africa, a region requiring more nutritious food to improve population health, still contributes only 2 percent to the global total.

Farmed aquatic plants contributed 28 million tonnes to the total world aquaculture production in 2015. Seaweeds is the dominant plant group, and are farmed in about 50 countries in the world (FAO, 2016a). Asia contributes the most and Indonesia has been the main contributor to the growth in aquatic plant

[3] The 2005 reviews published in 2006 are available at: www.fao.org/fishery/regional-aquaculture-reviews/reviews-2005/en/
[4] The 2010 reviews published in 2011 are available at: www.fao.org/fishery/regional-aquaculture-reviews/reviews-2010/en/
[5] Aquaculture includes both aquatic animals and aquatic plants. Aquatic animals in this document refers only to finfish, crustaceans, molluscs and other aquatic animals.

production at global level. Indonesian seaweed production increased significantly over the past decade. Total Indonesian aquatic plant production in 2015 was 10 million tonnes.

Table 1. Aquatic animal production by region: quantity (tonnes) and percentage of world production

Selected region and countries	2000	2010	2012	2013	2014	2015
Africa	**399 628**	**1 285 734**	**1 484 081**	**1 615 047**	**1 710 703**	**1 772 391**
	1%	**2%**	**2%**	**2%**	**2%**	**2%**
Sub-Saharan Africa	54 702	356 115	452 799	499 608	556 703	576 222
	0.2%	1%	1%	1%	1%	1%
North Africa	344 926	929 620	1 031 282	1 115 439	1 154 000	1 196 169
	1%	2%	2%	2%	2%	2%
America	**1 423 434**	**2 514 222**	**2 990 034**	**3 043 482**	**3 346 540**	**3 273 376**
	4%	**4%**	**4%**	**4%**	**5%**	**4%**
Caribbean	39 705	37 165	28 709	32 843	34 529	34 787
	0.1%	0.1%	0.04%	0.05%	0.05%	0.05%
Latin America	799 234	1 818 017	2 356 026	2 413 608	2 751 031	2 625 214
	2%	3%	4%	3%	4%	3%
North America	584 495	659 040	605 299	597 031	560 980	613 375
	2%	1%	1%	1%	1%	1%
Asia	**28 422 519**	**52 513 328**	**58 975 345**	**62 676 345**	**65 552 195**	**68 432 034**
	88%	**89%**	**89%**	**89%**	**89%**	**89%**
Asia excluding China	6 838 995	15 493 933	17 517 188	18 765 117	19 700 581	20 409 817
	21%	26%	26%	27%	27%	27%
China	21 527 083	36 741 677.59	41 114 957.4	43 555 494.12	45 474 840.06	47 615 733.97
	66%	62%	62%	62%	62%	62%
Near East	56 441	277 717	343 200	355 734	376 774	406 483
	0.2%	0.5%	1%	1%	1%	1%
Europe	**2 050 689**	**2 522 707**	**2 827 124**	**2 728 580**	**2 929 242**	**2 975 159**
	6%	**4%**	**4%**	**4%**	**4%**	**4%**
Non-European Union countries	650 022	1 263 642	1 616 089	1 547 193	1 650 746	1 679 756
	2%	2%	2%	2%	2%	2%
European Union Countries (28)	1 400 667	1 259 065	1 211 035	1 181 386	1 278 496	1 295 402
	4%	2%	2%	2%	2%	2%
Oceania	**122 258**	**191 744**	**188 587**	**183 961**	**191 176**	**188 066**
	0.4%	**0.3%**	**0.3%**	**0.3%**	**0.3%**	**0.2%**
World	**32 418 528**	**59 027 736**	**66 465 171**	**70 247 415**	**73 729 857**	**76 641 026**

Notes: data exclude aquatic plants.
Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Systems and practices

Aquatic animals are produced in an array of farming systems operated as extensive, semi-intensive and/or intensive production practices. Aquaculture is practiced in all aquatic environments; freshwater, brackishwater and marine. Systems range from small-scale, backyard-type low technology operations to sophisticated, high technology industrial systems. Since both land and water are becoming scarce for aquaculture, almost worldwide, due to many sectors are competing for these primary resources, sustainable intensification has become the mantra for aquaculture development. The increased production per unit land, water and/or energy has become the formula for economic viability in aquaculture worldwide. This is truly reflected in the increasing trend of modernization and intensification of aquaculture, globally.

The aquaculture systems mainly include ponds, cages, pens and raceways depending on the species cultured and the availability of land and water in the locality. Farming of freshwater species in earthen ponds and cages in lakes, reservoirs and rivers, is a global phenomenon, with increased contributions from Asia. While single species monoculture is practiced in all environments and regions of the world, the practice of polyculture continues and integrated agriculture-aquaculture systems such as rice-fish-farming have been on the rise, particularly in Asia. In recent years increasing use of shrimp-fish polyculture has been observed in order to reduce the risks of disease in shrimp aquaculture. Optimising production and minimising environmental impacts, some countries moved to practice integrated multitrophic aquaculture (IMTA) (FAO, 2009a).

Bulk of aquaculture production still originates from small-scale farming systems and practices, and there is a significant difference between per unit production between commercial and industrial intensive production systems and traditional extensive production systems. For example, Norwegian salmon cages aquaculture produces an average 1 850 tonnes per site, amounting to 1.3 million tonnes in 700 sites (Yngve Torgersen, personal communication, 2017). Although not easily comparable, certain intensive shrimp production systems in Thailand produce about 30 tonnes/ha/year (Matthew Briggs, personal communication, 2017). By contrast, traditional extensive fish and shrimp farming systems in Bangladesh produce only 350–500 kg/ha/year. However, over 70 percent of Bangladesh shrimp production still originates from this type of low productivity traditional systems. Since large numbers of small-scale farmers are engaged in such traditional low productivity practices, intensification of such systems for optimizing productivity is considered timely. Many technological advancements have been made that help sustainable intensification of aquaculture. Recirculating Aquaculture Systems (RAS), indoor grow-out facilities and high density, high carrying capacity intensive production systems are some examples. Continued risks and threats of disease outbreaks also paved the way for intensification of aquaculture, with the view to reduce risks of disease. Many commercial semi-intensive to intensive aquaculture systems are trying to implement full biosecurity in their production systems, since the loss of production due to increasing disease outbreaks, perhaps heightened due to intensification, has been intolerable.

While commercial aquaculture continues to intensify, many small-scale producers, at global scale, are struggling to survive, not having adequate capital investment to improve their systems and practices to produce a product that could compete in the global market. However, cluster management has been proposed as one of the ways to empower small-scale aquaculture farmers and to increase their market access (Kassam, Subasinghe and Phillips, 2011).

PRODUCTION AND VALUE

Trends

Aquaculture is a vibrant sector which produces high-protein, nutritious food, which can’t be easily substituted by any other food commodity. Its contribution to human nutrition has been fully recognized (Chan *et al.*, 2017), although nutrition-sensitive approaches must be promoted (Beveridge *et al.*, 2013, Bogard *et al.,* 2017) and the demand for aquatic food is expected to grow even higher in the coming decades. In 2015, aquaculture produced 76.6 million tonnes of aquatic animals, contributing 45 percent to the total global aquatic animal production and little over 53 percent to the total global fish consumption in the same year. Per capita food fish consumption has been estimated as 20.3 kg in 2015, compared to 19.7 kg in 2013 (FAO, 2017a). Table 2 provides recent data on world capture fisheries and aquaculture production and consumption.

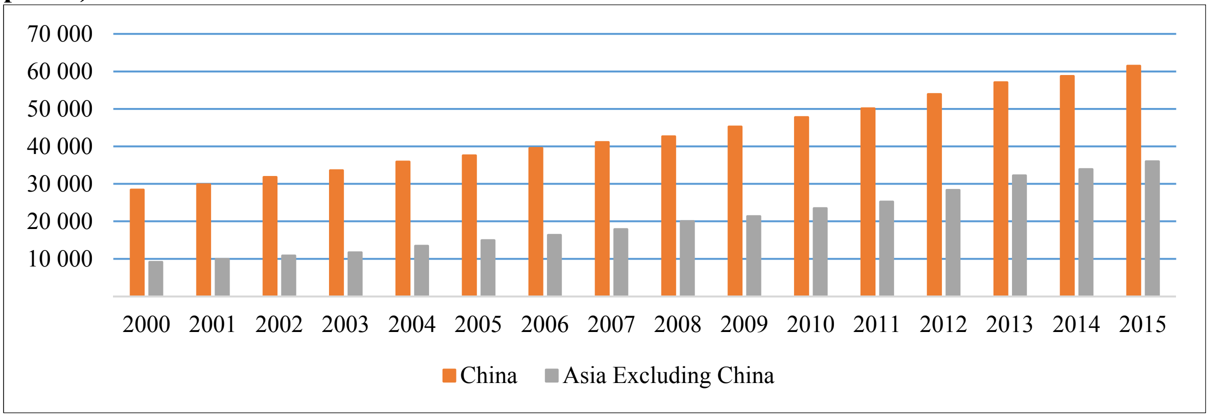
Table 2. World capture fisheries and aquaculture production, utilization (million tonnes) and consumption (kg), between 2013 and 2015

	2013	2014	2015
Total production	162	166.1	170.4
Capture fisheries production	91.8	92.4	93.7
Aquaculture production	70.2	73.7	76.6
Total utilization	162	166.1	170.4
Utilization for Food	133.5	137.8	141.3
Utilization for Feed (reduction)	20.6	20.2	20.8
Utilization for other purposes	7.9	8.1	8.3
Aquaculture's contribution (%)	43.4	44.4	45
Per capita food fish consumption (kg/year)	19.8	20.0	20.3

Notes: 2014 and 2015 per capita fish food consumption is estimated from 2013 data. Population data is from http://data.worldbank.org/indicator. No plants included.
Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

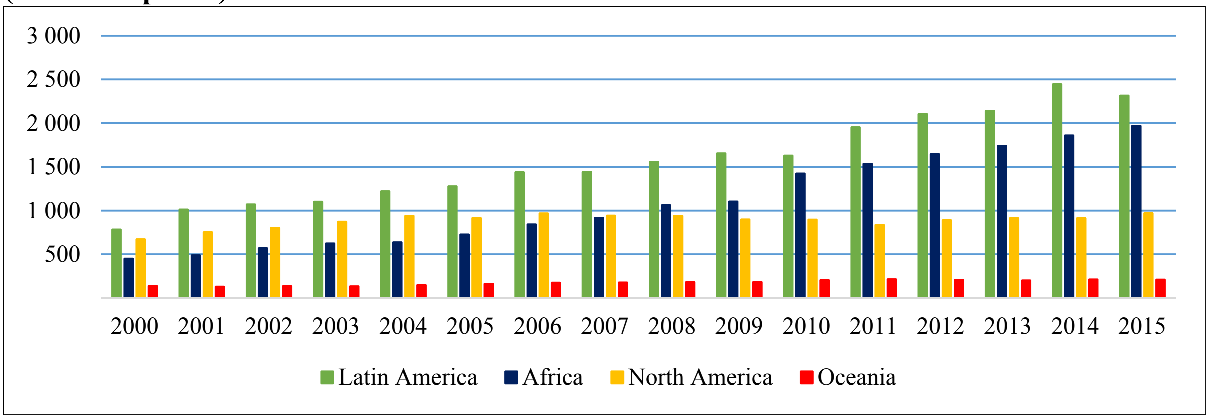
In 2015, reported global aquaculture production was 106 million tonnes (both aquatic animals and plants). Asia dominated this production with a contribution of 89 percent (Figure 2a, b).

Figure 2a. Total aquaculture production (thousand tonnes) from 2000–2015 in Asia (animals + plants)



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Figure 2b. Total aquaculture production (thousand tonnes) from 2000–2015 in non-Asian regions (animals + plants)



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

China, the world's largest aquaculture producer, contributed 47.6 million tonnes (69 percent) to the 2015 global production, while India and Indonesia maintained their second and third positions respectively (Table 3).

Aquaculture production in the top 15 producers demonstrates different growth rates (Table 3). Indonesia, Myanmar and Viet Nam showed the highest overall growth rates during 2000–2015 while, Italy, France and Japan recorded a negative growth during the same period. China, Bangladesh, Ecuador and India showed highest growth rates during 2014–2015, while Chile showed a negative growth during the same period.

Table 3. Top 15 aquaculture producers by quantity in 2015 and annual percent rate of growth

Country	Production (Thousand Tonnes)			Average Annual Percentage Growth Rate		
	2000	2010	2015	2000–2015	2010–2015	2014–2015
China	21 522	36 737	47 612	5.4	5.3	4.7
India	1 943	3 786	5 235	7.1	6.8	7.3
Indonesia	789	2 363	4 380	12.5	13.5	1.9
Viet Nam	499	2 683	3 438	14.1	5.1	2.9
Bangladesh	657	1 309	2 060	8.1	9.6	5.3
Norway	491	1 020	1 381	7.3	6.5	3.6
Egypt	340	920	1 175	8.8	5	3.3
Chile	392	701	1 046	7.9	9.7	-13.9
Myanmar	99	851	997	17.9	3.3	3.7
Thailand	738	1 286	897	1.9	-6.5	-0.1
Philippines	394	745	782	4.8	1	-0.8
Japan	763	718	704	-0.2	0.5	8.6
Brazil	172	411	575	8.6	7.1	2
Republic of Korea	293	476	479	4.2	0.9	-0.2
Ecuador	61	273	426	14.4	9.5	15.8

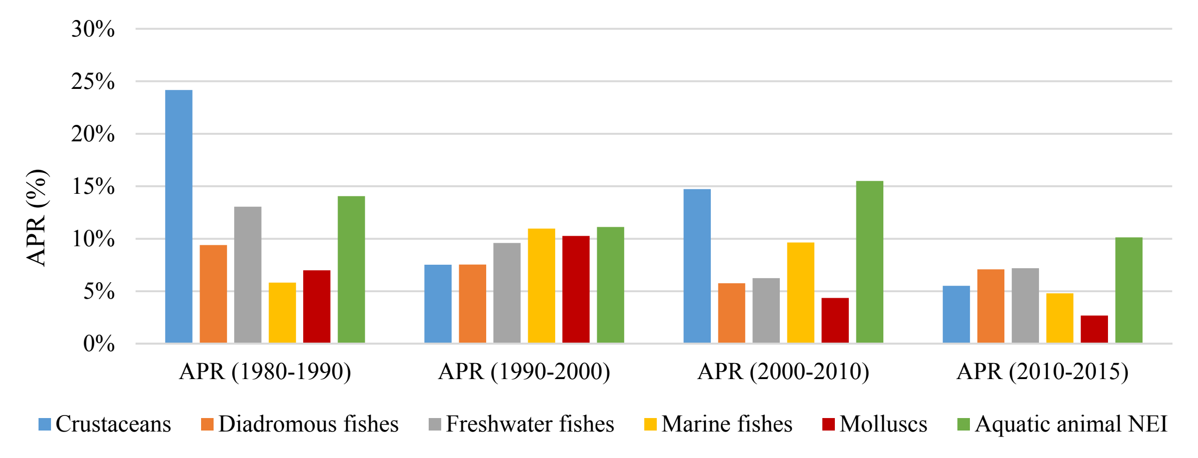
Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Regional trends

Regionally, aquaculture production has been dominated by the Asia-Pacific. Asia, including China, contributed 89 percent of the 2015 total global aquatic animal production (62 percent by China). All other regions produced 11 percent, out of which 2 percent by Africa, 4 percent by the Americas, 4 percent by Europe and 1 percent by the Near East (Table 1). The trends in major species group production is given in Figure 3. It is interesting to note the continuing trend of increasing production of freshwater fish and crustaceans.

The value of the total global production of aquatic animals in 2015 has been estimated at US$158 billion. If aquatic plants are included, world aquaculture production in 2015 was 106 million tonnes, with an estimated value of US$163 billion. However, the actual total output value from the entire aquaculture sector value chain is significantly higher than this. The above figures do not consider the value of aquaculture hatchery and nursery production and the breeding of ornamental fishes, and are based on farmgate prices.

Figure 3. Trends in world aquaculture production: average annual percentage growth rate for major species groups for 1980–2015

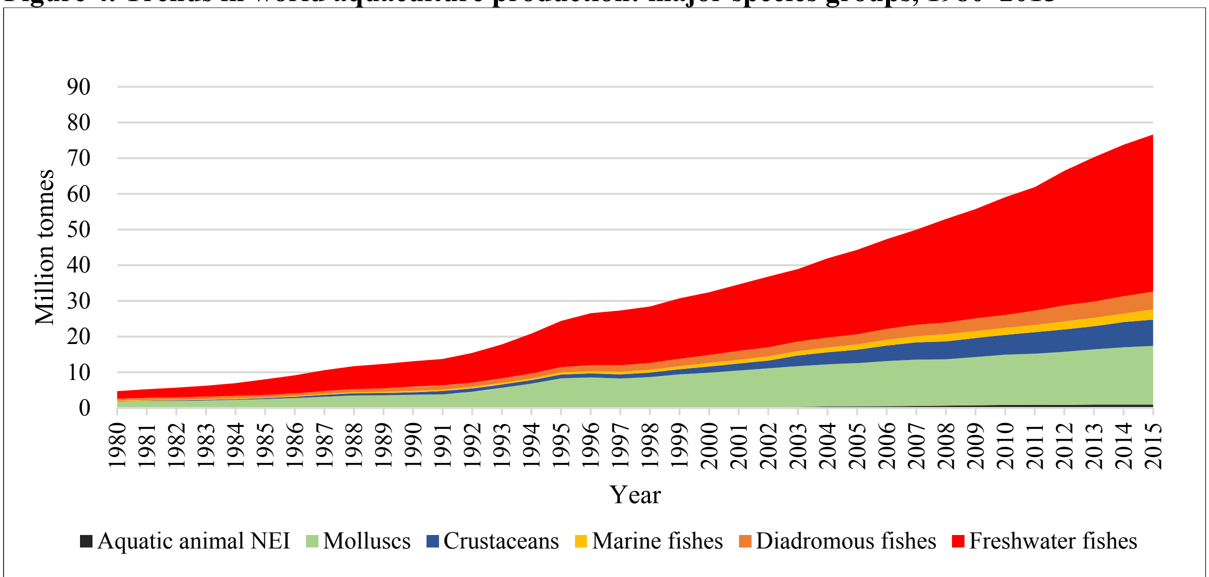


Note: APR refers to the average annual percentage growth rate; NEI refers to not elsewhere included.
Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Species

World aquaculture production by main species groups is given in Figure 4. Freshwater fishes contributed 57 percent while molluscs provided 21 percent and 10 percent by crustaceans, by quantity to the global total in 2015. Marine fish still contribute less than 5 percent. Interestingly, since crustaceans and marine fish are high value species, they represent 24 and 6 percent by value in total production (Figures 5a and 5b).

Figure 4. Trends in world aquaculture production: major species groups, 1980–2015



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Figure 5a. World aquaculture production of major species groups in 2015 – quantity (million tonnes) and percentage contribution

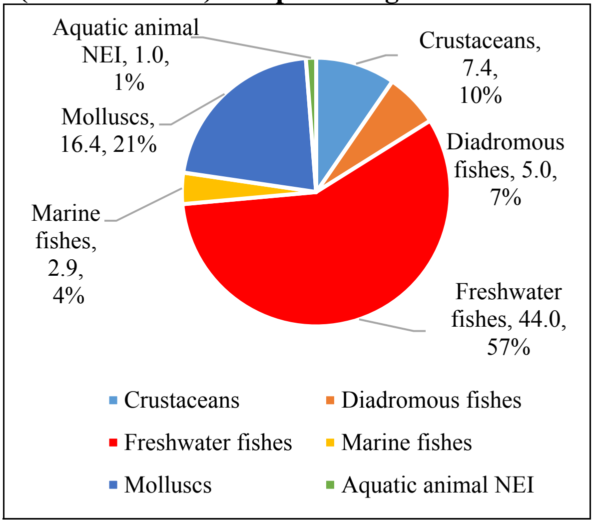
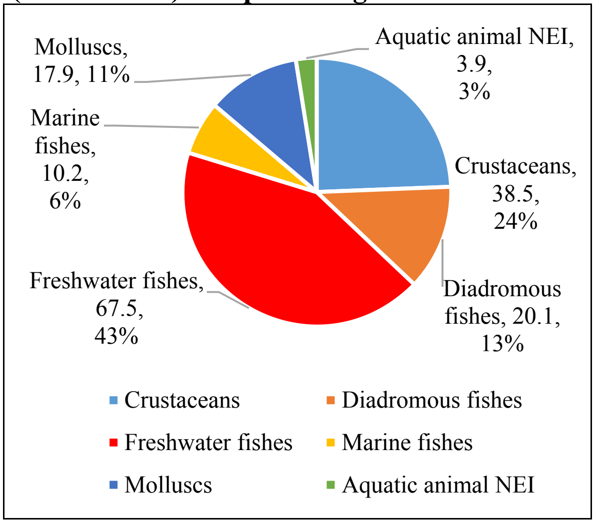


Figure 5b. World aquaculture production of major species groups in 2015 – value (US$ billions) and percentage contribution



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

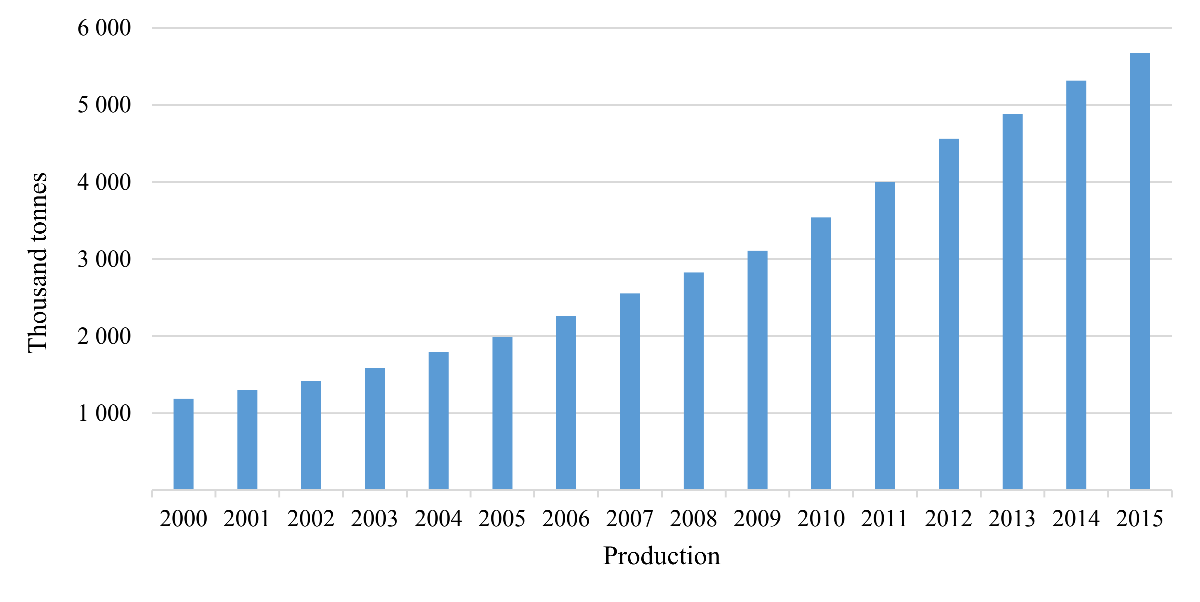
Aquatic plants account for 27.6 percent of global aquaculture production. In 2015, aquaculture produced 29.3 million tonnes (live weight equivalent) of aquatic plants, with a total estimated value of US$4.84 billion. Production of farmed aquatic plants has consistently expanded since the 1970s and remains dominated by seaweeds (over 99 percent by volume and value in 2015). Countries in East and Southeast Asia dominate the global seaweed culture production by volume and value. China, Indonesia, Philippines, Republic of Korea and Japan are the key players in the region.

Africa is the most important producer of farmed seaweeds after Asia. Total African farmed seaweeds production of 196 700 tonnes in 2015 was overwhelmingly dominated by Tanzania (179 200 tonnes, mostly from Zanzibar Island), followed distantly by Madagascar (15 400 tonnes). Other important seaweeds farming producers include Solomon Islands (12 200 tonnes) in Oceania and Chile (12 000 tonnes) in South America.

Production of freshwater fish in 2015 was dominated by carps (Cyprinidae, 20.4 million tonnes or 71.1 percent). The largest producer of all carps (cyprinids) in 2015 is China (78.7 percent), followed by India (15.7 percent). A further 10.2 percent of all carps are produced by Bangladesh, Myanmar, Viet Nam, Indonesia and Pakistan, collectively.

Total global tilapia production in 2015 was 5.6 million tonnes in 2015. The growth of the tilapia sector has been impressive (Figure 6) and currently the top five tilapia producers in the world are China (31 percent), Indonesia (20 percent), Egypt (15 percent), Bangladesh (6 percent) and Viet Nam (5 percent). Growth in the production of pangas catfish (*Pangasius* spp.) in Viet Nam, Bangladesh and Indonesia had been dramatic in recent years (Figure 7), with total global production of little over two million tonnes in 2015. Global production appears to be tapering off at around two million tonnes, market research indicates continued increasing demand for pangasius. Viet Nam accounted for 1.1 million tonnes while Indonesia and Bangladesh account for nearly 400 000 tonnes each in 2015.

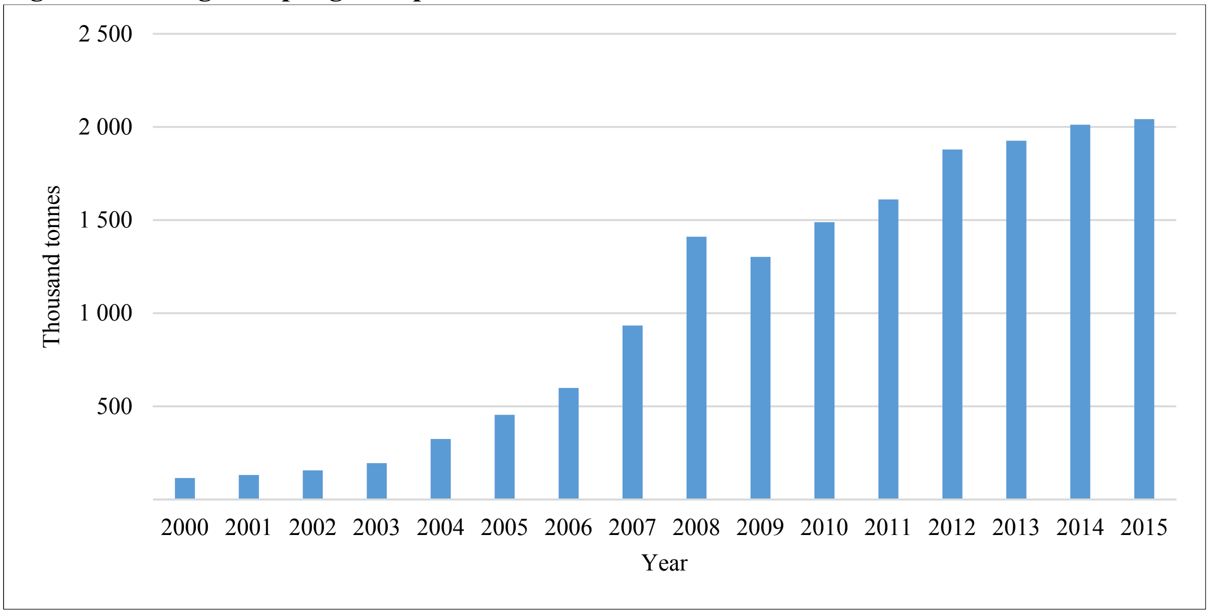
Figure 6. Global production of tilapia from 2000–2015



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Mollusc production in 2015 consisted of oysters (32.4 percent), carpet shells and clams (33 percent), mussels (12 percent) and scallops (12.6 percent). While mollusc production grew at an average annual rate of 3.7 percent in the period 2000–2015, the luxury group of abalones increased in production from 2 800 to 142 000 tonnes between 2000 and 2015, an annual growth rate of 30 percent.

Figure 7. Total global pangasius production from 2000–2015



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Global shrimp (marine and brackishwater) and prawn (freshwater) production increased over the past five years, despite several major disease outbreaks in Asia. In 2015, brackish and marine water shrimp production was recorded at 4.13 million tonnes while freshwater prawn production was 0.74 million tonnes. Table 4a and 4b provide the top 10 producers of the two major brackishwater shrimp species; *Penaeus monodon* (Black Tiger Shrimp) and *Penaeus vannamei* (White Leg Shrimp) in 2015, respectively.

Table 4a. Top ten *Penaeus monodon* producers in 2015

Country	Production (thousand tonnes)
Viet Nam	223
Indonesia	128
India	82
China	76
Bangladesh	75
Myanmar	50
Philippines	50
Thailand	14
Sri Lanka	7
Malaysia	4

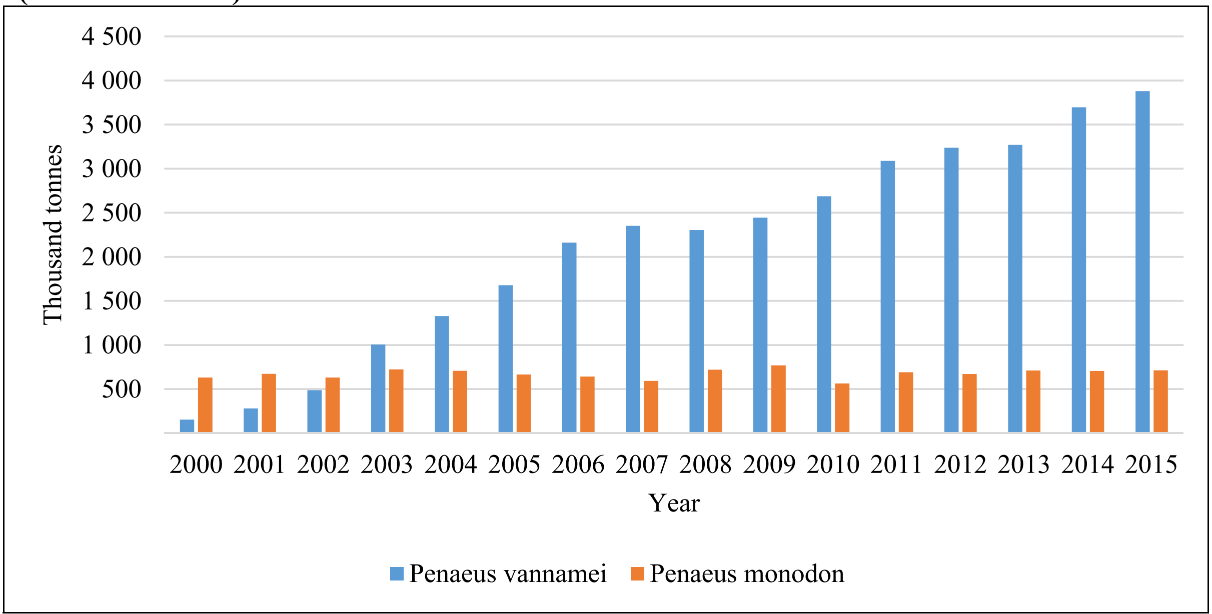
Table 4b. Top ten *Penaeus vannamei* producers in 2015

Country	Production (thousand tonnes)
China	1 625
India	416
Indonesia	410
Ecuador	403
Viet Nam	318
Thailand	280
Mexico	130
Brazil	70
Malaysia	48
Honduras	25

Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Despite the devastating disease outbreaks in late 1990s, with adoption of novel technologies and better biosecurity measures Ecuador has recovered and produced over 400 000 tonnes of *P. vannamei* in 2015. It is also interesting to note that, once a minor species, accounting for less than 100 000 tonnes annual production, *P. vannamei* has become the global leader in shrimp production, totally outpacing *P. monodon* (Figure 6). Better technology, availability of Specific Pathogen Free (SPF) post larvae and better resistance to diseases of this species made this transformation possible. Comparison of the total global production of *P. monodon* and *P. vannamei* over the past 15 years is given in Figure 8.

Figure 8. Total production 2000–2015 *Penaeus monodon vs. Penaeus vannamei* (thousand tonnes)



Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

Atlantic salmon (*Salmon salar*) dominated the production of diadromous fish in 2015 (2.38 million tonnes or 48 percent), followed by milkfish (*Chanos chanos*) (1.12 million tonnes or 22 percent), rainbow trout (*Oncorhynchus mykiss*) (0.76 million tonnes or 15 percent) and eels (Japanese eel, *Anguilla japonica,* and European eel, *A. anguilla,* combined) (0.27 million tonnes or 5 percent). Norway and Chile are the world's leading aquaculture producers of salmonids, accounted for 28 and 17 percent of world production, respectively, in 2015. Following the disease outbreak – infectious salmon anaemia (ISA) – in 2009, which reduced national production by 50 percent, production in Chile has been slowly recovering through use of better technologies and biosecurity measures. Europe and North America contributed 2.10 million tonnes to the global salmonid production in 2015.

Global marine fish production increased from 0.81 tonnes in 2000 to 2.31 tonnes in 2015, the leading producers being China and Spain. The major species concerned are turbot (*Scophthalmus maximus*), bastard halibut (*Paralichthys olivaceus*), and tongue sole (*Cynoglossus semilaevis*). For Norway, the production of Atlantic cod (*Gadus morhua*) grew significantly in the period 2000–2015. Slightly more than half the volume (0.35 million tonnes or 57 percent) of miscellaneous aquatic animals is produced in freshwater. The most important species are soft-shell turtle followed by frogs. Production in marine water (0.27 million tonnes or 43 percent) includes jellyfishes, Japanese sea cucumber and sea squirts as major species. Table 5 shows production of main groups of fish for human consumption from inland aquaculture and marine and coastal aquaculture in 2015.

Table 5. Production of main groups of fish for human consumption from inland aquaculture and marine and coastal aquaculture in 2015

		INLAND AQUACULTURE	MARINE AND COASTAL AQUACULTURE	TOTAL
			Tonnes	
Africa	Finfish	762 278	1 002 585	1 764 863
	Molluscs	0	3 770	3 770
	Crustacean	5	3 728	3 733
	Other animals	0	25	25
	Total Africa	732 283	1 010 108	1 772 391
Americas	Finfish	1 017 506	2 020 726	2 020 726
	Molluscs	-	465 295.9	465 296
	Crustacean	63 954	786 823	786 823
	Other animals	531	531	531
	Total America	1 081 992	2 191 384	3 273 376
Asia	Finfish	41 847 682	3 858 091	45 705 773
	Molluscs	283 744	14 946 627	15 230 371
	Crustacean	2 792 414	3 761 215	6 553 629
	Other animals	522 904	419 357	942 261
	Total Asia	45 446 744	22 985 290	68 432 034
Europe	Finfish	475 235	1 863 086	2 338 321
	Molluscs	-	636 520	636 520
	Crustacean	51.08	259	310
	Other animals	-	8	8
	Total Europe	475 286	2 499 872	2 975 158
Oceania	Finfish	5 013	72 775	77 788
	Molluscs	-	96 032	96 032
	Crustacean	162	6 693	6 854
	Other animals	0	7 391	7 391
	Total Oceania	5 175	182 891	188 066
World	Finfish	44 107 714	8 817 263	51 907 471
	Molluscs	283 744	16 148 245	16 431 989
	Crustacean	2 856 586	4 558 718	7 351 349
	Other animals	523 435	427 312	950 216
	Total World	47 771 479	29 951 538	76 641 025

Source: FAO Fisheries and Aquaculture Database – FishStatJ (FAO, 2017g).

EMPLOYMENT AND SOCIAL DEVELOPMENT

FAO 2016 reports that, in 2014, 56.6 million people were engaged in primary sector of capture fisheries and aquaculture, of which 18.7 million (31 percent) were fish farmers (FAO, 2016a). Most of the global aquaculture workforce are in Asia (94 percent of the global total), reflecting the 90 percent contribution of Asian aquaculture production to the global total (FAO, 2017a). The other regions only employed 6 percent from the world total.

In addition to the primary producers, many people are engaged along the aquaculture value chain, in other ancillary or secondary activities, such as processing, providing inputs such as seed and feed, and services such as health management and diagnostics, net and gear making, ice production, manufacturing of fish-processing equipment, packaging, marketing and distribution. Another group is involved in research, development and administration connected with the fishery sector. While no official data exist for such groups of people, it has been estimated that fishers, aquaculturists and those supplying services and goods support the livelihoods (including dependent family members) of a total of 540 million, or 8.0 percent of the world population (FAO 2017a).

Engagement of women in fisheries and aquaculture is significant. A recent report (FAO, 2016a) indicates that women accounted for more than 19 percent of all people directly engaged in the fisheries and aquaculture primary sector in 2014. De Graaf and Garibaldi (2014) mentioned that approximately 34 percent of those employed in the aquaculture sector in sub-Saharan Africa are women. Women also contribute to income generation through participation in various aquaculture activities, such as feeding and harvesting of fish and collecting of prawn larvae and fish fingerlings. This is more prominent in Asia and sub-Saharan Africa (FAO, 2017a; FAO, 2017f). However, their most important role is at the processing and marketing stages. While in some countries women have become entrepreneurs in fish marketing, processing, carrying out activities in their own cottage-level industries, etc., there are also many women who work as wage labourers in the processing industry.

The average per capita annual production of fish varies among regions and countries, reflecting the degree of industrialization of aquaculture-related activities and the key social role played by small-scale farmers. In the aquaculture sector, for example, fish farmers’ average annual production in Norway is 172 tonnes per person, while in Chile it is about 72 tonnes, in China 6 tonnes and in India 2 tonnes (FAO, 2017a).

RESOURCE USE, SERVICES AND TECHNOLOGIES

Land and water

Land and water are considered the most important resources for aquaculture development, worldwide. The challenge is to secure suitable land and water resources for the development of aquaculture at national levels. In many countries, management of conflicts and competition for scarce land and water resources from other sectors, particularly agriculture, shipping, urbanization, tourism and nature protection, have been reported as significant issues (FAO, 2010) and this remains the same (FAO, 2017a). Prioritization of development activities at national levels, based on political and policy decisions, directly affect land and water resource allocation for common resource activities. Many countries have realized the importance of appropriate allocation of resources for aquaculture development and have adopted or are in the process of adopting measures to address this challenge through an ecosystem approach to aquaculture (EAA), including multiple or integrated use of water resources, land-use planning and aquaculture zoning (FAO, 2017a; FAO, 2017b; Aguilar-Manjarrez, Soto and Brummett, 2017).

Land and water resources are scarce in some parts of sub-Saharan Africa (SSA). Recurrent droughts adversely affect water availability in some parts of SSA, particularly in the Sahelian western-central belt, Southern Africa and parts of Eastern Africa. The droughts justify the importance placed on the development and expansion of cage culture, viewed as efficient in terms of water use in common property resources (public lakes, reservoirs and coastal areas) (FAO, 2017f; Crespi and Lovatelli, 2011).

In the last 20 years, available fresh water resources have become greatly reduced due to severe and prolonged droughts in sub-Saharan Africa (UNECA, 2016). Many parts of sub-Saharan Africa (SSA) is facing freshwater shortage at a time when there is a trend towards intensification and diversification in SSA aquaculture, including increased importance and expansion of cage culture in several African countries (FAO, 2017f). In contrast, although land and water are becoming scarce resources in Asia, some good examples have been emerged in Asia towards addressing the issue. Development of integrated aquaculture, particularly rice-fish farming in China over the last three decades, is considered as a "success story in Asian aquaculture" (Miao, 2010). Rice-fish farming is being expanded in Asia and extended to Latin America and Africa through FAO's technical assistance, under its' Blue Growth Initiative.

The nature of conflicts and competition related to the utilization of water for aquaculture is different for freshwater, which originates from both surface water and groundwater sources, and marine water, and therefore warrants situation-specific strategic approaches. Freshwater aquaculture, which accounts for over 60 percent of global aquaculture production, concerns have been raised as to whether aquaculture can continue to use large volumes of freshwater, particularly in open or flow-through systems, for production purposes (FAO, 2010). There are also growing concerns about use of water to produce aquaculture feedstuffs (Pahlow *et al.,* 2015; Gephart *et al.,* in press).

Freshwater usage conflicts are common in arid countries, or places where freshwater is pumped from groundwater or aquifers. Nonetheless, even in such situations, aquaculture may not be a consumptive user, as effective integration of the water uses with agricultural activities such as crop and perhaps livestock rearing can result in net benefits for competing users (FAO, 2006). Depending on the situation, water-stressed areas may require more innovative approaches, for example, the use of wastewater in agriculture, hydroponics, recirculation systems, close-water systems, aquaponics, etc. (Somerville *et al.*, 2014). However, the use of more efficient integrated systems largely depends on financial viability, the species cultured and level of intensity practiced.

Certain technological advancements have been made to reduce water use in aquaculture (recirculated water systems – RWS; closed water systems – CWS; high density aquaculture, etc.). However, their use is restricted to commercial and industrial production systems producing high value species such as shrimp. Some freshwater species production systems such as tilapia are also experimenting with the use of RWS. Considering the nature of aquaculture production systems, whereby still a good 70 percent of production comes from small-scale aquaculture, practical use of such technologies towards enhancing water use efficiency at global level remains questionable.

Regarding the use of marine water for aquaculture, the competition is typically not for the quality or volume of water itself, but more often for the use of marine or coastal areas that are claimed for other purposes, such as fisheries, navigation, oil exploration, tourism and urban development. In many countries, effective land-use planning and coastal zoning have promoted complementary or even synergistic developments (Aguilar-Manjarrez, Soto and Brummett, 2017). Moreover, as land and coastal areas become scarcer, open waters (both near shore and offshore) of the sea are increasingly being considered for aquaculture, although economic, technical, social and environmental factors are often very relevant challenges (Lovatelli, Aguilar-Manjarrez and Soto, 2013; Kapetsky, Aguilar-Manjarrez and Jenness, 2013; Meaden *et al.,* 2016).

Entrepreneurs in some countries are moving towards sea farming, not only as an alternative to restricted availability of suitable land, but also to engage more with high value species production for greater economic benefits (Aguilar-Manjarrez and Dalton, 2017). However, over the past decade, on a global scale, there has been no significant increase in marine aquaculture production (FAO, 2016a).

Feed

The majority of the aquatic animal species cultured are fed with external feeds. As aquaculture expanded and intensified, the use of external feeds in aquaculture increased. In 2015, about 50.7 million tonnes of farmed fish (including Indian major carps) and crustaceans (66.2 percent of global aquatic animal production) were dependent upon the use of external feed (fresh feed ingredients, farm-made feeds or commercially manufactured feeds). In 2015, fed aquaculture contributed to 85.6 percent of global farmed finfish and crustacean production of 59.3 million tonnes. During the period from 1995 to 2015, production of industrial aquafeed increased from 7.6 to 47.7 million tonnes. Of this total, fed carps consumed the largest volume (30.5 percent), followed by tilapias (17.1 percent), shrimps (14.9 percent), catfishes (10.5 percent), salmon (7.0 percent), marine fishes (8.2 percent), freshwater crustaceans (4.6 percent) and trout (2.0 percent). The remainder is accounted for by milkfish, miscellaneous freshwater fish and eels. These estimates took no account of the commercial feed used by Indian major carp, which are increasingly fed with commercial feed along with supplementary feeds (Hasan, 2017).

In 2005, aquaculture consumed about 4.20 million tonnes (18.5 percent of total aquafeeds by weight) of fishmeal. By 2015, this has been reduced to 3.35 million tonnes (7.0 percent of total aquafeeds by weight). It has been predicted that, even with increasing aquaculture production globally, the use of fishmeal for aquafeeds will decrease further to 3.33 million tonnes by 2020 (5.0 percent of total aquafeeds by weight for that year). Nevertheless, for aquaculture to grow aquafeed production is expected to continue growing at a similar rate, to 69.0 million tonnes by 2020 (Hasan, 2017).

Sustainability of aquafeeds and the availability and use of feedstuffs are subjects of continuing concern. Although the discussion is centred around fishmeal and fish oil resources (including low-value fish/trash fish), considering past trends and current predictions, sustainability of the aquaculture sector is more likely to be closely linked with the sustained supply of terrestrial animal and plant proteins, oils and carbohydrate sources for aquafeeds (Troell *et al*., 2014). The aquaculture sector should therefore strive to ensure sustainable supplies of terrestrial and plant feed ingredients.

Regional status of aquafeed production and usage is different. It has been predicted that the Asia-Pacific region will continue to produce more fish and fish feed and will certainly utilise more feedstuffs than it does now. However, research into replacement of scarce and expensive ingredients, such as fishmeal and fish oil, has increased and the region is producing more less costly alternatives, as well as making greater use of fishmeal and fish from fish processing wastes. Thus, the use of fisheries resources for feeding fish will not grow as fast as might be expected in Asia-Pacific (Ye *et al*., 2017). However, it is important that the compromise between reducing the cost of feed and the nutritional status of the final produce is carefully balanced.

Africa is a net importer of aquafeeds, although there is an expansion of local feed mill capacity underway in several countries. However, there are frequent aquafeed shortages. High competition and demand for feed should stimulate continued development of local mills, improving aquafeed quality and making it more affordable and more widely available. Both imported and locally produced aquafeed are expensive and of unknown quality. There is also a variety of local feed manufacture solutions, especially in the less productive aquaculture countries, ranging from farmer-formulated meal-type diet to a quasi-pellet produced with a grinder and subsequent drying to form water-soluble, hard, sinking pellets. The price of aquafeeds varies between countries and within countries due to source of import, and for locally produced feeds the costs of feed ingredients and seasons. Feed costs are always in the increase. Many countries lack appropriate aquafeed policy, regulatory frameworks, and feed standards (FAO, 2017f).

In other regions, Latin America, North America and Europe, use of commercial aquafeed is increasing as systems are intensified. Major species such as salmon, tilapia and shrimp rely on commercial feed and the aquafeed production has been proportionately increasing with that of aquatic production.

In summary, there are a few feed-related issues that the aquaculture industry in the three regions needs to address. They are: (i) reducing dependence on fishmeal and fish oil, while maintaining the nutrient quality of farmed aquatic animal products; (ii) ensuring national quality standards for raw materials, feed additives and feeds; (iii) facilitating safe and appropriate use of aquafeeds produced by small-scale manufacturers; (iv) building the capacity of small-scale farmers to make more effective farm-made feeds, and (v) making more efficient use of feed through reduced FCRs.

Seed

Except for isolated experiences, the aquaculture seed sector worldwide has not changed much over the past five years. The availability of hatchery-produced, good quality fish, shrimp and prawn seed all around the world has increased, although quantitative data are still unavailable. Consequently, the use of wild-caught seed is reducing, although some species culture is solely depending on wild caught broodstock and/or seed. Cultures depend on wild caught seed include eels, southern Bluefin tuna, some grouper species and a still substantial proportion of milkfish production.

Over the past few years, Specific Pathogen Free (SPF) shrimp broodstock (both *P. monodon* and *P. vannamei*) have become more available in Asia and Latin America. Life cycles of the important crab and lobster species have been experimentally closed but commercial production of their seed is still rudimentary. Dissemination of GIFT tilapia (Genetically Improved Farmed Tilapia) seed and broodstock has been widened and they are now found in many countries in Asia and Africa (FAO, 2017a).

At present, freshwater seed supply (mainly tilapia and carps) is sufficient in most North East and North Africa (NENA) countries. Government and private hatcheries are abundant, although many of them still operate on rather rudimental farming technologies (FAO, 2017b).

Health management and biosecurity

Diseases continue to challenge the aquaculture sector globally. As disease has become one of the primary deterrents to aquaculture development of many species, investment and focus on aquatic biosecurity and health management has been on the increase worldwide.

A significant recent addition to the long list of aquatic diseases/pathogens severely affecting the aquaculture sector is Acute Hepatopancreatic Necrosis Disease (AHPND), which devastated shrimp aquaculture in several Asian countries (e.g. the People's Republic of China, Malaysia, the Republic of the Philippines, the Kingdom of Thailand) more than five years ago. The loss of revenue due to AHPND in Southeast Asia has so far been estimated at over US$ four billion. The causative agent is a virulent strain of *Vibrio parahaemolyticus*, an aquatic bacterium commonly found in coastal waters. Countries must be vigilant regarding other emerging diseases (e.g. *Enterocytozoon hepatopenaei* (EHP) in shrimps and tilapia lake virus (Tilapia Lake Virus) in Nile tilapia) with the potential to severely impact the sector if not addressed in a timely manner (FAO, 2017a).

New molecular diagnostic tools are now being applied to the identification of disease agents in very high sample numbers as well as to identify distribution patterns of disease agents in hatchery, farmed and wild fish in North America. A recently developed microarray has also been used to look at impacts of pathogen carrier status (sea lice and IHNv) on wild salmon (FAO, 2017e).

Almost all countries in sub-Saharan Africa, excluding South Africa, depend on services provided by government veterinary or public health departments managing aquatic animal diseases. Several disease problems and the occasional severe epizootic – such as the ulcerative syndrome (EUS) and white spot syndrome virus (WSSV) which decimated the shrimp industry of the Republic of Mozambique in 2011 – have exposed the vulnerability of aquaculture systems to pathogens and to the factors that make them virulent and promote their spread (FAO, 2017e). Recent confirmation of TiLV in several countries is alarming and stringent biosecurity measures are necessary to avoid likely spread of this virus into many countries producing tilapia for both trade and food (Fathi *et al.*, 2017).

No major disease outbreaks in aquaculture have taken place in Latin America over the past five years. Chile has made significant improvements in salmon production after the devastating Infectious Salmon Anemia (ISA) outbreak in 2009. However, there are worrying public claims that the Chilean salmon industry is using high levels of antibiotics against salmonid rickettsial septicaemia (SRS) disease. While struggling to prevent SRS, a harmful algal bloom has recently hit Chile, where nearly 23 million fish have already died and the economic impact from lost production has soared to US$800 million, industry and government sources claim.

Other important emerging issues that countries need to be aware of include the misuse and abuse of antimicrobials and other veterinary drugs, concerns about residues and development of drug resistant pathogens. With the recent approval of the Global Action Plan on Antimicrobial Resistance (AMR), spearheaded by WHO, it is now appropriate for countries to initiate development of national action plans on aquatic AMR to be integrated into the global action plan (FAO, 2017a).

Technology

Stakeholders that are involved in aquaculture have been responding to the challenges and opportunities inherent with novel technologies for the sustainable development of the sector. Remarkable improvements have been made in genetics and breeding, both in finfish and shrimp. SPF and SPR shrimp (*P. monodon* and *P. vannamei*), Genetically Improved Farmed Tilapia (GIFT), some carp species with better growth performance, and commercial-scale production of various species of grouper, pompano and cobia could be listed as success stories. There have also been significant technological improvements in the feed and nutrition sector and in health management and disease control, including a new vaccine for *Streptococcus* infections in tilapia. Advancements in production systems, including recirculation technologies, cages and integrated multi-trophic aquaculture, are also contributing to intensification, industry expansion and sustainability (FAO, 2017a). Molecular diagnostic procedures, including polymerase chain reaction (PCR) methods have already been developed for the recently identified disease of shrimp AHPND, in Asia.

An operating practice that has become widespread over the last five years is the use of cleaner fish in the cages to feed on lice. Farmed ballan wrasse (*Labrus bergylta*) is widely acknowledged as a sustainable means of controlling sea lice, as is the lumpsucker (*Cyclopterus lumpus*). However, considerable R&D is required to meet the nutritional and health needs of these relatively new farmed species and to maintain or enhance their behaviour of seeking and consuming lice in the environment of a salmon cage. Substantial research funds are being allocated both by public and private sector sources to develop such knowledge and to identify sustainable and reliable operating regimes (FAO, 2017b).

The main salmon production companies have also led the way in the development of non-chemical lice management regimes. The last 12 months have seen multi-million dollar investments, in Norway and Scotland, in Hydrolicer and Thermolicer machines installed in dedicated well-boats; the machines use rapid fresh water or thermal shock to kill lice.

More biotechnological developments with relevance to aquaculture over the last five years, centre on the use of molecular genetics in development of finfish broodstock, on analysis of interactions between farmed and wild stocks of the same species, and on development of transgenic finfish lines. Creating or refining broodstock is being revolutionized by the ability to locate genetic markers for desirable traits like growth and disease resistance. The tools of genomics are now allowing managers to trace the progeny of broodstock to determine how good breeding strategies have worked. The same DNA technology allows farms to monitor any breeding-related genetic diversity loss in aquaculture strains and can also be used to distinguish wild from cultured salmon found in the same waterway or to help manage interbreeding ("genetic pollution") (FAO, 2017e).

In terms of culture technology, various attempts have been made to use Recirculating Aquaculture Systems (RAS) in salmon aquaculture, with some positive outcomes. RAS is rapidly becoming the standard method for smolt and post-smolt production in Norway and Chile. The approximate capital investment cost is around US$60 million for a typical complete system (FAO, 2017c).

The transgenic AquaAdvantage™ Atlantic salmon has been under regulatory review by the United States Food and Drug Administration (FDA) for more than a decade. After an exhaustive and rigorous scientific review, FDA has arrived at the decision that AquAdvantage™ salmon is as safe to eat as any non-genetically engineered (GE) Atlantic salmon, and also as nutritious.[6] Approval for commercial production and consumption has been finally granted in November, 2015 in the United States of America and for commercial sale in Canada by Health Canada in May, 2016. The company is currently establishing a production facility in Prince Edward Island, on Canada's East coast. The extraordinarily long time to achieve approval underlines the strong societal resistance to "genetically modified foods" in North America, and it remains to be seen in which market the product will succeed (FAO, 2017e).

The use of spatial technology is increasingly prevalent in society. Spatial technology means systems and tools that acquire, manage and analyze data that has geographic or geospatial context. This includes remote sensing technology such as satellites images, aerial surveys; global positioning systems (GPS), geographic information systems (GIS), and Information and communication technology (ICT) more broadly such as mobile communication devices and other data gathering sensors such as meteorology sensors.

Over the past two decades, ICTs have dramatically transformed society and economic development, and it is not surprising that the 2030 Agenda for sustainable development embraced ICTs enabling technologies to address the Sustainable Development Goals. Society and governments worldwide are now cognizant of the power of ICTs for the advancement and transformation of the public, private, and civil society landscape. Building on ICTs and spatial technology, some tools and models are built specifically for disaster risk management, and many can be specifically applied in the aquaculture sector.

AQUACULTURE AND THE ENVIRONMENT

Having learned from past mistakes, many countries, as well as newcomers in aquaculture, now emphasize environmental sustainability and social responsibility. In addition to laws and regulations, and voluntary codes of practice that aim to ensure environmental integrity, some of the means of achieving this goal include innovative, less-polluting production techniques, such as those based on the ecosystem approach to aquaculture (EAA) which emphasizes management for sustainability.

[6] www.fda.gov/ForConsumers/ConsumerUpdates/ucm472487.htm

The EAA is a strategy to strengthen the practical and comprehensive implementation of sustainability principles by improved management approaches coherent with good governance. The strategy provides a planning and management framework for integrating the aquaculture sector effectively into local planning.

It has been noted that environmental impacts of aquaculture vary with species, system, management, production intensity, location and environmental carrying capacity to absorb impacts. Although recent efforts and trends in intensification have visibly resulted in decreased use of land and freshwater per unit of farmed fish produced, intensification has also led to an increase in the use of energy and feed, as well as an increase in water pollution per unit of farmed fish produced (Hall *et al*., 2011). More disease impacts have been observed. These experiences have led the aquaculture industry to adopt practices that ensure "sustainable intensification of aquaculture" in all regions of the world. Sustainable intensification of aquaculture in Asia has now become one of the major programmes of FAO, aimed at mitigating the negative impacts of intensification.

Although the aquaculture industry has been accused of causing negative environmental and social impacts by many, aquaculture has, from an ecological efficiency and environmental impact point of view, clear benefits over other forms of animal food production for human consumption. Farmed finfish are similar in feed conversion efficiency to poultry, and much more efficient than beef. Filter-feeding carp and molluscs are even more efficient producers of animal protein, as they require no human-managed feeds and can improve water quality. Because the aquaculture sector is relatively young compared with terrestrial livestock sectors, it offers great scope for technical innovation to further increase resource efficiency (Waite *et al*., 2014). Where resources are stretched, the relative benefits of policies that promote aquaculture over other forms of livestock production should be considered.

Regionally, environmental concerns and issue differ. Aquaculture in the Asia-Pacific region has generally become more environmentally friendly, a result of two decades of increasing awareness and publicity regarding the adverse impacts and perceived impacts of aquaculture on natural resources and the backlash of bad practices on the productivity and sustainability of farms. Farmers have learned that being environmentally friendly makes good business sense. Regulations have been instituted or tightened, but the most important development has been the increasing uptake of the development and application of BMPs, codes of conduct or practices, certification schemes and EAA. Almost all countries in the region now require licensing to practice aquaculture. All commercial aquaculture establishments must undertake EIAs or IEEs and register with the state authorities before commencing farming (FAO, 2017a; FAO, 2009b).

In North America and Europe, environmental concerns are very much centered on water quality, biosecurity and aquatic animal health. Sea lice are a problem only for traditional floating salmon farms, but the dominance of the salmon farming industry in North America means the problem is significant. Routes of disease transmission are ecologically and geographically complex and very challenging to study. Despite nearly a decade of management by industry and government, sea lice remain a lightning rod for environmental criticism of salmon farming. Transmission of diseases from farmed to wild salmon is also another concern. Other aspects such as replacement of forage fish meal and oil with nutrients from plant, algal or bacterial sources, impacts of offshore farming and public acceptance of genetically modified organisms are continuously being discussed (FAO, 2017e). Further, in November 2014, the European Union (Member Organization) (EU) published a new Regulation to address invasive alien species (IAS) and protect biodiversity. This Regulation entered into force across the EU in January 2015. Its aim is to "prevent the introduction of, control or eradicate alien species which threaten ecosystems, habitats or species" (Caffrey *et al*., 2015). Issues relating to reducing waste from aquaculture systems are continued to be debated and the increased use of integrated multitrophic aquaculture (IMTA) and RAS is being promoted.

Environmental concerns of Northeast and Southern African aquaculture are mainly focused on water availability. Negative environmental impacts from aquaculture waste disposal are also a concern in some countries such as Nigeria. Countries need to undertake a comprehensive and coordinated spatial plan to secure more and appropriate allocation of space in coastal/inland waters and land to support sustainable growth of aquaculture. Emphasis should be placed on capacity-building to develop and implement BMPs and COPs. As appropriate, countries should scale up mangrove reforestation programmes and mainstream Blue Growth Initiatives (BGI) in national programmes, as is happening in the Republic of Kenya's mariculture industry (BGI is further elaborated in the Aquaculture and FAO section). Introduction of species without science-based risk assessments has been a concern in African aquaculture. At the regional level, there is the Nairobi Declaration on Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species for Aquaculture in Africa. Both the CCRF and CBD seek to establish a precautionary approach to the use of alien species (FAO, 2017f).

In the NENA region, the expansion of aquaculture, together with intensive use of artificial culture inputs such as processed feed, drugs, hormones, fuels, etc., appear to pose environmental and socioeconomic threats. Water pollution in the Nile delta seems to affect sustainability of aquaculture in the region (El-Nemaki *et al.,* 2008) while there is concern about potential impacts of increasing cage culture. The culture of monosex (all-male) Nile tilapia is expanding in the NENA region, especially in Egypt. All-male seed is produced using oral administration of 17α-methyltestosterone (MT) in larval feeds. Hormone residues and metabolites can be a potential environmental contaminant, and may pose human health risk. It is not legally permitted in the European Union. Some alternate technologies such as YY males have been emerged and are being used commercially. Thus, the use of hormones for sex reversal of tilapia has been under increasing public criticism.

Recent introductions of several exotic species into the NENA region may pose risks to local habitats, including pathogen introduction and escape into the wild, causing genetic pollution and/or habitat destruction and potential ecosystem effects that could cause decline or disappearance of native species. Sturgeon is mentioned as an invasive species in NENA region. Four major environmental actions have been suggested for the NENA region by FAO (2017d): (a) management of introductions and transfers, (b) management of effluent and nutrient loading, (c) improvement of aquaculture legislation and (d) mandatory environmental Impact assessment (EIA).

In Latin America, environmental issues are often difficult to define and manage (FAO, 2017c). Several producer associations have developed their own best management practice manuals, as have NGOs, international organizations and others. Environmental Impact Assessments are becoming mandatory. Aquaculture in LAC increasingly is conceived as a possible source of seed or juveniles to replenish water bodies that have been depleted through overfishing, and where artisanal fishers can no longer make a living. Fish stocking, as done for decades in several Asian countries (Thorpe *et al.*, 2011), might be explored locally as a new way to exploit marine resources. Many environmental concerns are still attached to this idea, and their implications need to be considered before these initiatives become established (FAO, 2017c).

In general, environmental performance of aquaculture has improved significantly over the past decade, globally. According to Waite *et al.* (2014), if aquaculture is to double its production by 2030, and for growth to be sustainable, the sector must improve its productivity while at the same time improving environmental performance. Aquaculture is continuously being intensified all around the world, and to achieve "sustainable intensification," aquaculture must: (a) advance socioeconomic development; (b) provide safe, nutritious food; (c) increase production of fish relative to the amount of land, water, feed, and energy used; and (d) minimize environmental impacts, fish diseases, and escapes (FAO, 2017a).

PRODUCTS, MARKETS AND TRADE

Fish and fishery products are arguably the most traded food commodity in the world. Over 75 percent of global seafood products appears to be entering the international markets. Globally, in 2014, fishery trade represented more than 9 percent of total agricultural exports (excluding forest products) and 1 percent of world merchandise trade in value terms (FAO, 2016a).

Due to a multitude of reasons, including higher disposable incomes, urbanization, awareness of the value of fish in nutrition, global fish consumption has been growing at a faster rate than global population growth. Per capita consumption is rising annually by about 1 percent. Expected per capita consumption in 2016 was 20.5 kg per year, compared with 20.3 kg in 2015 and 17.6 kg a decade ago in 2006. The total value of world trade in seafood products in 2014 was US$148 billion. These values are subjected to fluctuation, mainly due to fluctuation of the US dollar against multiple currencies.

Estimates indicate that aquaculture products represent between 20 and 25 percent of traded quantities (33 – 35 percent in value terms), indicating that an important segment of the industry is export-oriented producing relatively high-value products. If only fish products for direct human consumption are considered, the share increases to 26 –28 percent of traded quantities and 35 – 37 percent in value (FAO, 2016a).

China is the largest exporter of fish and fishery products in the world. China's imports of fishery products are also growing, making it the world's third-largest importing country. The increase in China's imports is partly a result of outsourcing of processing from other countries, but it also reflects the country's growing domestic consumption of aquatic species which are not produced locally.

In 2014, Norway and Viet Nam recorded as second and third major exporters of aquatic food. Thailand has experienced a substantial decline in exports since 2013, due to reduced shrimp production resulting from the disease AHPND. Between Viet Nam and Thailand, considerable number of people are employed in the processing industry, contributing significantly to the economy through job creation and trade.

In 2014, combined imports of the EU, the United States of America and Japan represented 63 percent by value and 59 percent by quantity of world seafood imports. In addition, many emerging markets and exporters have gained importance over the last decade.

Intra-regional flows continue to be significant, although often this trade is not adequately reflected in official statistics, for Africa. Improved distribution systems, as well as expanding aquaculture production, have enabled increasing regional trade. The Latin America and the Caribbean region remains a net exporter of fishery products, as do Oceania and the developing countries of Asia. However, Africa has long been a net importer in quantity terms, reflecting the lower unit value of imports. Europe and North America are characterized by a fishery trade deficit. The value of Norwegian seafood exports, led by cultured salmon reached US$11 billion in 2014. With the significant weakening of the Norwegian currency against the US dollar since 2014, this value has been fluctuation slightly.

Due to disease outbreaks, especially the AHPND outbreaks in China, Thailand and Viet Nam, shrimp production in East and Southeast Asia fell between 2011 and 2015. Similarly, during the same period, production in the southern Indian states of Andhra and Tamil Nadu was also affected by disease outbreaks (white spot syndrome, *Terocytozoon hepatopenaei*, white faeces and running mortality syndromes) and flooding. However, owing to the general trend in shifting production from *P. monodon* to *P. vannamei*, overall supply in India has been balanced. India's annual production of shrimp is about 600 000 tonnes.

Asia continues to dominate global tilapia exports. Asia exports about 150 000 tonnes of tilapia annually. The top five producers in the region are China, Indonesia, Taiwan Province of China, Thailand and Malaysia. The emerging Near Eastern markets; Kuwait, the United Arab Emirates and Bahrain, are becoming strong and lucrative with reasonable price premiums. It is interesting to note that sashimi grade tilapia fillet is exported to Japan at an average price of US$1–12 per kg. The other main cultured species in the international market is the Basa Catfish – *Pangasius*. Various climatic conditions such as droughts and floods have been affecting pangasius production in Viet Nam, although during the first half of 2016, Vietnamese pangasius exports reached close to US$800 million. *Pangasius* is exported all-round the world and markets fluctuate slightly based on national and regional demands.

The giant river prawn *Macrobrachium rosenbergii*, industry has been facing significant disease challenges over the past several years. Hatchery production of postlarvae has been reduced and production in several countries, including Bangladesh, has gradually fallen. Macrobrachium rosenbergii noda virus (MrNV) has been considered the main course. No effective prevention method has yet been found. However, efforts towards developing SPF broodstock and post larvae has been successful and currently these SPF lines are commercially available in Thailand.

Aquaculture certification is a somewhat new area under discussion. Although only a small percentage of aquaculture products are currently certified, it appears that efforts by major certifiers are gradually paying off and more aquaculture products are entering the market with certified labels. Small-scale aquaculture has been a significant hurdle for the certifiers to progress, particularly due to the scale and not producing a volume which offers bargaining power in a market economy. However, strategies are being developed, particularly by empowering small-scale farmers through clustering them into manageable and certifiable groups (Kassam, Subasinghe and Phillips, 2011; Immink and Clausen, 2017). This is currently being piloted in several countries in Asia and products from small-scale sector, certified as sustainably produced will be available in the markets in the foreseeable future.

FOOD SECURITY, NUTRITION AND SOCIAL DEVELOPMENT

Aquaculture's contribution to global food security, nutrition and social development has been fully recognised and been highlighted in many publications and fora. There are several major reviews on the subject: World Bank (2007), Allison (2011), IFPRI (2015) and Béné *et al.* (2016). Furthermore, FAO (2017a) also recently echoed the importance of fish for improving global food and nutrition security over the coming decades. Aquaculture contributes to better livelihoods by creating employment in the aquaculture value chain, thus increasing income and providing a nutritious and affordable animal food source to the world.

The importance of fish and fishery-based activities to food security in less-developed countries is particularly prominent in those communities engaging in small- to medium-scale operations in Africa and Asia (IFPRI, 2015). This is the result of both the consumption of fish that takes place in the households engaged in fishing and fish farming operations as well as the income that these households generate. In 2014, 84 percent of the global population engaged in the fisheries and aquaculture sector was in Asia (FAO, 2016a). More than 18 million (33 percent of all people employed in the sector) were engaged in fish farming, and 94 percent of all aquaculture engagement was in Asia. The statistics clearly indicate the important and increasing contribution of aquaculture to Asia regional food and nutrition security and socio-economic development.

Aquaculture improves nutritional status of rural poor, especially among mothers and young children (Thilsted *et al.*, 2016), although there are concerns that growth of the sector, combined with intensifications of production methods, may result in a decrease in the availability of certain fatty acids and micronutrients (Bogard *et al.,* 2017). Considering the increasing global population and importance of feeding the future world with a heathy diet, Béné *et al.* (2016) stressed that fish should be on everyone's plate and access to fish is a key issue in creating healthy populations, especially among rural poor, worldwide. This trend is continuing, although some issues and concerns such as the true nutritional benefit of certain species of farmed fish for rural poor compared to the consumption of some local small fish species with high nutritional value, are brewing.

IFPRI (2015) claims that, dues to the high commodity value, there is a trend towards increasing production of shrimp in Asia. They argue that considering the increasing cost of fishmeal, which is a main ingredient for shrimp feed, there is also a trend in sourcing fishmeal locally using small local species that would otherwise have been consumed directly by humans. A trade-off exists between export value and local nutrition. In several countries in Asia, particularly in Bangladesh and India, efforts are being made to improve household fish consumption through increase traditional homestead fish production. These efforts are providing convincing results and these interventions and principles are now proving successful and adaptable and/or repeatable in other countries (Bogard *et al*., 2017).

The role aquaculture and fisheries could play in combating malnutrition is significant, as was highlighted during the preparations of the Second International Conference on Nutrition (ICN-2), held in November 2014 (HLPE, 2014). The wide range of highly bioavailable micronutrients present makes fish a unique food commodity. Both wild and farmed fish are healthy and a better alternative to almost any other animal source foods. Farmed fish have a more constant nutrient composition compared to their wild counterpart, whose environment, food and access to food varies during the year. However, with the intensification of aquaculture production methods, and with the increasing use of plant-based feedstuffs, care must be taken to ensure that farmed aquatic animal products have as high nutrient contents as possible (Beveridge *et al*., 2013; Bogard *et al*., 2017).

Consumption of fish and especially oily fish is essential for an optimal development of the brain and neural system of our children, since omega-3 fatty acids in the form of DHA (docosahexaenoic acid) rather than ALA (α-Linolenic acid) is needed to secure an optimal brain development (Thilsted *et al*., 2016). This is particularly important during pregnancy and the first two years of life (the 1000-day window).

Since fish oils are in increasing demand, alternatives as sources for long-chain omega-3 oils must be explored. Dependence on fish oil for fish feed should be reduced and more attention should be given to produce fish low in the food chain, especially the non-fed freshwater species. Fish should be considered and promoted as an alternative to less healthier diets in the present world. Particularly, small indigenous fish species, which could be eaten whole, which are very high in micronutrients such as vitamin A and B12, should be promoted and their production should be increased, where appropriate. This has been proven in Bangladesh by the research conducted by the WorldFish (Bogard, Thilsted and Marks, 2015).

Seafood consumption in Latin America is low compared to other geographic regions in the world. In 2013, local apparent consumption per person was about half of world levels, equaled only by Africa, the difference being that Africa achieves that level through net imports, while the LAC region is a net exporter (FAO, 2017c). Moreover, LAC's seafood contribution to protein availability in the average diet is also minimal at only 3.4 percent of the total intake (4.3 percent in Africa, and 6.6 percent as a world average). Fish performs better as a share of total animal protein in the average diets (16.8 percent at world level; 6.7 percent in the LAC region and a variable performance in other continents). These indicators suggest that aquaculture contributes moderately to food security in the LAC region. However, average figures hide the important contribution of fish to human nutrition in many LAC countries, due to inaccessibility and difficulties in enumeration of communities. That is the case of several areas in the

Brazilian Amazon, where fish consumption is much more significant to local populations than what averages suggest. Because of the high value of aquaculture products and limited domestic consumption in the LAC region, aquaculture exports are very important to many countries such as Chile, Ecuador and Honduras and provide fairly stable jobs in an array of activities ranging from primary production to services, R&D, etc.

However, in several Caribbean nations/territories and in the Republic of Peru, fish apparent consumption exceeds that of all red meats put together, so the nutritional role of fish is significant, as their share in total protein availability in the average diets surpasses 20 percent. At the opposite end, in most South American countries, seafood's contribution to average protein intake is very low, a situation that must be addressed by local authorities through promotional policies aimed at improving fish consumption and aquaculture production. Also, seafood contribution to the supply of calories in LAC's and the world's diets is extremely limited (FAO, 2017c).

The contribution of aquaculture to fish consumption in NENA region is insignificant, except in Egypt and Iran (Islamic Republic of), which represented 61 and 42 percent, respectively, of total per capita fish consumption in 2013 (FAO, 2017d).

A key concern about the development of aquaculture is the necessity of producing carnivorous and omnivorous fish. In Europe, carnivorous fish represent the largest sector (Atlantic salmon) and the faster growing segments (Atlantic seabass and gilthead sea bream) using fish meal and fish oils ingredients to feed them. However, as noted by the high-level panel of experts on food security and nutrition (HLPE, 2014), from a food security and nutrition perspective, the debate continues whether it would be preferable to use such fish directly for human consumption rather than for fishmeal, especially as 'lower grade' but nutritious fish could be consumed by food-insecure people. Recently, Peru has allocated – for the first time in the history – a quota for anchovy fishing for human consumption (Undercurrent News).[7]

Traditional extensive carp production in large ponds and waterways in Eastern Europe – mainly in the Russian Federation, Ukraine, Poland, Hungary, the Czech Republic and Germany – represents more than just a significant supply of fish (238 000 tonnes in 2014, the third most-produced finfish in Europe). The traditional pond systems and waterways, the design and original construction of which in many cases dates back hundreds of years, also represent managed landscapes with the ponds being crucial components for biodiversity conservation (Seiche *et al.*, 2015). The continuation of this sector of aquaculture also has strong social, cultural and ecosystem benefit (Stündl *et al.*, 2014) and provides food, nutrition and employment in rural areas (Váradi *et al.*, 2011).

GOVERNANCE AND MANAGEMENT

Good governance is key to achieving sustainable economic, institutional, environmental and social development in a country. While governance is a complex notion that is difficult to capture in a single and simple definition, it has been directly or indirectly referred to as 'the process by which governments are chosen, monitored and changed; the systems of interactions between the administration, legislature and judiciary; the ability of governments to create and implement public policy; and the mechanisms by which citizens and groups define their interests and interact with institutions of authority and with one another' (McCawley, 2005). In the case of the aquaculture sector, good governance is fundamental to successful formulation and implementation of aquaculture development policies, strategies and plans (Hishamunda, Ridler and Martone, 2014).

[7] www.undercurrentnews.com/2017/05/02/peru-launches-anchovy-quota-for-human-consumption/

With growing expectations of the aquaculture sector's contributions to food security, poverty alleviation, economic growth and sustainable development, the need for sound planning and area management (Brugère *et al*., 2010; FAO and World Bank, 2015) is increasingly being acknowledged by governments. Good planning and policy-making are the key means by which governance can be improved. Planning guides the evolution of the sector by leading to policies, strategies and action plans that provide incentives and safeguards, attract investments and boost development. Improved planning and policy formulations require several challenges to be addressed: integrating and managing multiple stakeholders' interests, ensuring availability of adequate funding, developing human capacity, preventing conflicts and developing mitigation measures, and having supportive legislation, rules and regulation in place that provide practical guidance to aquaculture policy-makers and implementers on policy.

In general, aquaculture governance has improved, globally, over the past decade. As production has increased, regional and international markets have improved, along with the quality of produce. Consequently, requirements for complying with international trading standards, including compliance to agreements from the World Trade Organization (WTO) and Sanitary and Phytosanitary Measures (SPS) became critical and policy, institutional and regulatory frameworks have been developed and implemented in many countries in the world. In parallel, environmental impacts checks, rules and regulations have also improved and almost all countries now apply EIAs and various other regulatory frameworks to make aquaculture more sustainable. The latest addition to the regulatory tools governing aquaculture sustainability is certification of aquaculture, although its significance to small-scale aquaculture has yet to be proven.

As aquaculture governance has improved and production increased in the Asia-Pacific region, many products have found markets internationally. However, aquaculture governance will need to become even more important in the future, as the sector marches ahead. All four facets of sustainability – social, economic, environmental, and governance – will face challenges in the coming decades. As described by Hishamunda *et al.* (2012), some of the likely challenges that are intrinsic to the industry as it grows include the emergence of oligopolies in the production of certain species, reconciling competing claims to water and land, the need to manage aquaculture within a deteriorating ecosystem, vocal opposition from well-funded NGOs and funding of local research. These all are fully relevant to the Asia-Pacific region and should be addressed when changing/improving appropriate policies and regulatory frameworks that govern better aquaculture (FAO, 2017a).

The principal regulatory and support frameworks for aquaculture in the European Union since the early 1970s have come from the Common Fisheries Policy (CFP). Norway and Russian Federation are two major players in Europe outside the EU. One of the main governance issues in aquaculture within the EU is the obstacles to obtaining permissions for a new aquaculture site. Allocating zones for aquaculture and exploiting competitive advantage involves building on the reputation of European products for environmental protection, health and consumer protection, informing consumers better through food labels and information campaigns, and exploiting niche markets through certification schemes such as organic aquaculture are few other topics of concern being discussed (Sanchez-Jerez *et al.*, 2016).

In Europe, recognizing the role of retail chains as "choice editors" for consumers, environmental and other lobby groups has applied pressure to retailers to be accountable for the provenance, safety and environmental and ethical credentials of the products they sell. This in turn has stimulated industry to develop appropriate standards and codes of practice, often in partnership with lobby groups and other stakeholders that can be certified by third parties.

The Norwegian government has decided that the environmental footprint of salmon farming will dictate official consent for future growth. It has moved from a position of "maximum allowable biomass in marine cage farms" to one where companies within designated zones are rewarded for effective environmental controls by receiving increased biomass allocations for 'eco-aquaculture' (fish farms that reduce escapes, manage sea lice without resort to chemicals and that reuse wastes) (FAO, 2017b).

In the NENA region, several gaps in governance and management of the aquaculture sector have been identified. In many countries, governance and regulation of the sector is generally carried out by more than one authority. Conflict of interest sometimes arises among authorities, leading to poor management strategies and policies. Fisheries and aquaculture legislation in some NENA countries may contain some overlaps. In many cases, specific laws and regulations may be outdated and do not reflect the recent concepts and approaches developed for responsible and sustainable aquaculture management or meet the needs of the sector. Regulatory provisions for quality, biosecurity, traceability and safety of farms and farmed fish products and fish feed inputs are weak and inactive in almost all NENA countries. Most NENA countries do not have comprehensive regulatory and quality control systems that address fish quality control inspections and human food safety hazards in animal feeds (including fish feed). No aquatic animal health control system for aquaculture is available, exposing the sector to potential disease risks. Fish farmers' associations and unions are generally weak, and in some cases, do not exist (FAO, 2017d).

Although several governments have made concerted efforts to improve aquaculture governance and management of the sector in sub-Saharan Africa in recent years, efforts have not been evenly spread. Many countries have yet to elaborate policies, framework strategies and plans, while the rate of implementation of elaborated instruments is low. There are long time lapses between policy formulation, policy adoption and the formulation of concerted action plans, so that strategies may no longer apply in rapidly changing circumstances. For all countries in SSA, the CCRF is the reference instrument for the management of the sector. Countries should update their essential instruments in line with changes in the sector; promote participatory and inclusive mechanisms involving all stakeholder groups in the formulation of essential instruments and build capacity for the implementation of developed instruments (FAO, 2017f).

FAO (2017c) indicates that governance through sound policy, planning and supporting mechanisms is inefficient or lacking in the LAC region. In only a few countries is aquaculture considered an extension of fisheries, a troubled and declining activity with different actors and problems, while aquaculture, a novel and growing undertaking needs more resources, space and attention to facilitate expansion. In most countries, these new mechanisms and strategies have yet to be developed and/or implemented. Therefore, it is not surprising that many governments have a conservationist approach to production, implementing barriers that make fish farming progress difficult. Some do not make a sufficiently clear distinction between small and large-scale producers, requiring small-scale farmers to adhere to norms and regulations which make it difficult for them to start new projects or become legally established.

In most instances the industry is not sufficiently well-organized to represent its members and their needs to authorities. Small-scale producers either work individually or become members of cooperatives or other organizations that are poorly managed. Licensing is an increasing problem in the LAC region. Authorization arrangements such as those related to licenses and permits vary a lot from country to country but generally may take several years to be completed; they are expensive and require expertise that is mostly available through external consultants. Negative public perception and a general lack of awareness of aquaculture in local and rural communities has also been the cause of concern and conflict, as aquaculture has become established in generally traditional environments, bringing employment policies, requirements and conditions which are often alien to people and disrupt their way of life (FAO, 2017c; Bacher, 2015; FAO, 2016a).

EXTERNAL PRESSURES AND RESILIENCE

Global aquaculture has faced several major natural, biological, technical and complex disasters in the past decade. According to a recent assessment conducted by FAO for the period 2003–2013, the agriculture sector – including fisheries and aquaculture – absorbs 22 percent of the economic impact caused by medium- and large-scale natural disasters in developing countries. More specifically, disease outbreaks have cost significant production losses in the aquaculture industry (Brown and Poulain, 2013; Cattermoul, Brown and Poulain, 2014).

It has been projected that tropical ecosystems are more vulnerable to climate change, with negative impacts on their dependent communities. FAO, 2016a claims that climate change will affect food security in Asia by the middle of the twenty-first century, with South Asia most severely affected (Handisyde, Telfer and Ross, 2016; Handisyde *et al.*, 2006).

In sub-Saharan Africa, the impact of climate change on aquaculture is not yet fully understood. However, indications suggest that changes such as increasing temperature, sea level rise, ocean acidification, water availability changes and water stress, effects of extreme weather, etc. are all likely to be important external pressures that could affect aquaculture in the coming decades. According to UNECA (2016), severe drought associated with El Niño,[8] civil arrests and terrorism have affected several economies in SSA which tend to increase the costs of inputs, particularly aquafeeds and farm machinery, resulting in increased production costs that makes fish more expensive.

Many climate related incidents created external pressures to aquaculture in Latin American and the Caribbean. Droughts near Sao Paulo, hurricanes, floods, earthquakes, volcanic eruptions, landslides and droughts in the Caribbean, volcanic eruptions in southern Chile, floods in many parts of the continent, red tides, algae blooms and unusually high temperatures in 2015 have challenged farm managers all over the region, confronting them with stressed fish, diseases, high mortalities, interrupted production cycles, massive economic losses, unemployment and supply interruptions that affect markets and prices. No single organization or technical body can deal with the above-mentioned circumstances on its own. LAC aquaculture is in need of international cooperation and serious improvements in management in all dimensions, to cope with the difficulties that impair, delay and make expansion and development of aquaculture more expensive (Soto and Quiñones, 2013; FAO, 2017c).

In Europe, potential external pressures considered include direct and indirect consequences of climate change, disease outbreaks of epidemic proportions and ecological changes not attributable to climate change. The use of RAS is considered as a mean for reducing the potential impact of environmental change on the aquaculture industry. Anticipation of future potential environmental conditions such more storms and more frequent, higher waves should be a consideration in designing new equipment. The current consideration of moving cage farming further offshore provides opportunities for designing for more extreme conditions and incorporating remote structural monitoring capability.

There are three main kinds of external pressures on the aquaculture sector in North America. Two of them – climate change and pollution events – act mainly on the natural and physical resources upon which aquaculture relies. The third category of external pressures is economic, and acts on the industry's ability to fund development and sell products. The main impacts of climate change on aquaculture include changing water temperatures, sea level rises, increase in number and severity of coastal storms, ocean acidification and water quality effects including groundwater salinity. The direct and indirect effects of higher water temperatures on aquaculture have also been discussed. Severity of coastal storms may be most acutely felt by shellfish aquaculture operations in the Gulf of Mexico. Ocean acidification

[8] El Niño is a climate cycle in the Pacific Ocean with a global impact on weather patterns.

has become a more pressing problem for shellfish farms in 2010–2015. In addition, the pollution events most likely to affect aquaculture are oil pipeline breaches (which can affect freshwater quality), offshore oil rig spills and spills from tankers travelling along coastal routes. The pivotal role played by currency exchange rates in the trade in aquaculture products between Canada and the United States of America is also an additional pressure on the sector. Economic impacts of increasing consolidation of many aquaculture operations in North America can't be ignored.

In the coming decades, survival and expansion of North American aquaculture will demand constant agility in the face of changing ocean conditions, including not only temperature but also weather, circulation patterns, sea level and ocean chemistry. Even the ecosystems within which aquaculture takes place will change, leading to changing interactions with predators, parasites and disease organisms (FAO, 2011; FAO, 2017d).

The aquaculture sector in the NENA region is fragile and highly sensitive to environmental conditions. In addition, economic, social and financial conditions and crises directly or indirectly affect the sector, especially when the availability of major inputs (such as feed, seeds and energy) is insufficient, or when their prices are affected. The implications of climate change for food security and livelihoods are profound in the NENA region. There have been occasional mass mortalities of farmed and wild fishes in Egypt and Gulf countries (e.g. Oman and United Arab Emirates) due to unexpected high water and air temperatures, oxygen depletion or harmful algal blooms (HABs) (FAO, 2017d). Military conflicts, civil wars and political instability limit the development of agricultural sectors, including aquaculture, in Libya, Iraq, Palestine, Sudan, the Syrian Arab Republic and Yemen.

Natural disasters have become more frequent and increasingly destructive during the last few decades. Communities depending on fisheries and aquaculture for their livelihoods are threatened both by natural hazards and human-induced disasters. Outbreaks of disease and other threats to farmed fish have caused large production losses. Preparedness to mitigate and adapt to the negative effects of climate change, natural disasters and drought is essential, and national and regional strategies need to be elaborated. Such strategies should be regularly evaluated, revised and improved.

Although disaster preparedness has not been adequate in all regions of the world, the collective efforts towards responding to the disasters that have happened so far are considerable. The sector has shown its resilience. However, what is important is to learn from past lessons and increase disaster preparedness for more efficient response to the possible events in the coming decades. This requires significant government involvement and it should increasingly be considered as state responsibility. Assistance from relevant international and regional agencies should be continued. As FAO (2016a) pointed out, promoting sustainable aquatic resource management through the development and implementation of ecosystem-friendly and participatory policies, strategies and practices should be given priority to reduce, prevent or mitigate impacts from disasters.

For mitigating the impacts, more options have been explored. This includes the introduction of market mechanism such as aquaculture insurance. Recently it is piloted in some countries such as China and Viet Nam. It is aimed to help reduce burden on the relieved and rehabilitation funds. It also deems as part of social protection policy, targeting small-scale operations for a quick recovery after a disaster (FAO, 2016b).

TOWARDS 2030

The Blue Growth Initiative (BGI) of FAO is a flagship initiative that aims at supporting 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. It is implemented during three broad phases: 1/the enablement of changes towards a Blue Economy, 2/the learning from the transformations occurring, and 3/the mainstreaming into policies and action plans. It considers three interlinked platforms of organizational change: the Blue Communities, the Blue Production (of which aquaculture and fisheries are part) and the Blue Trade. The FAO Blue Growth Initiative is expected to assist countries in developing and implementing blue economy and growth agendas. It is fully recognized that the efficient implementation of the Code of Conduct for Responsible Fisheries (CCRF) will help achieving the Blue Growth (FAO, 2015; FAO, 2016c).

In agriculture and food – the way food is grown, produced, consumed, traded, transported, stored and marketed – lies the fundamental connection between people and the planet, and the path to inclusive and sustainable growth. In fact, the 2030 Agenda emphasizes people, planet, prosperity, peace and partnership. FAO has been highlighting the fact that food and agriculture are key to achieving the 2030 Agenda.

Agenda 2030 and the SDGs are highly relevant for policy-making, planning and management for sustainable development of aquaculture. In particular, SDGs 1 (end poverty), 2 (end hunger), 5 (gender), 8 (growth, employment), 12 (production and consumption), 13 (climate change), 14 (marine resources and ecosystems) and 15 (biodiversity) will have significant bearing for aquaculture, but also other SDGs will influence the work of FAO Members and partners in their efforts of promoting sustainable aquaculture development. Aquaculture, when developed appropriately, will also contribute to the achievement of many other SDGs.

A recent analysis shows that most available international guidance focusing on aquaculture development broadly matches the expectations of the SDGs. Existing international commitments and calls on sustainable aquaculture development, such as in the Code of Conduct for Responsible Fisheries, its associated Technical Guidelines for implementation of the CCRF, the 2000 Bangkok Declaration and the 2010 Phuket Consensus, and the FAO Blue Growth Initiative – which includes the Ecosystem Approach to Fisheries and Aquaculture (EAF/EAA) – are generally well aligned with Agenda 2030 and will generally support the delivery of the SDGs (FAO, 2017h).

Fish provides more than 4.5 billion people with at least 15 percent of their average per capita intake of animal protein. Fish's unique nutritional properties make it also essential to the health of billions of consumers in both developed and developing countries. Fish is one of the most efficient converters of feed into high quality food and its carbon footprint is lower compared to other animal production systems. Fisheries and aquaculture value chains contribute substantially to the income and employment and therefore to the indirect food security of more than 10 percent of the world population, essentially in developing countries and emerging economies.

Fish is more than just a source of animal protein. Fish contains several essential amino acids, especially lysine and methionine. The lipid composition of fish, with the presence of long-chain, poly-unsaturated fatty acids (LC-PUFAs), is unique. Fish is also an important source of essential micronutrients – vitamins D, A and B, and minerals (calcium, phosphorus, iodine, zinc, iron and selenium), which makes it particularly attractive in the current fight against malnutrition in low income and food deficient countries (LIFDCs).

The geography of fish as a source of protein is also significant to food security and nutrition. Twenty-two of the 30 countries where fish contribute more than one-third of the total animal protein supply were officially referred to as LIFDCs in 2010 (Kawarazuka and Béné, 2011). In other words, almost three-quarters of the countries where fish is an important source of animal protein are poor (income-wise) and food-deficient. Yet in these LIFDCs, even if fish is a substantial proportion of the food intake, undernourishment can still occur as total food intake is often insufficient.

UN predicts that the global population will reach 8.5 billion in 2030.[9] This will inevitably increase the pressure on the food sectors to maximize production and reduce waste. Production increase must occur in a sustainable way and in a context where key resources, such as land and water, are likely to be scarcer and where climatic change impact will intensify. The fish-production sector is no exception.

In this context two key questions emerge. First, will fisheries and aquaculture be able to maintain the current supplies for a global fish consumption rate of 20 kg per capita per year, and the equivalent regional values, and if not, how will society address the needs of expected winners and losers (Barange *et al.*, 2014). The second key question is whether sustainable fisheries and aquaculture will be able to help address the bigger food security issue that will affect the world in the coming decades?

Recently, the FAO Fisheries and Aquaculture Department has developed a projection model (Cai and Leung, in press) to assess and monitor potential future fish demand and supply at the country, regional and global levels for 9 species groups at different aggregate levels. The results indicate that, if an income driven future for world fish demand is predicted and a production of fish takes place as “business as usual” (supply based on continued recent growth trends), there will be a demand-supply gap of 48 million tonnes by early 2020 (i.e. only 40 percent of the demand will be met by the supply based on a “business as usual” scenario). Since the trend of aquaculture growth would only cover 40 percent of the projected world fish demand growth and capture fisheries production is expected to have little growth, the resulting excess demand would tend to drive up fish price, which would dampen the demand growth. Therefore, per capita fish consumption (as realized fish demand) in the early 2020s would likely be less than 25 kg/year if global aquaculture follows its recent trend, or what we consider business as usual. However, the 25 kg/year consumption target could be sustained if aquaculture growth could be accelerated from 4.5 percent business as usual growth to 9.9 percent a year.

In contrast, Chan *et al.* (2017) in an analysis of future aquaculture production in the Association of Southeast Asian Nations (ASEAN) region concluded that both aquaculture and capture fisheries production will continue to grow, but capture fisheries will remain the dominant fish supply by 2050, and aquaculture will supply more than half of fish consumed in the coming decade.

Golden *et al.* (2017), in a recent study focussing 41 nutritionally vulnerable nations (NVNs), tried to find whether aquaculture meets human nutritional demand directly via domestic production or trade, or indirectly via purchase of nutritionally rich dietary substitutes. They found that a limited number of NVNs have domestically farmed seafood, and of those, only specific aquaculture approaches (e.g. freshwater) in some locations have the potential to benefit nutritionally vulnerable populations. They also determined that subpopulations who benefit from aquaculture profits are likely not the same subpopulations who are nutritionally vulnerable, and more research is needed to understand the impacts of aquaculture income gains.

Development of both aquaculture and fisheries should ideally be dealt at regional levels to strengthen regional policies, as there is considerable interaction between the sectors as well as with the regional socioeconomic development of coastal and rural communities. Although, both fisheries and aquaculture contributes significantly to food and nutrition security, the potential implications for environmental sustainability should not be forgotten. Therefore, the relevant regional policies for promoting aquaculture should be drawn with the view to also strengthen regional fisheries governance and management.

[9] www.un.org/sustainabledevelopment/blog/2015/07/un-projects-world-population-to-reach-8-5-billion-by-2030-driven-by-growth-in-developing-countries/

The FAO forecast of the apparent supply-demand gap in early 2020s and Golden *et al.* (2017) study suggest that aquaculture is unlikely to contribute substantially to human nutrition in NVNs, together with the need for more integrated efforts to develop policies addressing both fisheries and aquaculture for human wellbeing, leave us to rethink and redesign our strategies towards aquaculture development worldwide. We need a paradigm shift in thinking from “aquaculture development” to “aquaculture for sustainable development”, targeting fish as the entry point for improving nutrition and livelihoods of targeted communities consisting billions of people worldwide.

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