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REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN ASIA-PACIFIC – 2020

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REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN ASIA-PACIFIC – 2020

by

Sena S. De Silva
School of Life & Environmental Sciences
Deakin University
Victoria
Australia

Derun Yuan
Network of Aquaculture Centres in Asia-Pacific
Bangkok
Thailand

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PREPARATION OF THE DOCUMENT

The present document "Regional review on status and trends in aquaculture development in Asia-Pacific" was prepared by FAO as one of the six regional reviews commissioned in 2020. The preparation of the document was carried out with the overall guidance of Matthias Halwart and coordination of Uwe Barg. The review was compiled by Sena S De Silva as a consultant and Derun Yuan, a senior programme officer of the Network of Aquaculture Centres in Asia-Pacific (NACA). FAO professional staff in Headquarters and Regional Office for Asia and the Pacific, reviewed the drafts at different stages. The entire FAO review process of the document and finalization of the document was coordinated by Miao Weimin. The key messages of the document were presented and discussed during a public webinar on 26 October 2020 with the participation of more than 600 participants representing government authorities, academia, aquaculture practitioners, regional aquaculture organizations, professional associations, and civil society organizations.

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

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

Key words: *aquaculture development, Asia, Pacific, production trends, value, markets, major commodities, consumer preferences, technology developments, external pressures, governance, policies, strategies.*

ABSTRACT
This regional review presents the development status and aquaculture trends in the Asia-Pacific region from 2008 to 2018. It analyses the factors that drive aquaculture growth, examines the issues and challenges and provides perspectives of the way forward for future development of the sector. The document is one of a series of reviews on aquaculture development in different regions and globally prepared for the Global Aquaculture Conference 2020+ to be held in Shanghai.

Aquaculture in the Asia-Pacific region continued to grow from 2008 to 2018 at an average annual growth rate of 5.2 percent. Total aquaculture production in the region reached a historical high of 105 million tonnes in 2018, which accounted for 92 percent of global aquaculture production. Eastern and South-eastern Asia produced 90 percent of the region's total, while negligible production was observed from Oceania and Central Asia, accounting for 0.3 percent of the region's total.
Aquaculture contributed significantly to achieving SDGs in the region. It provided over 60 percent of the 2017 average annual per capita food fish consumption in the region of 24.1 kg , supplying 25.2 percent of the average animal protein intake. The total value of aquaculture production in the region reached USD 223 billion and the sector directly employed 19.6 million people across the region in primary production and about the same number of people in related supporting and service businesses in 2018. Aquaculture in the region has been making good progress to address its negative impact on environment and adapt to climate change for sustainability and resilience. It also contributes to conservation of aquatic biodiversity with hatchery seed production of endangered species for production and wild stock enhancement.

Growth of aquaculture in the region has been driven by increasing demand for aquatic food in both domestic and international markets. The region has been the major producer and consumer of aquaculture products. It is also the major supplier, exporter and an increasingly important importer of aquaculture products in international trade. There has also been steady increase in the intraregional trade. Aquaculture development in the region has largely benefited from and been sustained by conducive government policies, well-established services such as aquafeed and quality seed production and supply, production intensification, improved animal health management, and strengthened overall sectoral governance.

However, aquaculture growth in terms of the annual production growth rate has been slowing down especially in recent years and development is not geographically balanced across the region, indicated by production dominance by Eastern and South-eastern Asia, though great potential exists in other sub-regions. Some major issues challenging the growth of aquaculture in the region include the vulnerability of small-holders in access to resources and services, adaptation to climate change and other natural disasters, changing socioeconomic environment such as migration of young generation and market volatility caused by trade conflicts.

Aquaculture in the region is expected to continue to grow to meet increasing demand for aquatic foods for growing populations. The growth will mainly be sustained through intensification with enhanced productivity and environmental performance. There is a need to further mainstream aquaculture into the national food production and nutrition security systems with adequate policy and resource priorities. Good governance needs to be promoted. Research needs to be strengthened with increased investment. Collaboration among multiple stakeholders and across the region needs to be strengthened to facilitate knowledge sharing, information dissemination and technology transfer.

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Abbreviations and acronyms

AMR	Antimicrobial Resistance
APFIC	Asia-Pacific Fishery Commission
APR	annual percent rate of growth
BMPs	better/best management practices
BOB-IGO	the Bay of Bengal Inter Governmental Organization
CAFS	Chinese Academy of Fishery Sciences
CBF	culture-based fisheries
EIAs	Environmental Impact Assessments
FAO	Food and Agriculture Organization of the United Nations
GAPs	Good Aquaculture Practices
GDP	gross domestic product
GIFT	Genetically Improved Farmed Tilapia
GNI	gross national income
IMTA	integrated multi-trophic aquaculture
IUCN	International Union for Conservation of Nature
MRLs	maximum residue limits
NACA	Network of Aquaculture Centres in Asia-Pacific
NGOs	Non-Governmental Organizations
SDGs	Sustainable Development Goals
SEAFDEC	Southeast Asian Fisheries Development Center
SMEs	Small to Medium sized Enterprises
SPC	South Pacific Commission
SPF	specific pathogen-free
SPR	specific pathogen-resistant
TiLV	tilapia lake virus
UNDP	United Nations Development Programme
VASEP	Viet Nam Association for Sea Food Exports
WHO	World Health Organization
WSSV	White spot syndrome virus
WTO	World Trade Organization

Executive Summary

The Asia-Pacific region is remarkably diverse and wide ranging, geographically, in its flora and fauna, culturally, institutionally and economically. The region includes the two most populous countries in the world, China and India, a greater part of the Asian continent, the Australian continent, and many small islands, mostly in the Pacific Ocean, which are some of the smallest island nations in the world.

Fisheries and aquaculture are socio-economically important sectors to most nations in the Asia-Pacific region and most nations in the region have high rates of fish consumption, mostly sourced from aquaculture although the small island nations depend to a greater extent on capture fisheries.

This review entails analyses of the aquaculture sector in Asia-Pacific including the status and trends, progress made in achieving sustainable development, salient challenges, issues and anticipated future development. Status and trends are based on data extracted from the FAO Fishery and Aquaculture Statistics (FAO, 2020a; FAO, 2020b), unless stated otherwise, and are mostly for the period from 2008 to 2018 and occasionally for the period from 1990 to 2018 for relevant historical comparison and longer-term contextual analyses.

It is evident that from 2008 to 2018 Eastern Asia continues to be the major contributor to the aquaculture production in the Asia-Pacific region, contributing 65 percent to 70 percent, followed by South eastern Asia (20-25 percent) and Southern Asia (ten percent) and the rest including Central Asia and Caucasus subregion and Oceania contributing less than one percent collectively. China continued to dominate production in Eastern Asia and the region as a whole. Overall, regional aquaculture grew at an average annual rate of 4.9 percent and 8.5 percent for production volume and production value, respectively, from 2008 to 2018. The Asia-Pacific region accounted for more than 90 percent of global production. If China is excluded from this computation, the contribution of the rest of the region to global production is around 30 percent for the analysed period. The data suggests that aquaculture in the Asia-Pacific is essentially the “backbone” of global aquaculture, the main nation contributor to this status being China.

In 2018, total aquaculture production and its value in the Asia-Pacific region were 104.85 million tonnes and USD 210.89 billion, respectively, having increased from 64.06 million tonnes and USD 92.23 billion in 2008. However, the rate of aquaculture production growth fluctuated remarkably from a high value of 8.4 percent in the year 2012-2013 to low point of 2.1 percent in the year 2017-2018 and showed declining rates of increase from 2013 to 2018.

Aquaculture production in brackish water, fresh water and marine environments all showed a gradual increase over the years in the region, with the highest growth of marine aquaculture due to fast growth in cultured seaweed production, followed by culture in fresh and brackish waters. However, the total production values of marine culture were the lowest because of relatively lower unit value of seaweeds. Aquaculture in freshwater dominated the total production value from the three culture environments throughout the period from 2008 to 2018.

Finfish dominated aquaculture by volume in the region, followed by aquatic plants, molluscs, and crustaceans. Finfish also dominated aquaculture production value in the region, but crustaceans had the second highest production values in all years among the cultured commodities. In a global context many Asian nations were ranked among the top global aquaculture nations over the years, with China being top-ranked for the last four decades. The other Asia-Pacific nations that have been making major contributions to global aquaculture are Indonesia, India, Viet Nam, Bangladesh, the Philippines, Republic of Korea, Myanmar, and Thailand.

Low-cost species such as Chinese carps, Indian major carps, and tilapias remained dominant in finfish culture in the region, and indeed globally, contributing both the highest production volume and value among all species groups, indicating the significant importance of these species in aquaculture in the region and globally and their vital roles in food and nutrition security and rural development. Production of these species also has comparatively low carbon footprints compared with high trophic level finfish and shrimp.

The review examines in detail the changes in the well-established, aquaculture shrimp and tilapia subsectors, over the past few decades in the region and the reasons for the observed trends are highlighted. Emerging farming practices in the region are culture of mitten crab *(Eriocheir sinensis*), crayfish (*Procambarus clarkii*), a non-native species, and yellow catfish (*Pelteobagrus fulvidraco*), all grown in China for domestic markets.

There are a diverse range of production systems and farming technologies are in the region but pond culture at various levels of intensity dominates. Culture practices in general have been evolving and improving in the past decade to achieve better sustainability as indicated by improved resource use efficiency, better compliance with environmental regulations and reduced use of drugs and chemicals. Farming systems are likely to be further intensified to increase production in the wake of growing limitations on land and water resources and increasing demand for food fish by increasing populations. The past decades have seen significant innovations in traditional integrated aquaculture with many new practices emerging and combined with modern practices. The principles of reduce, reuse, and recycle will remain the main themes in new developments. Recirculating aquaculture and offshore cage culture, as two potential growth points for the sector, are expected to take more adaptive development approaches to local resources and business contexts if they are to play more important roles in further aquaculture production increases in the region. It is also noted that further extension of culture-based fisheries in shared water bodies with community-based management can contribute significantly to the local nutrition and livelihood.

The region has established reliable production and supply of aquaculture seed and feed. Related issues exist, for example, variation in seed and feed quality, dependence on imported feed ingredients including soy, fish meal and fish oil, as well as limited accessibility for small-scale farmers to quality and cost-effective feed and seed. The issues related to feeds and feeding in Asia-Pacific aquaculture are particularly elaborated in the review.

The review also presents the information on the status of aquaculture governance, animal health management and food safety in aquaculture, contribution of aquaculture to food security, social and economic development, impacts of external factors such as climate change and the COVID-19 pandemic on the aquaculture sector and regional networking for development collaboration.

The review shows there is a need to further integrate aquaculture into the national strategies for food security and nutrition with adequate policy and resource priorities, which will ensure its sustainable development through new initiatives embedded in policies, governance, technology development and services for greater contribution to attainment of sustainable development goals regionally and globally. Good governance needs to be promoted, research needs to be strengthened with increased investment in developing resource-efficient production systems, innovative farming practices, genetic improvement of strategically important species, biosecurity and aquatic animal health management. It is also suggested that collaboration among multiple stakeholders and across the region needs to be strengthened to facilitate knowledge sharing, information dissemination and technology transfer.

1.1 Social and economic background of the region

1.2 Background

The status and major issues relating to development of the aquaculture sector were discussed at two major global conferences, *Aquaculture in the Third Millennium* (Subasinghe et al., 2001) and *Farming the Waters for People and Food* (Subasinghe et al., 2012) while regular reviews on the status and trends in aquaculture development in Asia-Pacific have been published by FAO, most recently covering the period to 2015 (FAO, 2017a).

Fisheries and aquaculture are socio-economically important sectors for most nations of the Asia-Pacific region, most of which have high fish consumption rates. Fish for human consumption in the region now relies more on aquaculture although the small island nations depend to a greater extent on capture fisheries to obtain the food fish.

The current review analyses the aquaculture sector in the Asia-Pacific region for the period from 2008 to 2018, including the status and trends, progress made in achieving sustainable development, salient challenges, issues and its anticipated future development. The review attempts to trace the role of aquaculture in the region and evaluate its impact on the sector globally, as well as assess the extent to which aquaculture is contributing to food security as well as social and economic development. An attempt is also made to focus on the contribution of Asia-Pacific aquaculture developments to agendas that are of general importance and concern to the public, such as biodiversity conservation, food safety, climate change mitigation and environmental wellbeing. It should be noted that in the modern era the public perceptions and expectations on aquaculture production have changed considerably with an emphasis that all developments should ensure environmental sustainability.

The review covers the countries and territories in in the following sub-regions of the Asia-Pacific region:

- Eastern Asia, including China, China, Hong Kong SAR, China, Macau SAR, Democratic People's Republic of Korea, Japan, Mongolia, Taiwan Province of China and Republic of Korea.
- South-eastern Asia, including Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Viet Nam.
- Southern Asia, including Afghanistan, Bangladesh, Bhutan, India, Iran (Islamic Republic of), Maldives, Nepal, Pakistan and Sri Lanka.
- Central Asia and Caucasus sub-region, including Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.
- Oceania, including Australasia (Australia, New Zealand, Norfolk Island), Melanesia (Fiji, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu), Micronesia (including Kiribati and Marshall Islands) and Polynesia (Cook Islands, Samoa and Tonga).

Aquaculture production, value of produce, commodities, culture environments and other related aspects are based on data extracted from the FAO Fishery and Aquaculture Statistics (FAO, 2020a; FAO, 2020b), unless otherwise stated. For clarity, convenience and in relation to previous reviews, the trends in the sector have been considered mostly for the period from 2008 to 2018, and occasionally for the period from 1990 to 2018 for relevant historical comparison and longer-term contextual analysis. With a view to understanding the relative trends in the region, where appropriate and relevant, comparisons are made with equivalent trends globally.

1.3 Social and economic context of the Asia-Pacific region

The Asia-Pacific region is remarkably diverse and wide ranging geographically, in its flora and fauna, culturally, institutionally and economically. The region includes the two most populous countries in the world, China and India, a greater part of the Asian continent, the Australian continent, and many small islands, mostly in the Pacific Ocean, which are some of the smallest island nations in the world. Some relevant geographic, and socio-economic data on selected countries and territories of Asia-Pacific are provided in Annex 2.

The region accounts for more than half of the world population and contributes more than a third of global GDP. Since 2010, China has been the second largest and Japan the third largest economies in the world, with China being one of the fastest growing economies in the last three decades. The relative contributions from different sectors to gross domestic product (GDP) varies greatly between countries, with high-tech industry, manufacturing and services being the major contributing sectors in developed and some middle-income countries and territories, while agriculture and primary industries are the mainstays of economies in many other countries.

The Asia-Pacific region has seen tremendous economic and social progress over the last 50 years, as average income levels more than tripled, life expectancy at birth has increased from 46 to 75 years and close to 1.1 billion people in the region have been lifted out of poverty since 1990 (UNESCAP, 2019). Eastern Asia, the Pacific and central Asia have less than 3 percent of their populations living in extreme poverty (surviving on less than USD 1.9 per day). Most countries and territories in Asia-Pacific have also achieved very-high, high or medium rankings of the Human Development Index thanks to growing incomes and improving public health and education systems.

However, there are wide differences between nations in the region in their socio-economic status as demonstrated by the wide disparity in gross national income (GNI) per capita between the economies in the region. Of the 60 countries and territories in the region, 11 (with the total population of 1.9 billion, or 44 percent of the regional population) had a GNI per capita less than USD 2 000 in 2019 (Annex 2). In Southern Asia, some 216 million people were still living in extreme poverty in 2015 (Shafer, 2018), which accounted for more than a quarter of the global extreme poor.

The Asia-Pacific region is experiencing rapid population ageing, with the number of older persons (60 years or older) expected to more than double by 2050. In 2019, it was estimated that 60.1 percent of the world's older population resided in the region, while the region makes up 59.4 percent of the world's total population. The number of older persons is expected to increase from an estimate of 548 million in 2019 to nearly 1.3 billion by 2050 (UNESCAP, 2020). In the Asia-Pacific region in 2017, the age dependency ratio, old (dependents older than 64 compared to the 15 to 64 year old working-age population, expressed as percentage) was highest in Japan (45 percent), followed by Australia, New Zealand, Georgia and China, Hong Kong SAR with ratios over 20 percent. In China, the most populous country in the region, the ratio was 14.85 percent and expected to exceed 15 percent in 2018. Other aging populations with age dependency, old ratios over 15 percent included Armenia, Taiwan Province of China, Republic of Korea, Singapore, and Thailand. Most of the other countries and territories in the region have relatively younger populations including populous countries such as India and Bangladesh with age dependency, old ratios lower than 10 percent, indicating strong productive work forces.

The economic challenges in the region include growing income inequality, technology development that drives job change and shift of production, rising protectionism and trade tensions, political disparity and governance, regional conflicts and natural calamities. The current COVID-19 pandemic has already had a devastating impact while climate change has long been a threat and could be catastrophic to world food security and economic development.

Aquaculture is one of the most important food production sectors in the Asia-Pacific region and a driver for rural development. While it is indispensable for many developing countries as it contributes to overall socioeconomic development, its progress is also greatly affected by the pace of that development.

1.4 General characteristics of the aquaculture sector

1.5 Status and trends

1.5.1 Regional production, value, and relative contributions of the sub-regions

Aquaculture occurs in all sub-regions of the Asia-Pacific region where total aquaculture production, including aquatic animals and aquatic plants was 104.9 million tonnes in 2018, compared to 64.1 million tonnes in 2008. The region consistently contributed between 91 percent and 92 percent of global aquaculture production from 2008 to 2018 (Figure 1) with an average annual growth rate of 5.1 percent over this period.

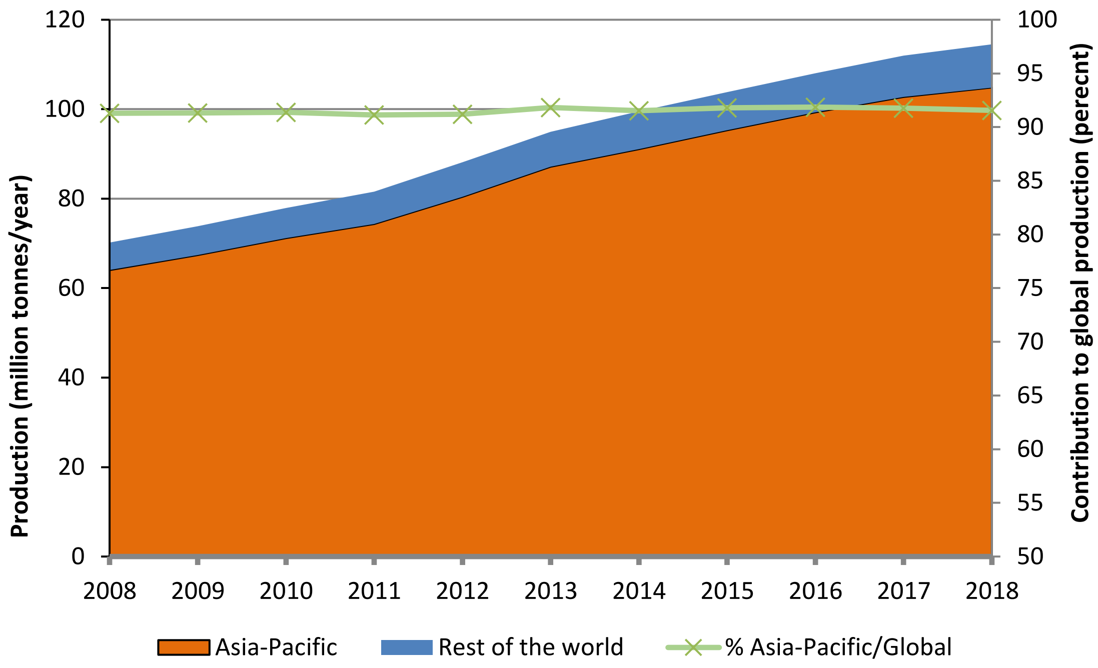

Figure 1. Global and Asia-Pacific aquaculture production from 2008 to 2018 (million tonnes/yr)

Production varied widely among sub-regions with Eastern Asia, South-Eastern Asia and Southern Asia being by far the dominant sub-regions (Figure 2). The Eastern Asian sub-region contributed most, although the relative contribution gradually decreased from 74.1 percent in 2008 to 67.1 percent in 2017. On the other hand, the contribution from South-eastern Asian sub-region has increased steadily over the years from 17.5 percent in 2008 to higher than 20 percent since 2010, which rose to 25.3 percent in 2015 before decreasing to 22.9 percent in 2018. The contribution of the Southern Asian sub-region also increased over the period from 8.1 percent in 2008 to 9.7 percent in 2018.

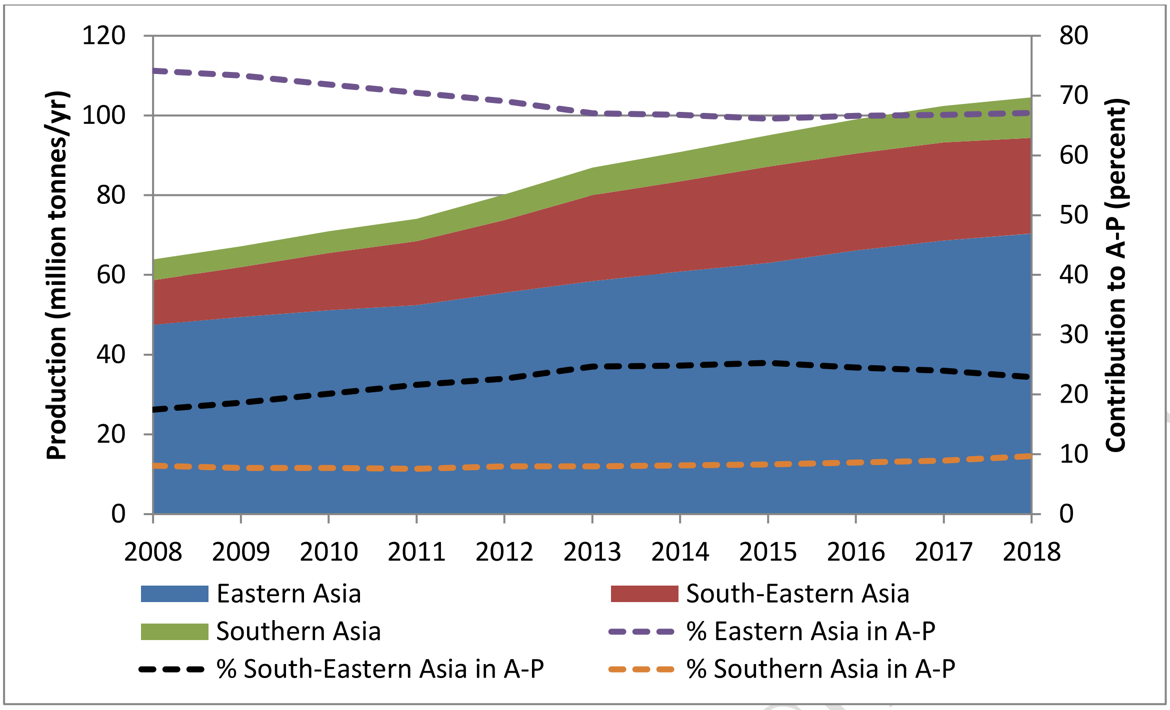

Figure 2. Aquaculture production (million tonnes/yr) and the relative contribution (broken lines, percent) from the three main aquaculture producing sub-regions to total Asia-Pacific production from 2008 to 2018

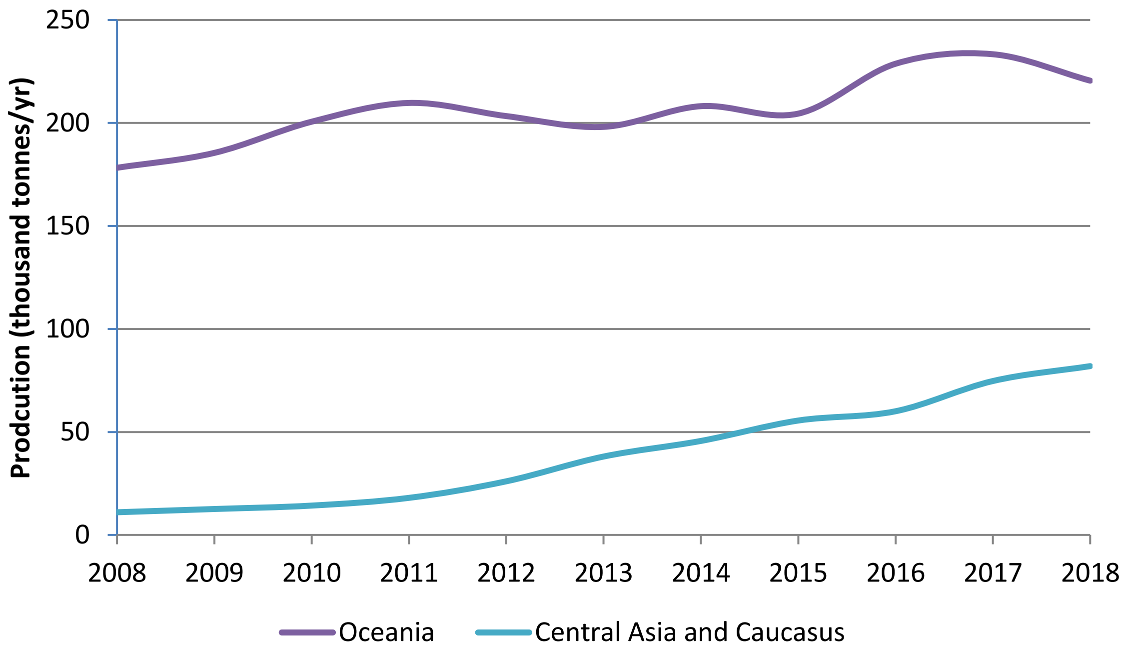

Figure 3. Aquaculture production in Central Asia and Caucasus sub-region, and Oceania sub-region from 2008 to 2018 (thousand tonnes/yr)

The Oceania sub-region, and Central Asia and Caucasus sub-region also witnessed a steady increase in aquaculture production from 2008 to 2018 (Figure 3). Total production from Australia, New Zealand

and Pacific Island nations and territories (Oceania sub-region) increased from 178 247 tonnes in 2008 to 220 536 tonnes in 2018, while eight countries in Central Asia and Caucasus sub-region produced a combined volume of 11 016 tonnes in 2008 and 81 952 tonnes in 2018. However, production from these sub-regions each contributed less than one percent to Asia-Pacific total production in 2018.

In this regional review, no distinction has been made between the contributions to the sector by individual sub-regions, except where appropriate. For example, the importance of China and its major contribution to facets of the aquaculture sector are highlighted, where appropriate.

Figures 4 and 5 represent the trends in the volume of aquaculture production for the period 2008 to 2018 and the value of that production. Also shown in the two figures are the corresponding changes in the percentage contribution to global aquaculture production and value from the total Asia-Pacific region and excluding China from the region. In 2018, total aquaculture production and its value in the Asia-Pacific were 104.9 million tonnes and USD 223.5 billion, respectively, having increased from 64.1 million tonnes and USD 92.2 billion, respectively, in 2008. This means that total aquaculture production increased by 64 percent while the value of aquaculture produce rose by 142 percent over this ten-year period.

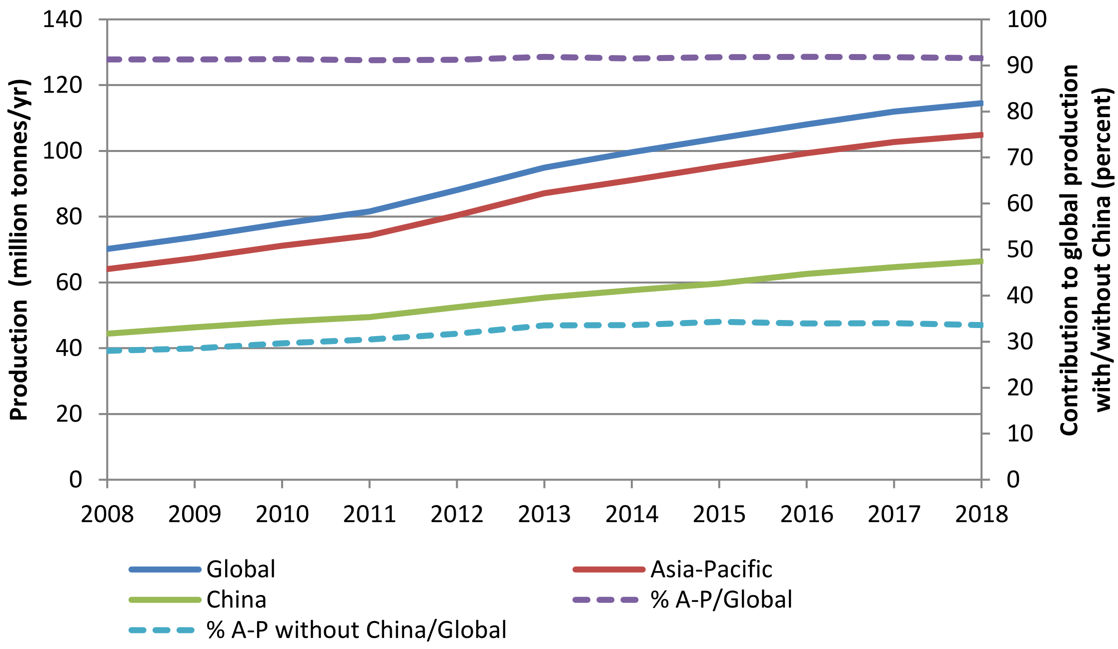

Figure 4. Aquaculture production (million tonnes/yr) from 2008 to 2018 in the Asia-Pacific region, in China and globally and relative contributions (broken lines, percent) to global production from Asia-Pacific with and without China.

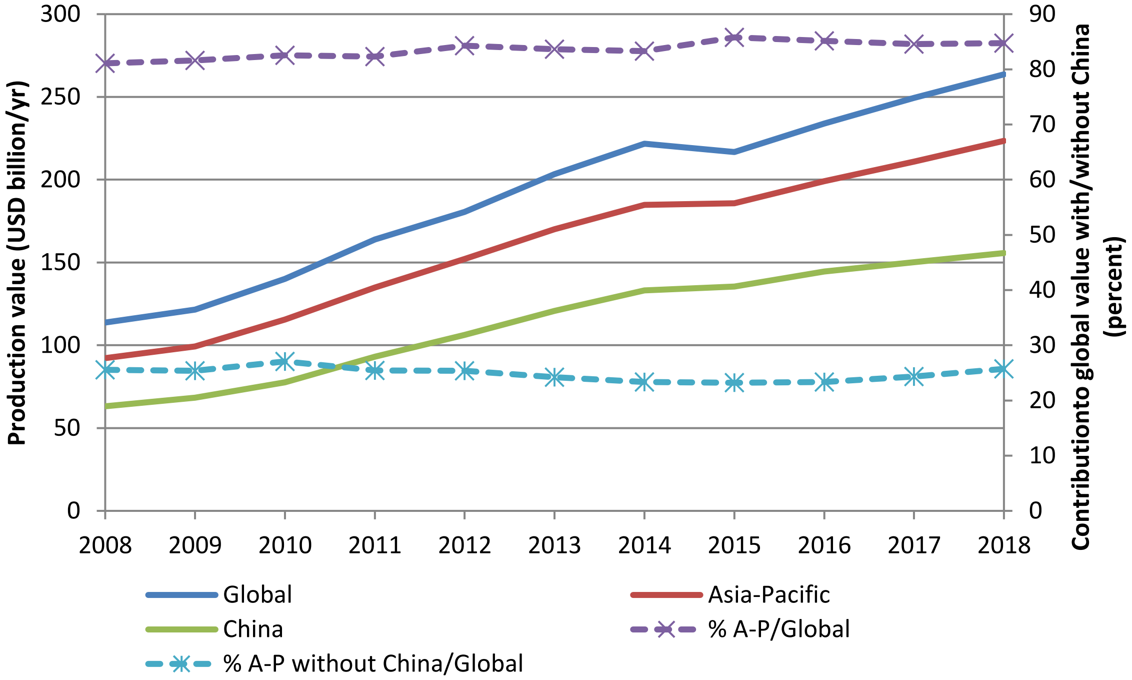

Figure 5. Value of aquaculture production (USD billion) from 2008 to 2018 in Asia-Pacific, China and globally and the relative contributions to global production (percent) from Asia-Pacific with and without China.

Total aquaculture production and value has grown steadily in the Asia-Pacific region as well as in China, as the gradients of the three solid lines in both figures for Asia-Pacific, China and global are almost parallel. These figures also reveal the trends in relative contributions to global aquaculture production and value from the Asia-Pacific region, with and without China. It is evident that the Asia-Pacific region continued to maintain a contribution of over 90 percent to global production over the years. However, if the contribution of China is removed from Asia-Pacific data, the contribution to global production ranged from 28 percent in 2008 to 33.6 percent in 2018. Meanwhile the contribution in value of Asia-Pacific aquaculture to global value ranged from 81.1 percent in 2008 to 84.8 percent in 2018 (Figure 5). Excluding China from the computation of the contribution in value of aquaculture produce to global value of production, the contribution from the region ranged from 25.6 percent in 2008 to 25.7 percent in 2018, which indicates a steady contribution in value over the years from other countries in the region. This trend may indicate that there has been a relative increase in the unit value of aquaculture production in China, where the culture of high value products including Mandarin fish (*Siniperca chuatsi*), red swamp crayfish (*Procambarus clarkii*) and the Chinese mitten crab (*Eriocheir sinensis*) has increased (Wang *et al*. 2015).

It is evident from the above data that the Asia-Pacific region is the main contributor to the aquaculture sector globally, as a food source as well as a significant source of revenue. Also, that this trend has continued for many decades, perhaps since aquaculture became a major food production sector to the growing population of the world. In other words, the Asia-Pacific region can be considered as the 'backbone' of global aquaculture. Over the last decade, countries in the region have represented seven to nine of the top ten global aquaculture producing nations, including Bangladesh, China, India, Indonesia, Myanmar, Philippines, Republic of Korea, Thailand and Viet Nam. Equally important to note is the large contribution that Chinese aquaculture makes to total Asia-Pacific production and hence to the status of the sector globally. China stands out as the dominant nation in the sector, a status that it has achieved over the years and is likely to continue.

1.5.2 Aquaculture production and value growth rates

Despite the steady increase in Asia-Pacific aquaculture production volume and value from 2008 to 2018, the rate of annual growth fluctuated remarkably. In terms of production, the annual growth was the highest in the year of 2012-2013 (8.4 percent) and lowest in the year 2017-2018 (2.1 percent). A trend of continued declining growth rates happened from 2013 to 2018 (Figure 6). Fluctuations and a general trend of declining growth rates were also observed in terms of production value (Figure 7).

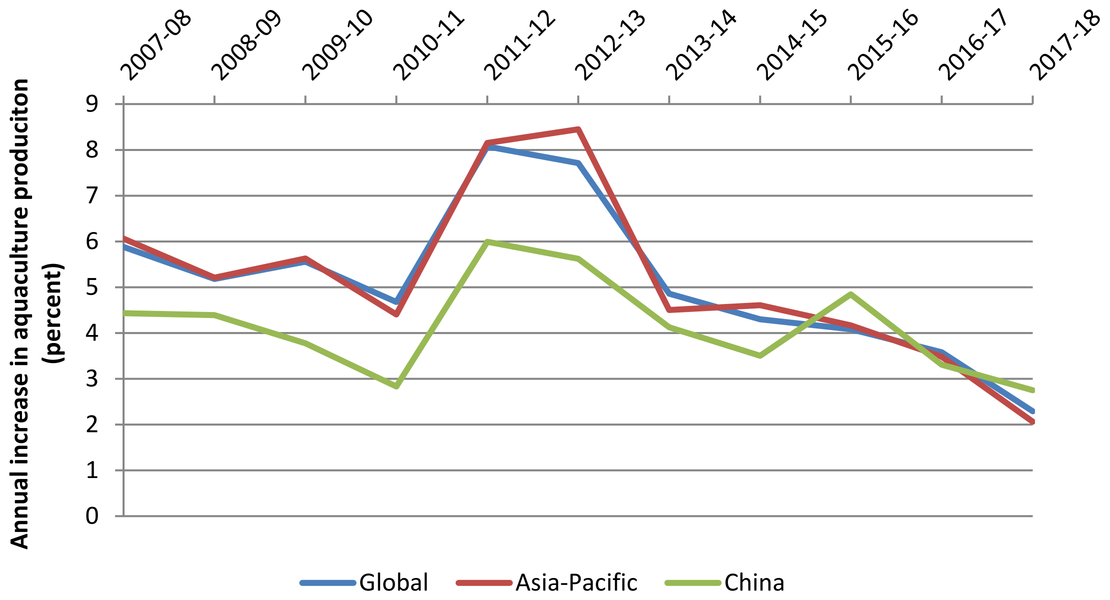

Figure 6. Annual growth rates of aquaculture production in Asia-Pacific region, with corresponding data for China and globally from 2008 to 2018 (percent/yr).

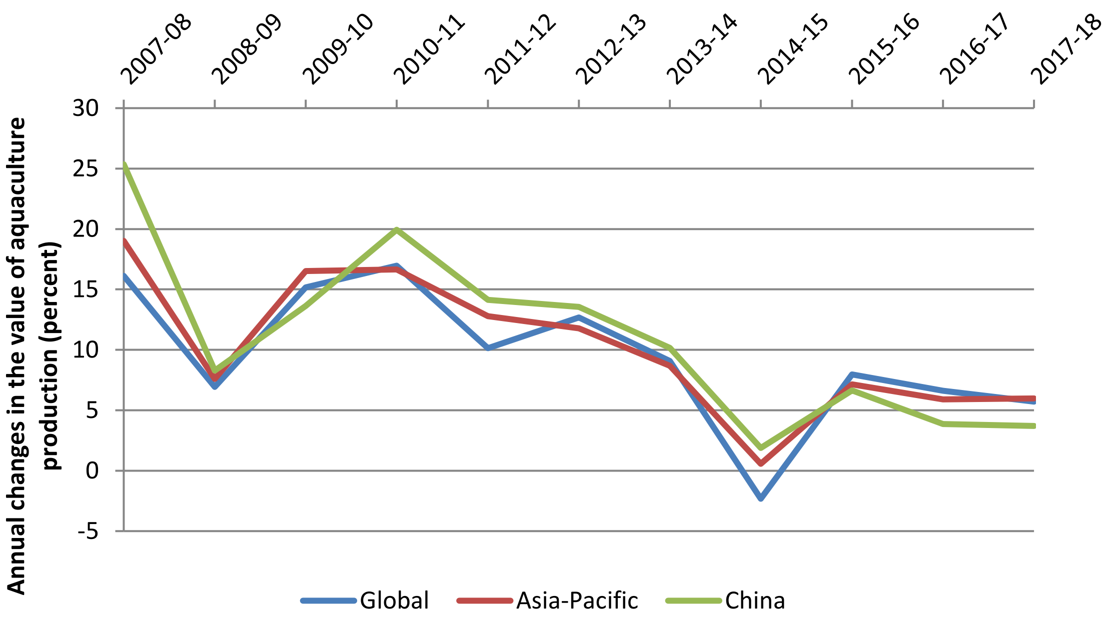

Figure 7. Annual changes in the value of the aquaculture produce in Asia-Pacific region, with corresponding data for China and globally from 2008 to 2018 (percent/yr)

1.5.3 Production environment

Asia-Pacific aquaculture production volumes and values in freshwater, brackish-water and marine culture environments are shown in Figure 8 and Figure 9, respectively. Production from all environments showed steady increases while production was highest from aquaculture in marine environments, mainly due to the volume of seaweed production. Similar trends were observed in production from marine, freshwater, and brackish water environments in China with faster increases observed in the production from marine and freshwater environments than from brackish water (Figure 8).

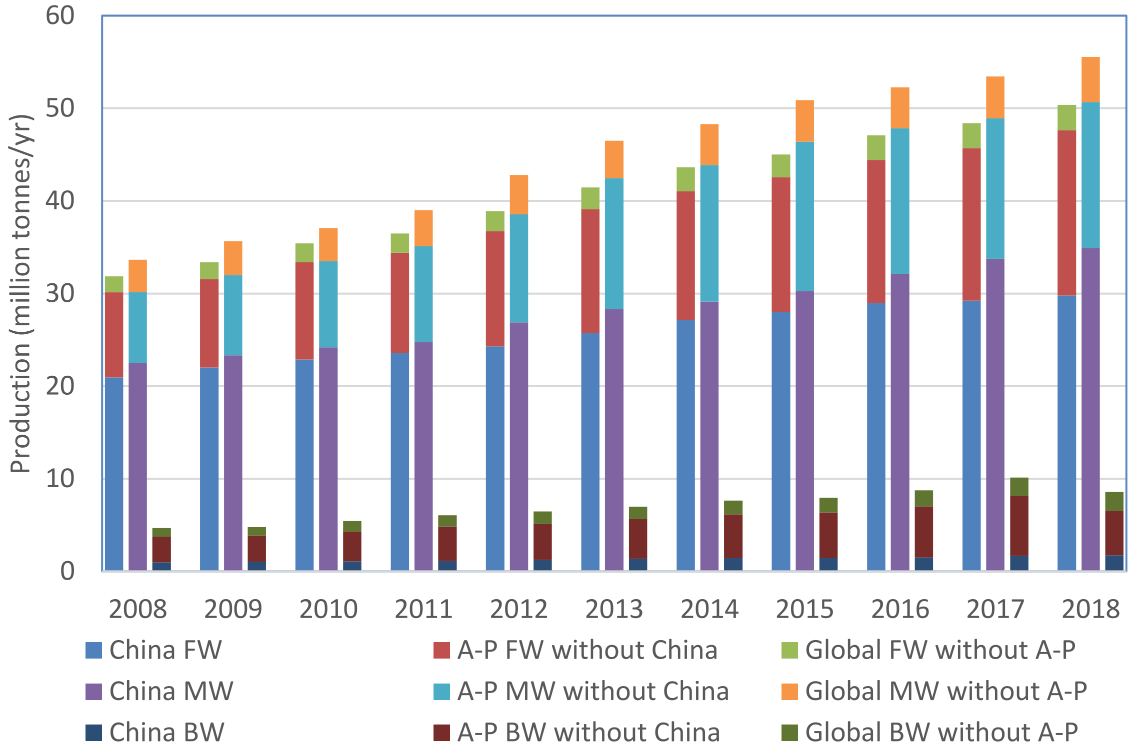

Figure 8. Aquaculture production (million tonnes/yr) in different environments (FW: freshwater, the first column; MW: marine water, the second column; BW: brackish water, the third column) in China, Asia-Pacific, and globally from 2008 to 2018.

However, as seen from Figure 9 the value of aquaculture production from the three environments was not directly proportional to production volumes. Although marine production exceeds that from freshwater, the production value from marine environments was significantly lower because it was dominated by seaweeds, which have considerably lower unit values than finfish and shellfish. These trends were also seen in the data from China and globally again reiterating the dominance of the Asia-Pacific region in global aquaculture, which in turn is heavily dependent on the contribution to the sector from China.

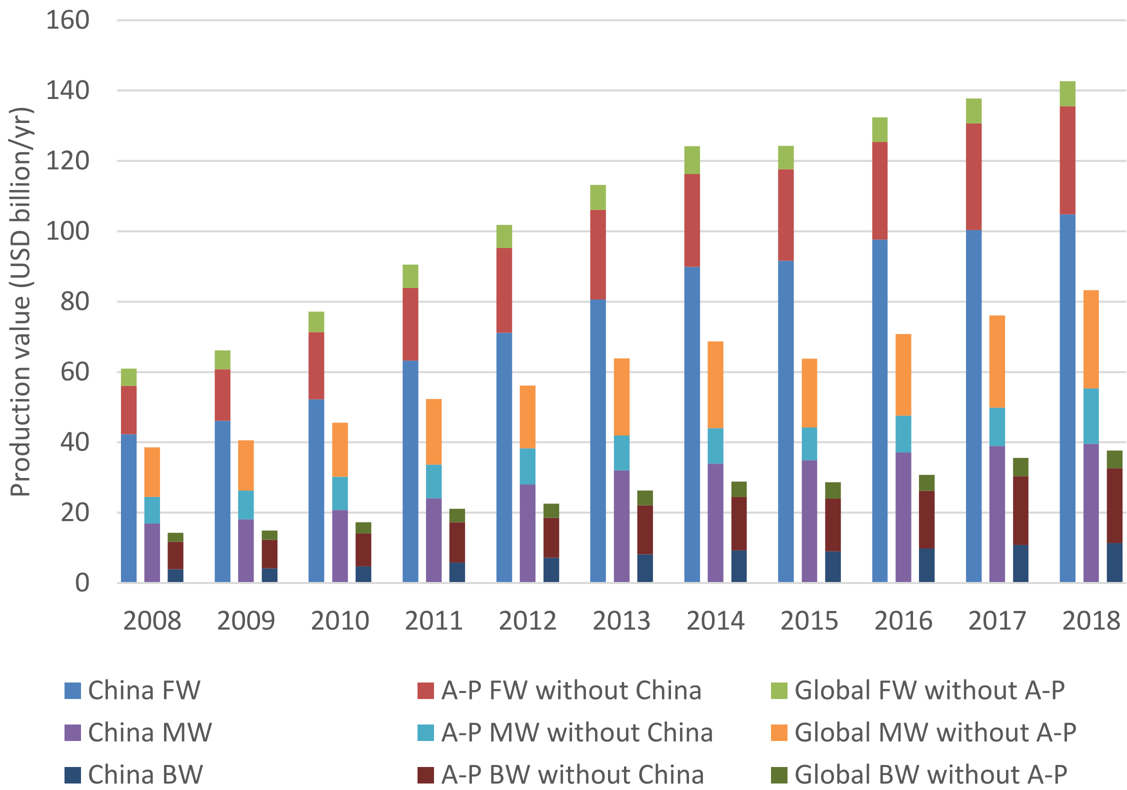

Figure 9. Value of aquaculture produce (USD billion/yr) in the different environments (FW: freshwater, the first column; MW: marine water, the second column; BW: brackish water, the third column) in China, Asia-Pacific, and globally from 2008 to 2018.

1.5.4 Production of the major commodity groups

Production volumes of the main aquaculture commodity groups in the Asia-Pacific region from 2008 to 2018 are shown in Figure 10 and Figure 11 while Figure 12 shows the corresponding values by commodity groups. In general, all the production volumes of all major groups increased steadily and were dominated by finfish in terms of both production volume and value. Although the second-highest production volume was aquatic plants, its value was far below that of crustaceans and molluscs. Compared to these major categories, production of amphibians and reptiles, and invertebrates were rather insignificant commodity groups in terms of both volume and value.

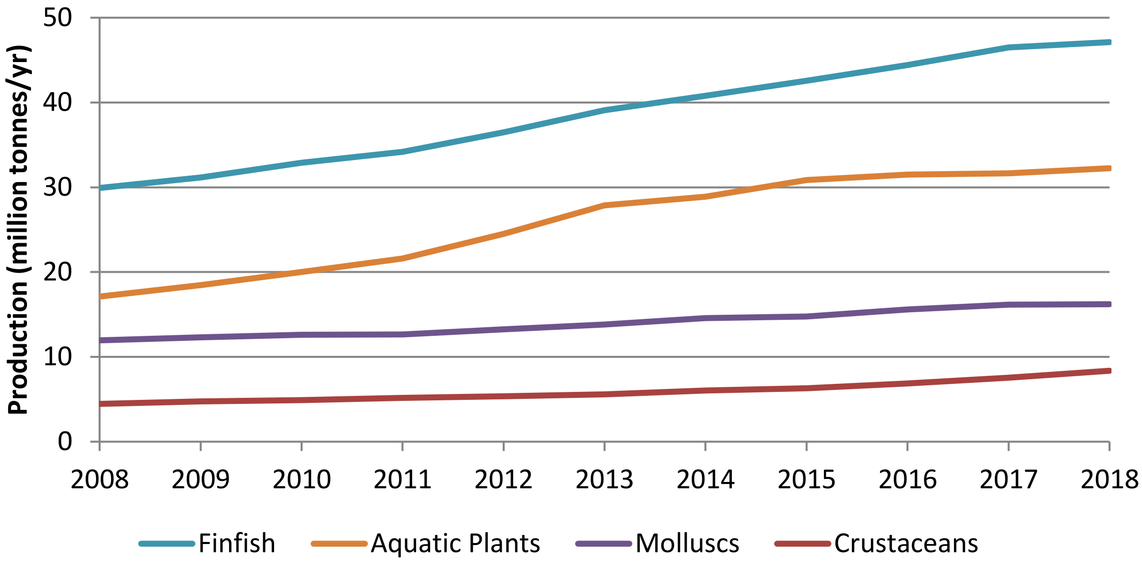

Figure 10. Production of finfish, aquatic plants, molluscs and crustaceans in Asia-Pacific region from 2008 to 2018 (million tonnes/yr)

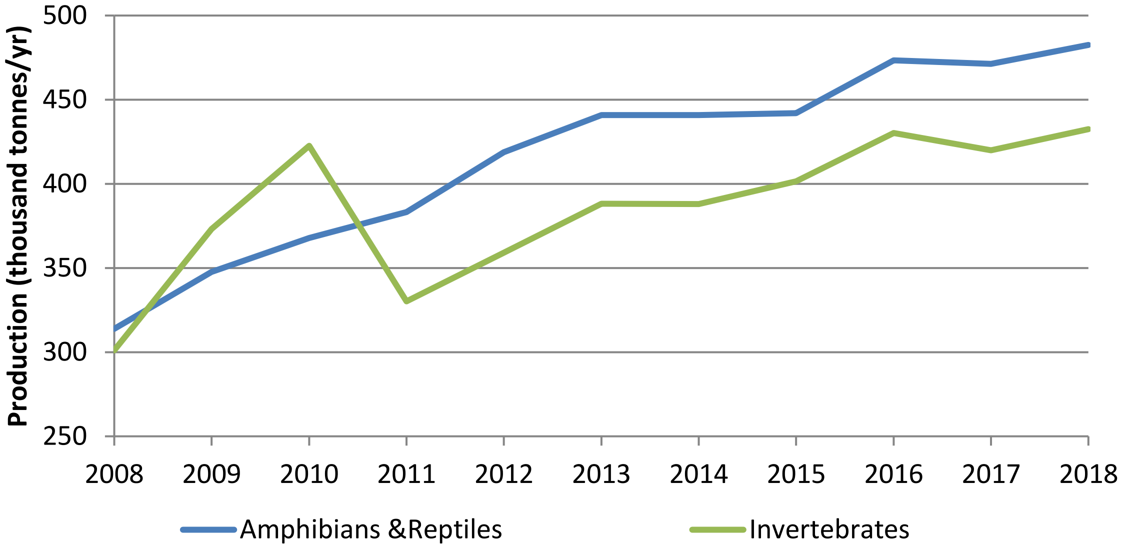

Figure 11. Production of amphibians and reptiles, and invertebrates in Asia-Pacific region from 2008 to 2018 (thousand tonnes/yr)

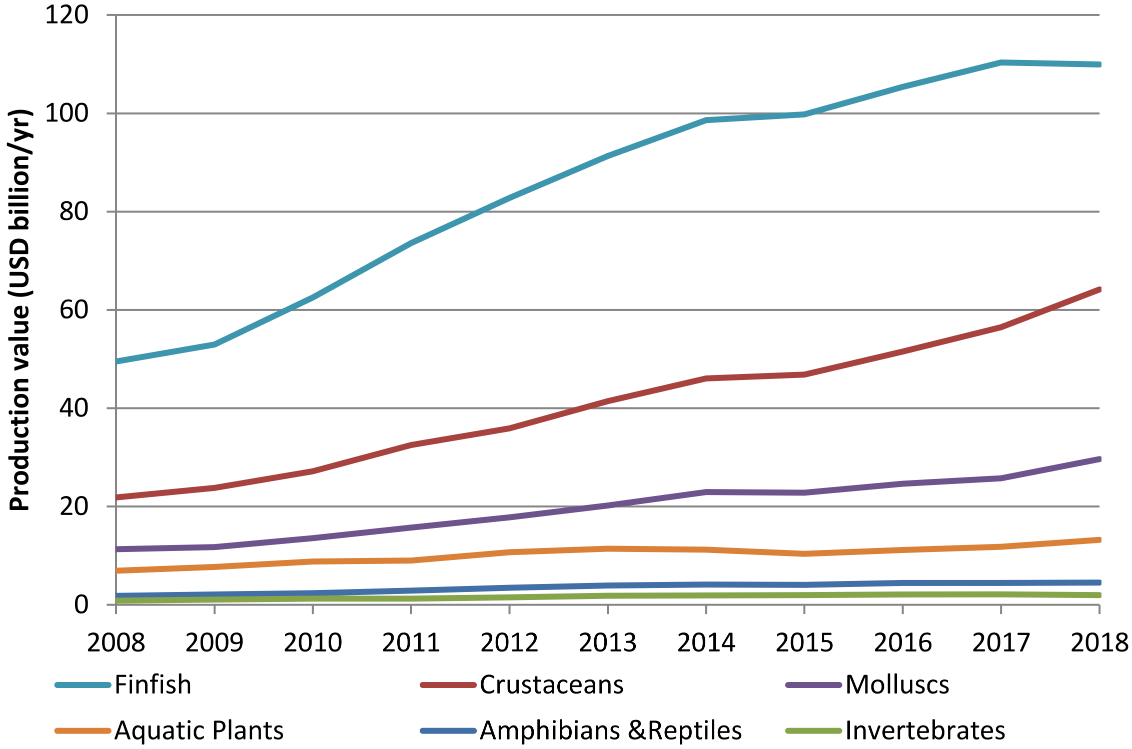

Figure 12. Production value of the major commodity groups in Asia-Pacific region from 2008 to 2018 (USD billion/yr)

Asia-Pacific production in all the commodity groups consistently contributed more than 85 percent to global production, with aquatic invertebrates, amphibians and reptiles, and aquatic plants each accounting for almost the total production of these commodities globally (Figure 13). The Asia-Pacific contribution of molluscs was around 92 percent and finfish 87 percent from 2008 to 2018. The Asia-Pacific contribution of crustaceans was around 89 percent from 2008 to 2017, with a sharp increase from 2017 to 2018 mainly because of a production surge of red swamp crayfish in China.

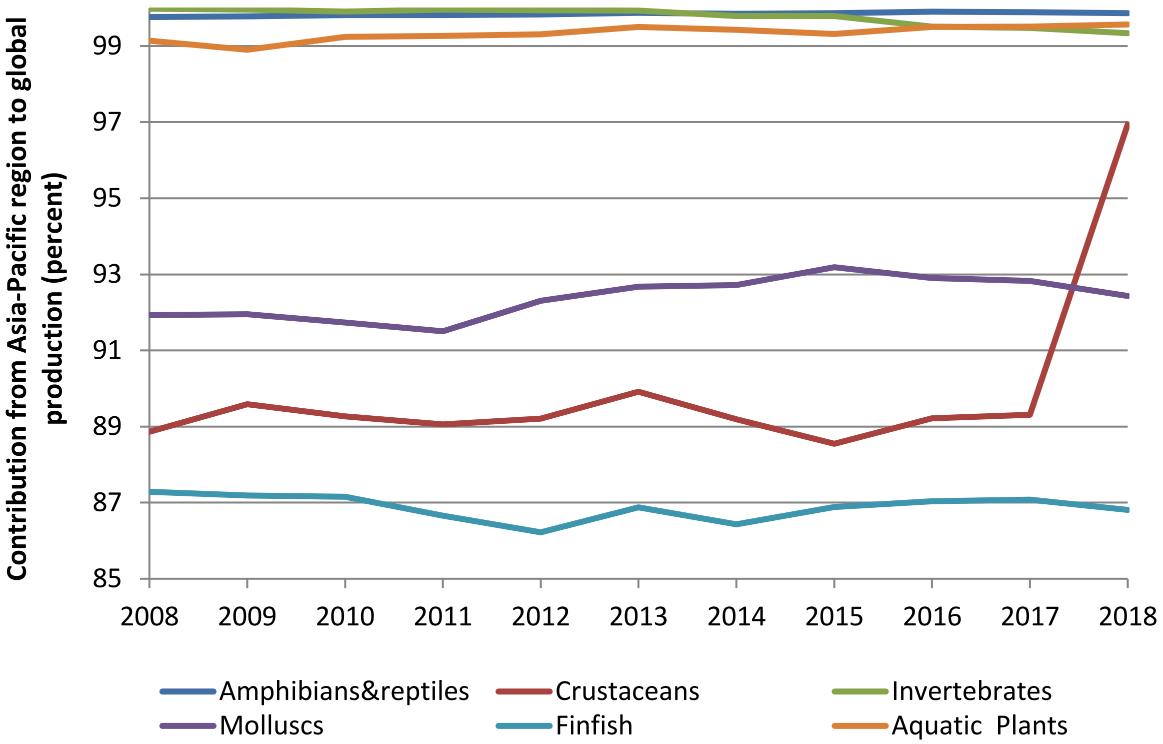

Figure 13. Contributions from the Asia-Pacific region in each of the major cultured commodity groups to global production from 2008 to 2018 (percent)

The average unit value of each commodity group in Asia-Pacific region from 2008 to 2018 is illustrated in Figure 14 showing that the per unit value of amphibians and reptiles, crustaceans and invertebrates increased from 2008 to 2014 and was level from 2014 to 2018. Meanwhile, unit values of finfish and molluscs had only small increases and the unit value of aquatic plants was constant over the decade. Even though aquatic plant aquaculture results in relatively low production values it is an important practice that benefits remote communities such as those in the Indonesian archipelago. Aquatic plants can be simply sun-dried by individual farmers and traded at their convenience without requiring special facilities for storage over a long period, which is an advantage that is not matched by other aquaculture commodities (Aslan *et al.*, 2015).

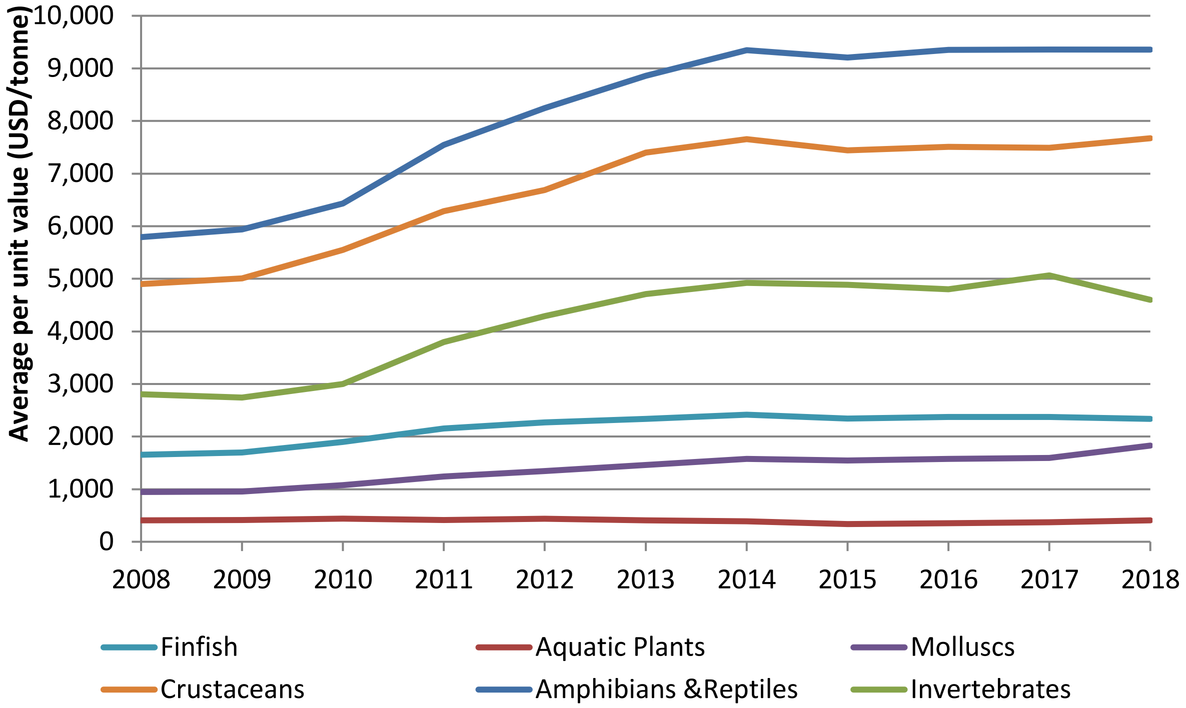

Figure 14. Average per unit values of the major aquaculture commodity groups in Asia-Pacific region from 2008 to 2018 (USD/tonne)

1.5.5 Production of major farmed species

In 2016, over 550 species or species items were being farmed worldwide (FAO, 2019a). Asia farms the most aquatic species because of its long tradition of aquaculture and diverse farming environments. In 2016, 299 species or species items reported to FAO were produced through aquaculture in Asia including 192 finfish, 30 molluscs, 39 crustaceans,15 other animal species and 23 algal species. There were also 74 species or species items under culture in Oceania (FAO, 2019a). Despite the large number and diversity of species being cultured, production is dominated by a small number of species.

Table 1. Asia-Pacific region production of the ten top-ranked species or species groups in 2008, 2013 and 2018 (tonnes/yr)

	2008		2013		2018
Japanese kelp, ***Laminaria japonica***	6 169 255	Japanese kelp	7 437 800	Japanese kelp	11 448 250
Grass carp, ***Ctenopharyngodon idella***	3 782 878	Grass carp	4 745 283	Grass carp	5 687 026
Silver carp, ***Hypophthalmichthys molitrix***	3 735 694	Silver carp	4 198 768	Cupped oysters nei	5 162 010
Cupped oysters nei*	3 372 449	Cupped oysters nei	4 056 574	Silver carp	4 719 535
Japanese carpet shell, ***Ruditapes philippinarum***	3 074 846	Japanese carpet shell	3 692 954	Tilapias and other cichlids	4 136 223
Common carp, *Cyprinus carpio*	2 767 976	Common carp	3 457 864	Japanese carpet shell	4 100 777
Bighead carp, Hypophthalmichthys nobilis	2 316 465	Tilapias and other cichlids	3 555 324	Whiteleg shrimp	4 022 167

Tilapias and other cichlids	2 133 363	Bighead carp	2 780 963	Common carp	3 935 924
Carassius spp.	1 955 500	Whiteleg shrimp	2 556 075	Bighead carp	3 135 744
Whiteleg shrimp, ***Penaeus vannamei***	1 827 989	Carassius spp.	2 358 600	Carassius spp.	2 771 565

*nei – not elsewhere included

Table 1 shows the ten top-ranked species in terms of production volume in Asia-Pacific in 2008, 2013 and 2018. In all these years, Japanese kelp (*Laminaria japonica*) was the species that was produced in the largest quantity in the Asia-Pacific region. Cultured finfish production was dominated by carp species indigenous to China with grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), common carp (*Cyprinus carpio*), bighead carp (*Hypophthalmichthys nobilis*) and *Carassius spp.* ranking in the top ten species or species item produced in all the years under consideration. Cupped oysters nei and Japanese carpet shell (*Ruditapes philippinarum*) also ranked in the top ten species or species items produced in all years. This indicates that the highest contributions to Asia-Pacific region aquaculture comes from indigenous fish species, seaweeds and a few mollusc species. Two introduced species, tilapia and whiteleg shrimp (*Penaeus vannamei*) also significantly contributed to production and constantly ranked in the top ten in all years. It is notable that the top ten species in production in Asia-Pacific remained the same from 2008 to 2018 although the ranking of individual species changed in some years. These top ten species constantly contributed 43 percent to 48 percent towards total aquaculture production in the region (Figure 15) over the ten-year period 2008 to 2018.

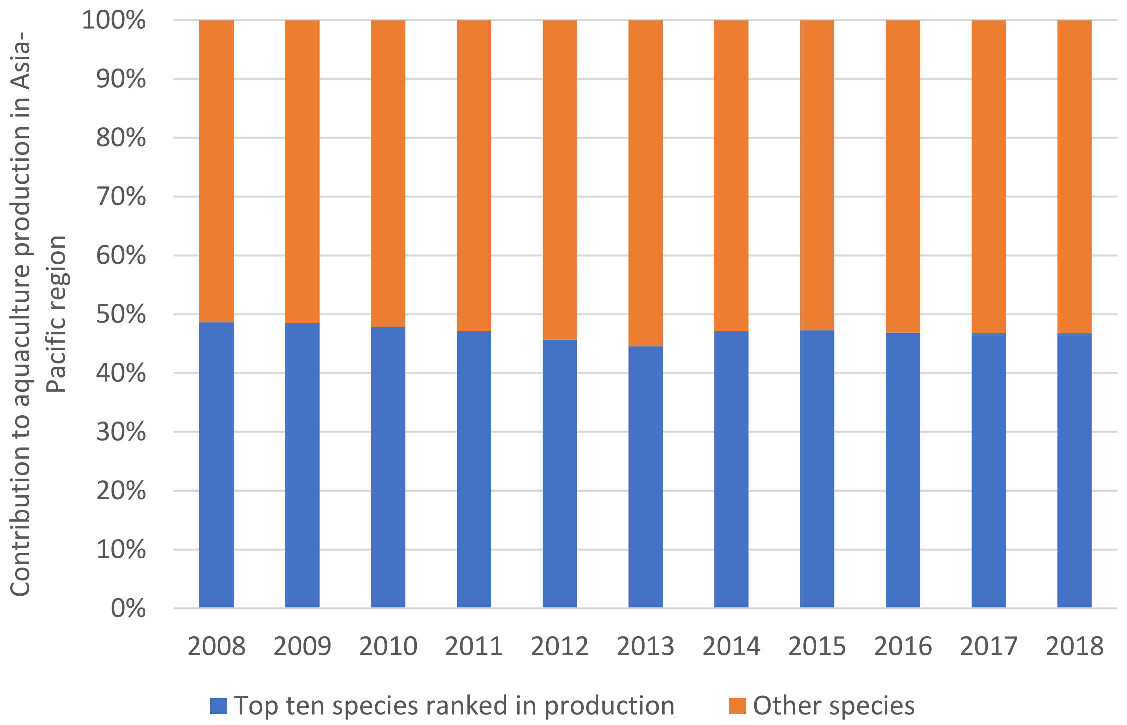

Figure 15. Contribution of the top ten ranked species in terms of production to total aquaculture production in the Asia-Pacific region from 2008 to 2018 (percent).

It is worth highlighting that carp species including Chinese carps, common carp, *Carassius* spp. and Indian major carps accounted for total production of 29.3 million tonnes in 2018, making up 60 percent of total finfish production, or about 28 percent of total aquaculture production in the region (FAO, 2020a), demonstrating the dominance and significant importance of this species group in the region and globally. A significant contribution to fish production was also made by tilapias. Both the carps and tilapias are often considered low-cost in terms of production, as they are herbivores, omnivores, filter feeders or detritus scavengers. This means they adapt well to low-cost and often diverse forms of integrated farming systems that usually have low environmental and carbon footprints, perhaps making them more resilient to climate change. Although they may have lower market unit values compared to carnivorous finfish species, their roles in nutrition and food security, and rural development are important and could never be overstated.

Table 2. The ten top ranked species/ species group by production value in Asian-Pacific region in 2008, 2013 and 2018 (USD thousand/yr)

	2008		2013		2018
Whiteleg shrimp	7 714 619	Whiteleg shrimp	16 707 345	Whiteleg shrimp	25 400 327
Grass carp	5 319 135	Grass carp	10 280 196	Red swamp crayfish	14 235 057
Silver carp	5 175 340	Silver carp	8 826 111	Grass carp	12 995 863
Chinese mitten crab, ***Eriocheir sinensis***	4 016 136	Chinese mitten crab	7 980 321	Silver carp	10 224 670
Common carp	3 474 924	Tilapias and other cichlids	7 397 047	Chinese mitten crab	9 617 084
Giant tiger prawn, *Penaeus monodon*	3 329 455	Common carp	6 812 826	Tilapias and other cichlids	8 431 064
Bighead carp	3 300 829	Bighead carp	6 127 188	Common carp	8 047 990
Japanese carpet shell	3 057 079	Japanese carpet shell	5 680 548	Bighead carp	7 304 604
Tilapias and other cichlids	3 014 178	Giant tiger prawn	4 543 383	Japanese carpet shell	6 677 487
Carassius spp	2 372 022	Red swamp crayfish	4 510 526	Giant tiger prawn	6 234 549

Table 2 shows the ten top-ranked species in terms of production value, in the Asia-Pacific region in 2008, 2013 and 2018, providing a contrasting scenario to that illustrated in table 1. Whiteleg shrimp was the top-ranked species in terms of the total value of the production. Grass carp, silver carp, common carp, bighead carp and tilapia were all ranked in the top ten in all the years. This trend shows the economic importance of whiteleg shrimp to Asia-Pacific aquaculture and the dominance of Chinese carps and tilapia both in production volume and values. The ten top-ranked species in terms of production value contributed between 42 percent to 49 percent of total aquaculture production value in Asia-Pacific from 2008 to 2018 (Figure 16).

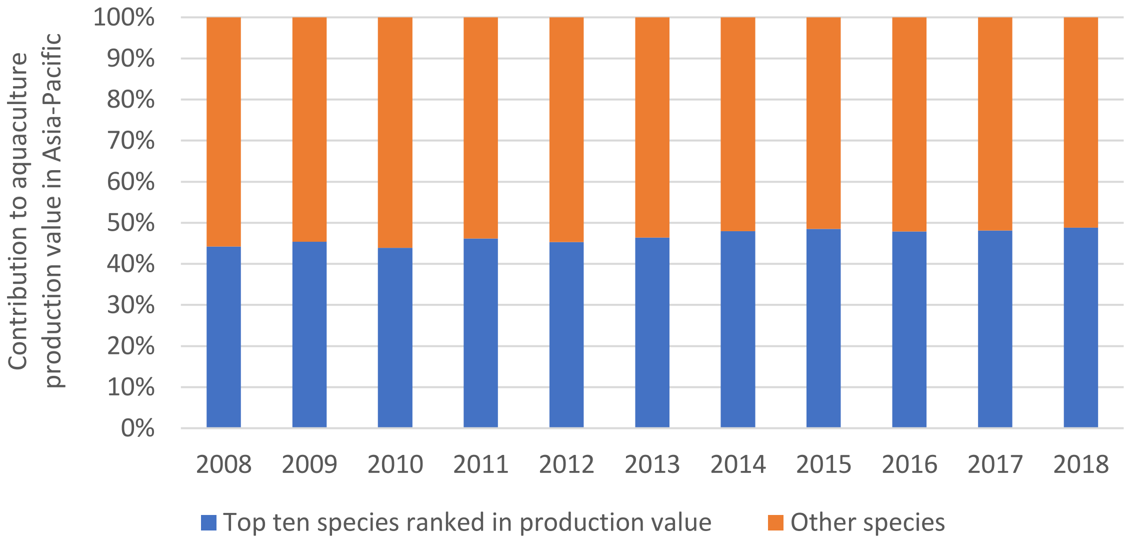

Figure 16. Contribution of top ten ranked species in terms of production value to total aquaculture production value in Asia-Pacific region from 2008 to 2018 (percent).

Three species that did not appear in the top ten in terms of production emerged in the top ten in production value. These were giant tiger prawn (*Peneaus monodon*), Chinese mitten crab (*Eriocheir sinensis)* and red swamp crayfish (*Procambarus clarkii*). Giant tiger prawn, despite the significant scale down in production since early 2000s, still ranked among the top ten species in production value. Chinese mitten crab has been in high market demand in China since early 2000s as a species generating high production value. It provided a market value of USD 9.6 billion from production of 756 950 tonnes in 2018, which equates to a unit value of USD 12 705/tonne. Obviously, in view of its economic importance there is a recent upsurge in research to improve production and make culture systems sustainable (Wang *et al.*, 2016; Wang *et al.*, 2018; Cui and Ning, 2019). It is important to note that mitten crab is a commodity mainly produced for Chinese domestic markets. Table 2 also shows that the non-native species, red swamp crayfish (*Procambarus clarkii*), cultured semi-intensively, in rotation with rice cultivation (Wang *et al*., 2018) has become one of the top ranked species. In 2018, it generated a value of USD 14.2 billion from production of 1 638 662 tonnes, which equates to a unit value of USD 8 687/tonne.

Tilapia

Tilapia is one of the major cultured species groups globally and has been extensively introduced beyond its native range of distribution (De Silva *et al*., 2004). The most commonly farmed species is Nile tilapia (*Oreochromis niloticus*) and various hybrids including those with blue tilapia (*Oreochromis aureus).* Nile tilapia has been genetically improved (Pullin, 1988; Pullin and Capili, 1988; Gupta and Acosta, 2004a; Gupta and Acosta, 2004b) for aquaculture purposes. At the beginning of tilapia culture, following its introduction to Asia a few decades back, it was hailed as the era of the aquatic chicken (Smith and Pullin, 1984) and the accolades continue to come with the most recent being that tilapia is becoming one of the most important food fishes on the planet (Fitzsimmons and Martinez-Garcia, 2013).

Tilapia production in the Asia-Pacific region increased from 321 204 tonnes in 1990 to 4 136 223 tonnes in 2018 and corresponded to 84.7 percent and 68.6 percent contributions to total global production of tilapia in these respective years (Figure 17). In general, tilapia production in the region has been increasing steadily and it continues to be an important contributor to the aquaculture sector in the region and globally, with China the largest global producer.

Figure 18 shows the value of cultured tilapia in Asia-Pacific, globally and in China. It is evident that the total production value from tilapia culture has increased steadily over the years with a rapid increase in value from 2007 to 2018 while the tilapia aquaculture sector in Asia-Pacific makes a major global contribution.

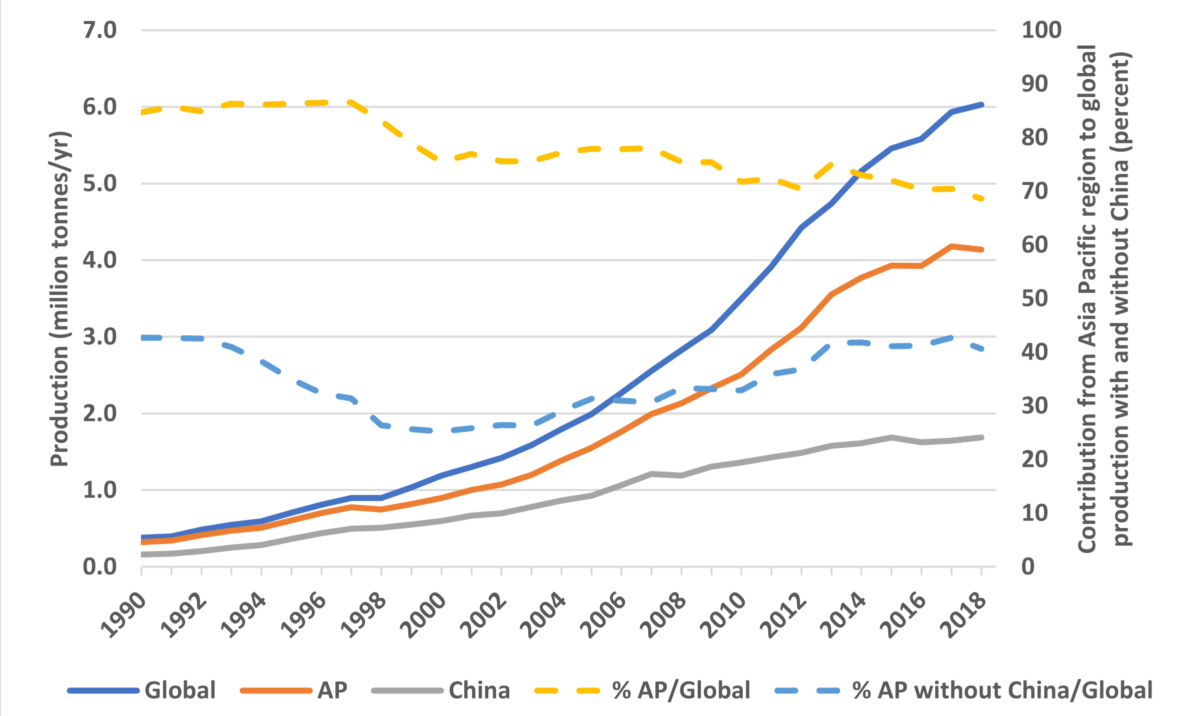

Figure 17. Tilapia production in Asia-Pacific region, in China and globally (million tonnes/yr), with relative contributions from Asia Pacific region to global production with, and without, China (percent) from 1990 to 2008.

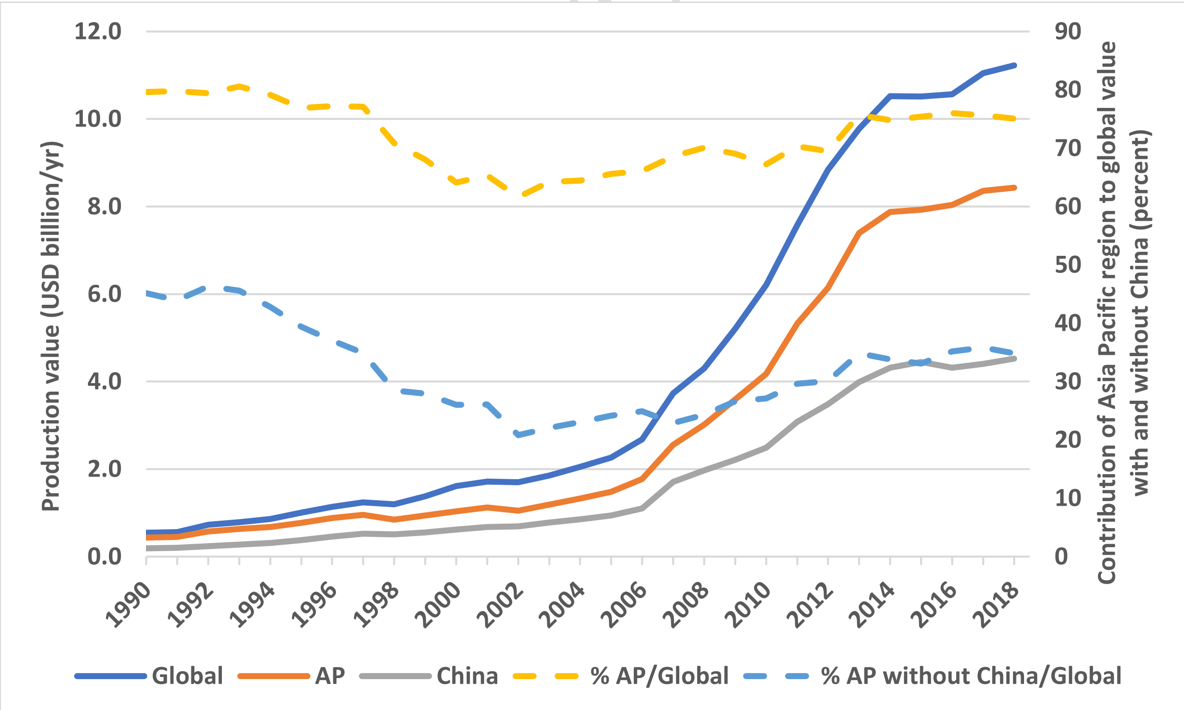

Figure 18. Value of tilapia production in Asia Pacific region, in China and globally (USD billion/yr) with contributions from Asia Pacific region to global value with, and without, China (percent) from 1990 to 2018.

Whiteleg shrimp

Shrimp farming has attracted attention in both the Asia-Pacific region and worldwide as it has become of economic importance to many countries and is a globally traded aquatic food commodity. The shrimp aquaculture sector has gone through many cycles of rapid development followed by setbacks and there have been major changes in the species being cultured in Asia. The native giant tiger prawn (*Penaeus monodon)*, was badly impacted by diseases such as white spot syndrome (WSSV) and yellow head disease in the late 1990s. As a solution to keep the shrimp farming sector growing as an important economic activity, most Asian countries made a policy decision to introduce the whiteleg shrimp (*Penaeus vannamei*), native to South America, based on the premise that the culture practices would be centred around specific pathogen free (SPF) post-larvae. Figure 19 shows the trends in the shrimp culture sector in Asia-Pacific as well as globally. Evidently the culture of whiteleg shrimp rapidly became established in Asia and it gradually became the most dominant species in shrimp culture in the region.

The shrimp sector in Asia-Pacific and globally, can be divided into two phases: the giant tiger prawn era in the last millennium and the whiteleg shrimp era in the new millennium. The whiteleg shrimp industry has the highest production value among all cultured individual species in Asia-Pacific and was worth US 25.4 billion in 2018 (Table 2). The changes in production and value of the components of the shrimp farming sector in Asia-Pacific are shown in Figure 19 and Figure 20, respectively. The giant tiger prawn was cultured in the Asia-Pacific region and accounted for all of the global production which was around 500 000 to 700 000 tonnes per year. However, the expansion of whiteleg shrimp culture in the region resulted in a rapid increase in production. In 2018 it reached more than 4 million tonnes, accounting for 81 percent of the global production of this species. The value of cultured shrimp reflected the changes in production. The total value of Asia-Pacific giant tiger prawn production in 1990 was USD 1.88 billion which increased to USD 6.23 billion in 2018, while that of whiteleg shrimp reached USD 25.40 billion over the period from 2000 to 2018. The predominance of intensive culture systems for whiteleg shrimp in Asia has incentivised genetic improvement of the species (Gitterle and Diener, 2014) and cultured farmed types are increasingly being derived from breeding programmes based in the region and elsewhere.

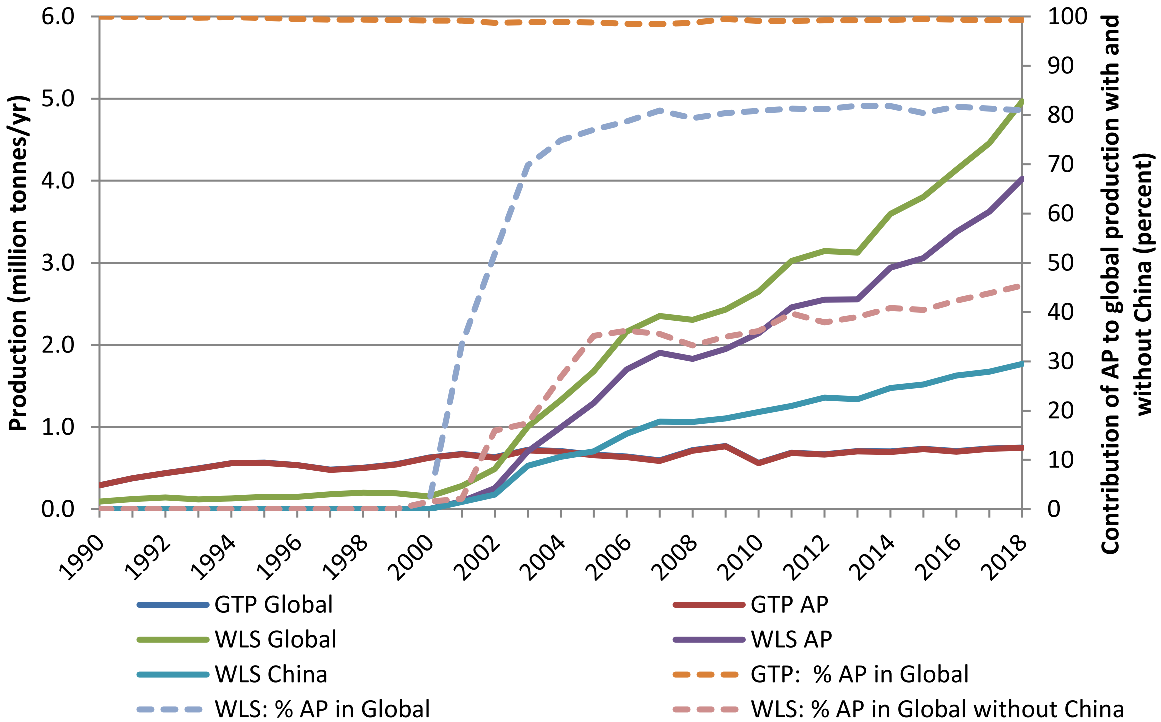

Figure 19. Production of giant tiger prawn (GTP) and whiteleg shrimp (WLS) in Asia-Pacific region (AP) and globally, and Chinese WLS production from 1990 to 2018 (million tonnes/yr) with relative contributions to global production (percent).

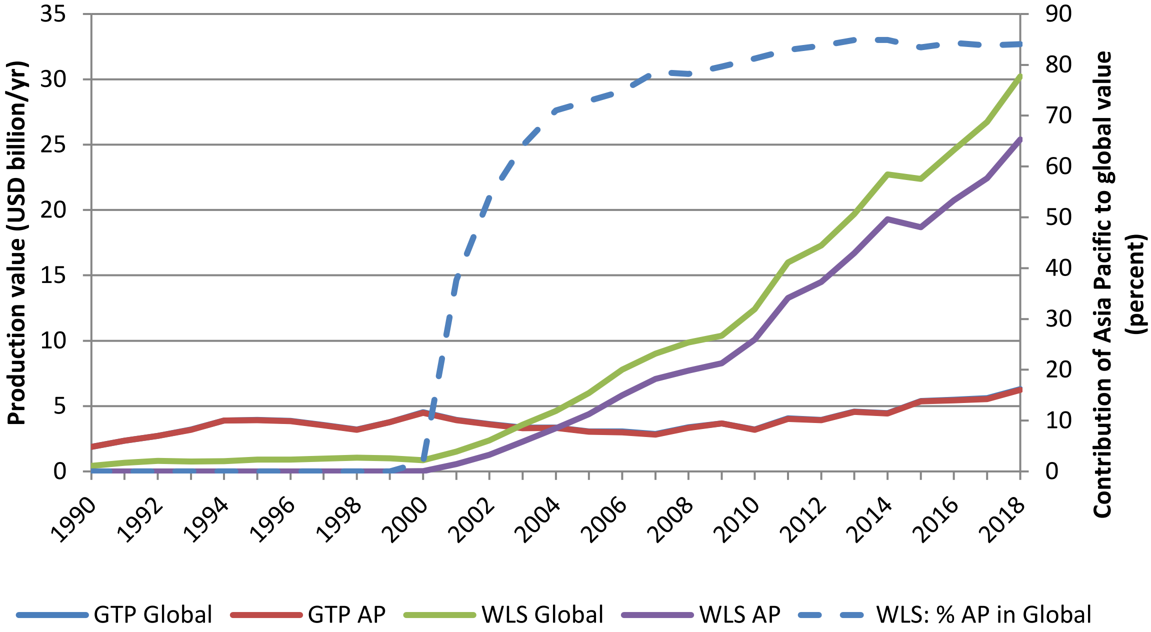

Figure 20. Value of giant tiger prawn (GTP) and whiteleg shrimp (WLS) in Asia-Pacific and globally from 1990 to 2018 (USD billion/yr) with relative contribution of Asia-Pacific whiteleg shrimp production to global value (percent).

Shrimp culture is one of the few activities possible in the coastal zone that offer real potential for improving living standards of many rural farming communities in developing countries. It has been one of the most lucrative businesses and investment objectives in the food production sector over the past three decades.

The top producers of whiteleg shrimp in Asia include China, India, Indonesia, Viet Nam and Thailand (Figure 21). Thailand was the top producer and exporter of farmed shrimp, mainly giant tiger prawn, from 1993 to 2001. However, the collapse of the tiger prawn farming sector did not significantly constrain continued growth of shrimp production in Thailand, largely due to rapid replacement by whiteleg shrimp culture. Meanwhile China overtook Thailand to become the largest global shrimp producer in 2002 and has since been leading growth of the sector. Expansion of whiteleg shrimp farming has played a major role in development. Other countries, including Indonesia and Viet Nam, have also experienced rapid increases in shrimp production since the early 2000s and since 2010 shrimp aquaculture also expanded in India because of the widespread culture of whiteleg shrimp. Despite some issues and challenges, expansion of whiteleg shrimp culture has been one of the major driving forces that successfully sustained stable growth of the vitally important aquaculture sector in Asia.

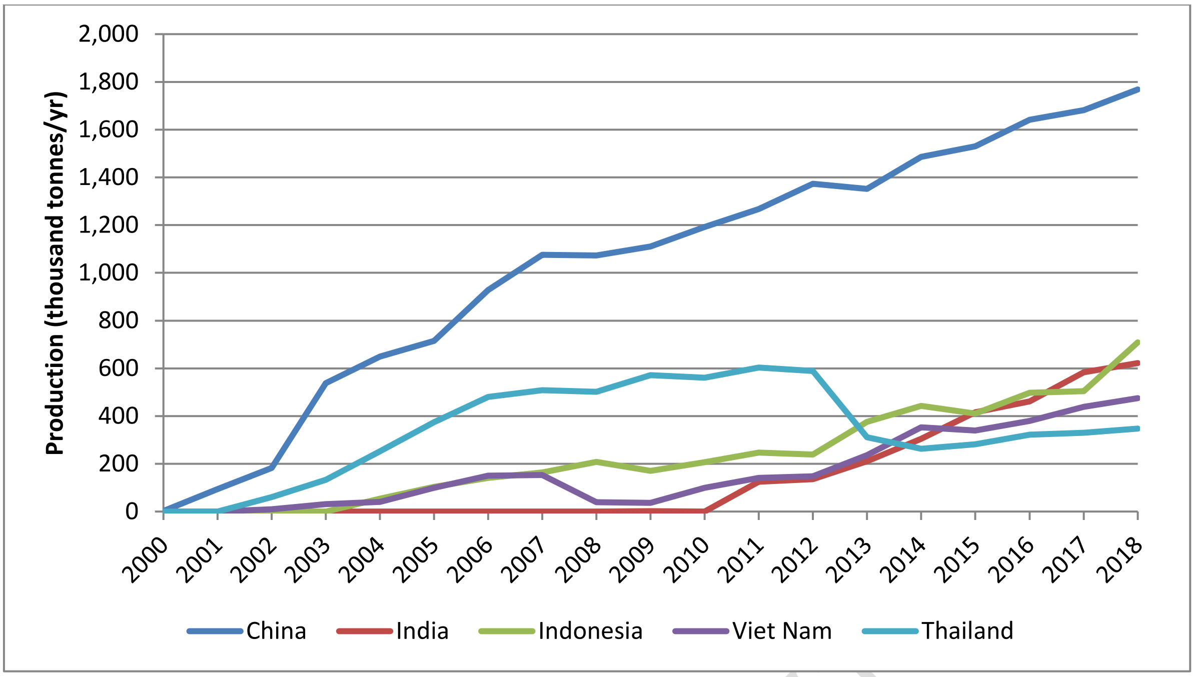

Figure 21. Production of whiteleg shrimp by selected countries in the Asia-Pacific region, 2000 to 2018 (thousand tonnes/yr).

Emerging species

The culture of mitten crab and the non-native, red swamp crayfish have made major strides in China in addition to the yellow catfish, *Pelteobagrus fulvidraco*, in recent years. The three species have become increasingly important in terms of production and economic value. These developments are most welcome in a scenario where the overall rate of growth of the sector has slowed down.

The trends in production and corresponding values for the three species are shown in Figure 22 and Figure 23, respectively. Also shown are the corresponding values for tilapia, the culture of which was well established by the dawn of the millennium and had been steadily growing at a fast pace. This indicates that the rate of production growth for these three emerging species has been comparable to, or outperformed, that of tilapia over these years. The trends are summarised in Table 3. It is evident from the data that all three species have shown very rapid growth. For example, red swamp crayfish production grew by 4.5 times while the value grew by a 7.4 times, from 2008 to 2018. The corresponding figures for the more established tilapia sector were only a 1.5 times growth in production and 2.4 times growth in value. This is a remarkable growth rate, that may not have been witnessed before for any species, anywhere in the world.

The key factors that have to be noted is that both mitten crab and crayfish culture are not entirely dependent on feeds as the main culture environments are paddy fields, ponds and lakes. These are cordoned off to manageable sizes with small dykes or banks and the culture environment is managed to produce natural food for the cultured stocks (Wang *et al.*, 2016; Wang *et al.*, 2018). For example, in mitten crab pond farming systems, macrophytes are grown in the pond. Mitten crabs can feed on macrophytes as well as aquatic invertebrates naturally occurring in the pond ecosystem (Wang *et al.*, 2016). Both species can be cultured in paddy fields, especially red swamp crayfish. In 2018, more than two million hectares of rice fields were used for rice/aquatic animal integrated culture in China (BoF/MARA, 2019), of which more than 840 000 ha were for rice-crayfish culture. Adoption of the farming practice at a massive scale explains the steep increase in crayfish production in recent years.

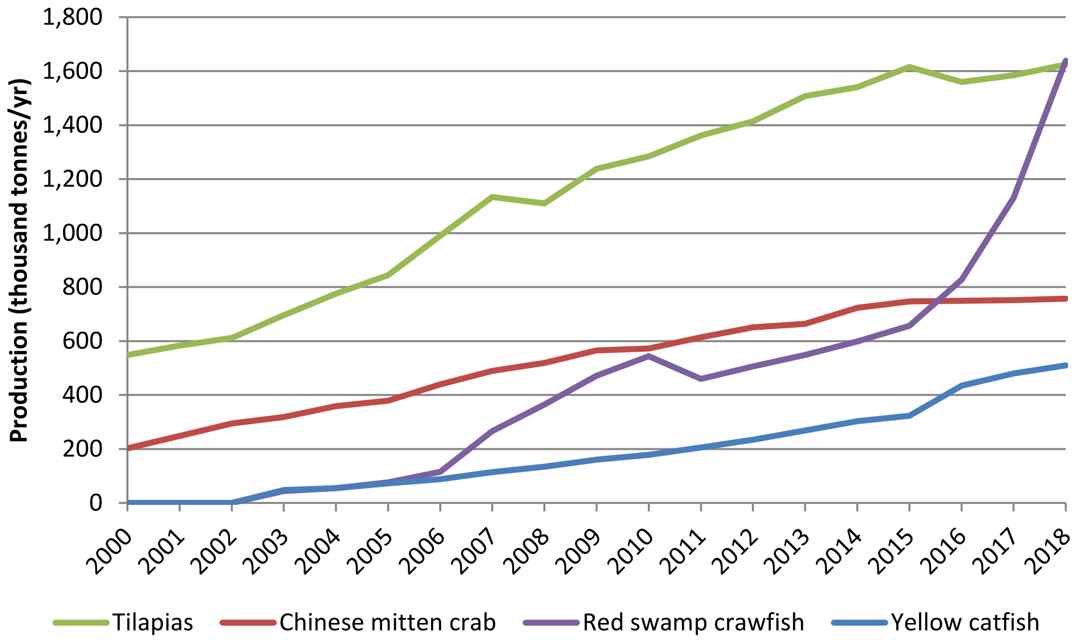

Figure 22. Production of mitten crab, red swamp crayfish, yellow catfish and tilapia in China, 2000 to 2018 (thousand tonnes/yr).

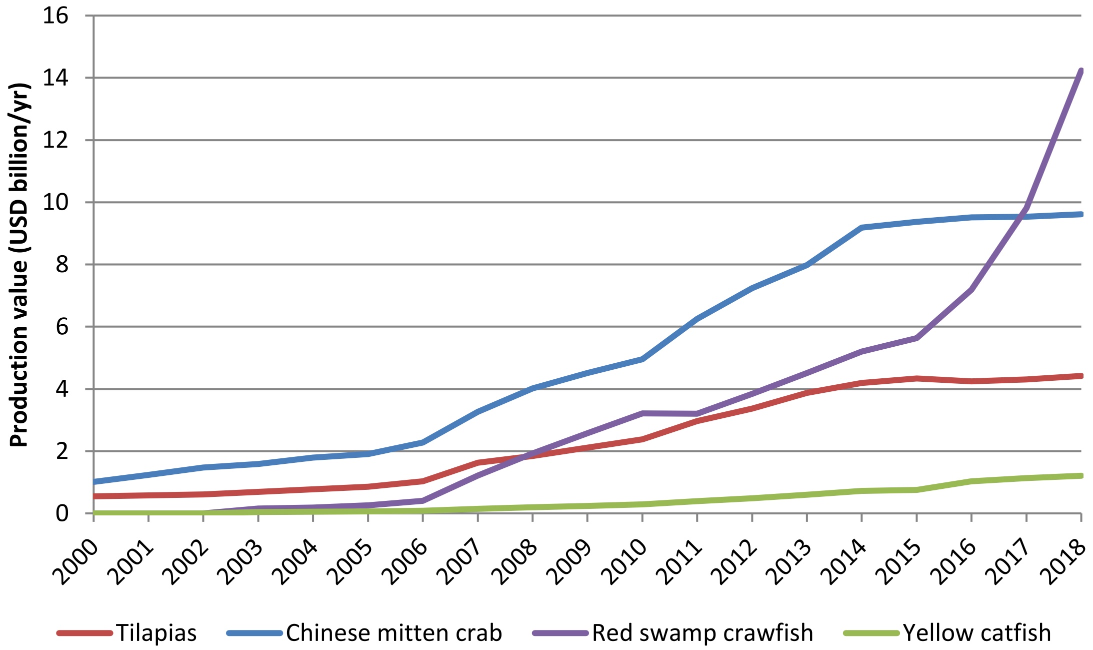

Figure 23. Value of mitten crab, red swamp crayfish, yellow catfish and tilapia production in China, 2000 to 2018 (USD billion/yr).

Table 3. Production (tonnes/yr) and value (USD thousand/yr) of Nile tilapia, Chinese mitten crab, red swamp crayfish and yellow catfish in China in 2008 and 2018

Species	Production (tonnes/yr)			Value (USD thousand/yr)		
	2008	**2018**	**Increased by** (multiplier)	**2008**	**2018**	**Increased by** (multiplier)
Nile tilapia	1,110,298	1,624,547	1.5	1,840,874	4,417,143	2.4
Chinese mitten crab	518,357	756,877	1.5	4,015,712	9,613,852	2.4
Red swamp crayfish	364,619	1,638,662	4.5	1,931,752	14,235,057	7.4
Yellow catfish	134,448	509,610	3.8	194,546	1,208,795	6.2

1.5.6 Production systems

Asia-Pacific aquaculture is carried out in a diverse range of culture systems and with a wide variety of technologies. Extensive, semi-intensive and intensive cultures are all practiced ranging from small-scale, backyard, family fishponds to highly industrialized, technologically sophisticated, commercial operations. Culture facilities include earthen ponds, tanks, cages/pens, rice-fields and in some cases raceways for particular species or production purposes. Monoculture, polyculture and integrated culture systems have all been developed depending on resources available for species or species combinations with different biological characteristics. Both closed and open systems exist with various degrees of water treatment or water recycling through recirculation. However, system-wise statistical data are not yet readily available, so it is difficult to determine what quantities and what species are produced in different systems. However, there are some notable development trends as described in this section.

There has been a general and continuing trend towards intensification for higher yields and better economic efficiency as well as responding to increasing market demand and growing resource limitations. While conventional, pond-based, semi-intensive culture is still widely practiced in the region for culture of most omnivorous species and species that thrive at low levels of the food web such as Chinese carps, Indian major carps and tilapia, resource inputs and management intensity have been increasing. Carp culture in China is an example of such intensification where farm layouts, pond designs, water systems and management have been modified to transform conventional pond culture into more productive and environmentally friendly operation particularly in the past ten years. Commercial pellet feed constitutes a large part of nutrient supply to the system while ponds are usually mechanically aerated to increase both land and water productivity. At the same time, effluent treatment and recycling have also been added to some of the farming systems to increase nutrient use efficiency and reduce environmental impacts.

There have been continuing efforts to promote cage culture in Asia in last decade, with cages of various materials, designs and sizes depending on the biological character of cultured species and resource availability. These were placed in rivers, lakes, reservoirs, canals, estuaries and nearshore coastal waters wherever feasible. It is estimated that more than 70 species are being cage-cultured in both freshwater and marine environments. However, there have been environmental concerns associated with nutrient discharges from cages especially in cage culture sites and water bodies that provide other important functions such as urban water supply and tourism and where the carrying capacity has not been assessed. In China there was large-scale removal of fish pens and cages from lakes, rivers, reservoirs and nearshore coastal areas in recent years to eliminate fed-species aquaculture in many provinces, in an attempt to alleviate water pollution and restore ecosystem functions.

There are potential improvements that could be made to existing cage culture practices. In China, many designs of multiple-layer, cage farming systems have been adopted. The main, usually high market-value species is stocked in the inner cage and the outer cage is commonly stocked with species such as bighead carp, silver carp, and crucian carp to use up uneaten feed and help maintain water quality. Such practices have been adopted in the emerging cage culture of yellow catfish (Li *et al*., 2018a) and channel catfish, *Ictalurus punctatus* (Li *et al*., 2018b). In both these cases silver carp and bighead carp are used as the secondary species in the outer cages and these species prevent and or minimise algal growth on the cages and facilitate water exchange. In Indonesia, the "lapis dua", meaning two cage systems has been commonly adopted in cage culture operations, thereby increasing the overall production levels and yield while also helping to reduce effluent discharges into the environment by reducing feed wastage. Abery *et al*. (2005) described this practice in detail for three Indonesian reservoirs, Saguling, Cirata and Jatiluhur, of the greater Ciratum watershed, West Java. In the "lapis dua" system the inner 7 m × 7 m × 3 m cage is used for common carp culture and the outer cage (7 m × 7 m × 5-7 m) is stocked with Nile tilapia. However, the choice of species could be tailored to the needs in each country and market demands, the relative ease of obtaining fingerlings and the overall economic benefits. However, these two cage systems should be encouraged in cage culture operations in the region as a tool to increase fish availability and improve farmer incomes.

Considerable development has been made in offshore and deep-sea cage culture. For example, in China, aquaculture production from deep-sea cages reached 153 978 tonnes in 2018, a 14 percent increase over the previous year (BoF/MARA, 2019). These cages are better designed to resist waves and currents than conventional cages used in nearshore or inland waters. They can accommodate more technological sophistication and innovations that enable production processes such as stocking, feeding and harvesting to be mechanized and automated, while water quality parameters can be monitored in real time and precisely controlled. While there is an urgent need for such development due to the increasing scarcity of inland and coastal aquaculture resources and demand for more fish from the sea, offshore cage culture has yet to be widely adopted in the region because of the level of technical difficulties and high investment.

Various pond-based recirculation systems have been developed with diverse engineering designs for intensive culture of fish in tanks, raceways or cages, as well as shrimp in tanks or ponds. In these systems, filter feeding fish, aquatic plants and/or shellfish are raised in separate ponds to extract excess nutrients from effluents produced by the intensively farmed primary species. This minimizes nutrient discharge into the natural environment, while increasing nutrient and water use efficiency.

In China, shipping containers have been modified to be used for intensive culture of fish including mandarin fish, grass carp, largemouth bass (*Micropterus salmoides*) and tilapia. Some of the shipping container-based culture units are equipped with automated feed dispensers and water quality monitoring systems. Earthen ponds are sometimes used for water treatment and remediation where filter feeding fish are grown and aquatic plants are cultivated. In-pond raceway systems have also been adopted by some farmers in China where the main fish species being grown is intensively cultured in specially designed raceways set within earthen ponds. The pond area is used for water treatment by stocking filter feeding fish or growing aquatic plants (Brown, Boyd and Chappell, 2012; Li *et al.*, 2019).

Many shrimp farms in China, Thailand and Vietnam have also adopted the concept of recirculation with various farm configurations, including complete earthen pond-based recirculating systems and indoor culture units integrated with outdoor earthen ponds. In these, earthen ponds are used for water treatment where fish, shellfish, seaweeds or other aquatic plants are raised. The purpose of the integration is to maximize use of water inside the system and reduce or eliminate water exchange from outside in a crop cycle to minimize any possibility of introducing pathogens.

Indoor, intensive, recirculating systems are gradually gaining attention for shrimp culture in major shrimp producing countries such as China, Thailand, and Viet Nam. Conventional cement structures are common, but PVC pipe and steel frame-supported, polystyrene tanks are also used as the culture units. Such relative isolation from the surrounding environment with near zero effluent discharge allows for maximum biosecurity and minimal environmental impacts.

Conventional integrated aquaculture such as poultry-fish and livestock-fish integrated farming, particularly the commercial operations that once flourished in countries such as China and Thailand a few decades ago, have become less common in the past decade because of food safety, hygiene and environmental concerns. However, many small-scale farms continue to practice various degrees of integration among farming components as part of their aquaculture system, especially in rural areas where resources are not readily accessible. In recent decades, rice-fish culture has evolved from traditional small-scale farming to large-scale, commercial farming in China. The major species used in rice-fish culture have changed from carps to high-value species such as red swamp crayfish, Chinese mitten crabs, soft-shell turtle and Asian swamp eel (*Monopterus albus*).

Integrated multi-trophic aquaculture (IMTA) in coastal areas has been drawing attention (Fang et al., 2016). Such systems often consist of seaweeds, molluscs, invertebrates and other species low in the food chain and are operated in an extensive way without artificial nutrient inputs. They have low greenhouse gas emissions and have the potential to harvest nutrients in coastal waters thereby helping to reduce pollution and maintain the health of coastal ecosystems.

There are various forms of extensive aquaculture that are practiced in the region including culture-based fisheries (CBF) which involves the utilisation of small, existing water bodies, both perennial and non-perennial, which cannot support a fishery through natural recruitment processes, for fish production through a stock-recapture strategy. CBF is environmentally friendly as the only external input is seed stock. It often engages a co-management approach involving farming communities. In most cases, farming communities are already organised into functional entities as the principal beneficiaries. This has been accepted as a significant development strategy, requiring minimal capital outlay, for increasing food fish production and improving rural community wellbeing by some countries in Asia, including Cambodia (Government of Cambodia, 2010) and Lao People's Democratic Republic (Lao PDR, Ministry of Agriculture & Forestry, 2010), and also globally, to increase inland fish production (Beard et al., 2011). CBF is an attractive development strategy as it mobilises dryland farming communities such as rice farmers to use existing water bodies for the secondary purpose of fish production.

This has been beneficial to communities in Cambodia (Limsong *et al.*, 2011), Lao PDR (Saphakdy et al., 2009; Phomsouvanh, Saphakdy and De Silva, 2015) and Viet Nam (Nguyen et al., 2001) among the South-eastern Asian nations. The development of CBF strategies in small water bodies have even become government policy that are considered to be low-cost investments with nutritional and monetary gains to communities. It may be beneficial for other Asia-Pacific nations to consider adopting this development strategy to increase aquaculture production and the nutritional status of the communities involved (FAO, 2015). In Southern Asia, CBF practices have been effectively implemented in reservoirs, initially in small reservoirs and later on extended to medium and large reservoirs, as secondary users of the water resources (Pushpalatha and Chandrasoma, 2010; Chandrasoma and Pushpalatha, 2018). Comparable developments in the flood plains of Bangladesh were observed when equitable and inclusive strategies were introduced generating fish incomes 3.74 times higher for the households involved in culture-based fisheries (Haque and Dey, 2017).

1.6 Challenges and issues

The slowdown of the annual growth in aquaculture production in the past decade leads to the question whether aquaculture will be able to bridge the gap between the demand and supply of aquatic food for growing populations. It is estimated that to maintain the current fish consumption level, 120 million tonnes to 130 million tonnes of food fish will have to be produced through aquaculture in 2050 (assuming that global population will reach 9.7 billion in 2050 and production from capture fisheries remains stable). If the consumption per capita continues to increase at the same rate as that for the period 1960-2016, around 200 million tonnes of food fish will need to be produced in 2050 to meet the increased demand. This would require an average annual growth rate of global aquaculture production of about three percent to achieve the production target in the coming three to four decades. In 2018, aquaculture production in Asia-Pacific increased by 2.1 percent over the previous year, the second lowest in the past three decades (the lowest growth of 0.8 percent was registered in 1996-1997). Growth in 2019 and 2020 could be even lower or even negative due to COVID-19. It is hard to predict how fast aquaculture will grow in the years to come, but it is likely that resource limitations, environmental pressure and external factors associated with climate change and other natural calamities may further negatively impact the sector.

Small-scale operations still dominate aquaculture in the Asia-Pacific region in terms of the number of farms. Limitations in access to resources and services prevents them from rapid adoption of new technologies and innovations, hence they tend to have lower system productivity, efficiency and profitability compared with their larger-scale counterparts. They are less able to respond to changes in external factors such as market conditions and are vulnerable to climate change and natural calamities.

Aquaculture development is not geographically balanced. Eastern Asia and South-eastern Asia dominate production in the region while the contributions from Central Asia and Oceania are negligible. Fast growth of aquaculture has been observed in Southern Asia particularly in the past decade from India and Bangladesh, but its potential has yet to be fully realized. Culture, traditions, dietary habits and resource availability might in one way or another influence the development process. Suitable development strategies need to be developed to mainstream aquaculture into overall food production and nutrition security systems.

1.7 The way forward

Despite declining trends in aquaculture growth rates in recent years, aquaculture in the Asia-Pacific region can generally be considered as a success in the past ten years and production will continue to increase. Waite et al. (2014) advocated the need to improve the productivity and environmental performance of aquaculture, which they considered to be an attractive option for expanding animal protein supply. Furthermore, they suggested that the aquaculture sector is relatively young compared with terrestrial livestock sectors, therefore it offers great scope for technical innovation to further increase resource-use efficiency.

China will remain dominant in terms of production although the annual growth rate is likely to slow down further. Significant growth in production volume may be expected from Southern Asia, led by India, where resource optimisation may favour continuing growth of the sector. It is also expected that the aquaculture potential of Central Asia and countries in the Caucasus region needs to be further explored, serving as new growth points for aquaculture.

Sustainable intensification remains as the development focus through innovations to increase productivity and environmental performance. Resource limitations, increasing needs for biosecurity, compliance with environmental regulations and practice ethics will pressure the industry to adopt more isolated, closed, or semi-closed systems, and continue to explore opportunities of marine culture and deep-sea cage culture. On the other hand, diverse, integrated aquaculture should come to play a more important role in aquatic food supply. It is likely that current conventional pond culture will have to be transformed to more eco-friendly modes and to comply with practice standards and ethics while maintaining similar or higher productivity. Rice-fish culture, IMTA, and other forms of integrated agriculture-aquaculture will continue to evolve and hopefully further expand.

Molluscs and seaweeds will play more important roles in supporting our food systems and food security. Production needs to be better planned and promoted, including technology development, and establishment and improvement of value chains while their roles in providing ecological services need to be further exploited.

Technological development, research efforts and farming practices may bring more growth if they can concentrate on a smaller number of well-established species to maximize advantages of specialization and sector scale, while new species will continue to be explored to seek new growth points. The development of culture-based fisheries should be further encouraged to unleash the fish production potential of many water bodies in the Asia-Pacific region and increase their contributions to food fish production and rural community development.

1.8 Resources, services, and technologies

1.9 Status and trends

1.9.1 Land and water resources

In general, there are considerable water and land resources for aquaculture in the Asia-Pacific region. Rivers, lakes, underground water and land can support substantial inland aquaculture in most countries and territories, even in landlocked, relatively dry areas such as Central Asia (Annex II). Countries along the coast of the Pacific and around the Indian Ocean also have long coastlines suitable for marine aquaculture. Meanwhile most South-eastern Asian nations are blessed by rich water resources and warm weather that favour aquaculture.

However, water and land resources are becoming scarce under heavy pressure of exploitation, often in conflict with multiple use and in some cases are polluted. Coastal areas suffer from overpopulation and are facing increasing competition with other development sectors. This means there is limited scope and potential to increase aquaculture production through expansion of aquaculture areas in inland, estuarine and nearshore coastal waters in the region.

1.9.2 Seed production and genetic resources

Artificial breeding and hatchery seed production have long been established for most cultured species and species items in the region. These include finfish such as Chinese carps, tilapia, Indian major carps (*Catla catla, Labeo rohita*, *Cirrhinus mrigala*) pangasius catfish, clarias catfish (*Clarias gariepinus*), snakehead (*Channa* spp.), Wuchang bream (*Megalobrama amblycephala*), yellow catfish, Asian seabasses (*Lates* spp.), seabreams, a few groupers and a number of other indigenous finfish species in various countries in the region. Breeding systems for crustacea include those for whiteleg shrimp, giant tiger prawn, Chinese mitten crab, mud crab (*Scylla serrata*), and red swamp crayfish, while seaweeds and molluscs are also reproduced.

Indoor cement structures are the most common type of holding system for aquaculture hatcheries. These involve a series of cement tanks of various shapes and sizes for broodstock conditioning, induced spawning, egg incubation, larval nursing and various steps of advanced nursing. There are usually support systems including water treatment, aeration and live food production. Advanced nursing to produce large size fingerlings using earthen ponds is common for finfish species, though indoor tank-based intensive nursing is now being used for some species such as Asian seabass (*Lates calcarifer*) and groupers.

However, there are several species where aquaculture still relies on wild sourced seed for aquaculture. For example, the Japanese amberjack (*Seriola quinqueradiata)* and greater amberjack (*Seriola dumerili)*, are both economically important in Japan, accounting for 25 percent of the country's total aquaculture production. Other species such as eels (*Anguilla* spp.), lobsters, southern bluefin tuna (*Thunnus thynnus*), and a few species of tropical groupers also rely on wild seed collection.

Mollusc culture largely relies on hatchery produced seed, because the hatchery produced spat or juveniles are generally considered to be of higher quality, uniform in size and with well-timed availability in large quantities. However, collecting spat from wild is still practiced in some locations. It is believed that aquaculture in fact replenishes natural stocks in certain coastal areas such as in China which makes natural spat collection seemingly much easier than before.

Artificial seed production of a few commercially important lobster and crab species such as spiny lobster (*Panulirus* spp.), mud crab (*Scylla* spp.) and blue swimming crab (*Portunus pelagicus*) has been explored experimentally with success. Commercialization of artificial seed production of mud-crab and swimming crab has been realized in China, the Philippines and Thailand.

Asian countries have successfully developed nurseries for all the major cultivated seaweed species, producing large quantities of high-quality seedlings and cuttings for example, of kelp *Sacchalina japonica*, Wakame *Undaria pinnatifida*, laver *Porphyra spp*., and *Gracilaria lemaneiformis*. Propagation of commercially important seaweeds for aquaculture has been successful in countries such as China, Indonesia, and Philippines.

Many Asian nations have state-supported or state-owned seed production facilities for aquaculture, often affiliated with government fisheries stations, research institutes and technology extension agencies. They produce seed to be distributed and sold to farmers or stocked into reservoirs and natural water bodies as part of stock enhancement efforts. These state-owned facilities also play important roles in large-scale efforts for genetic resource conservation and genetic improvement for culture species, as well as the development of new species for farming and support to other aquaculture research. However, their role in supplying seed directly to farmers has been reducing and in major aquaculture producing countries seed supply for commercial farming relies almost entirely on private commercial hatcheries.

Apart from relatively large and medium-scale commercial hatchery operations, there are many backyard hatcheries that play an important role in aquaculture seed supply in many Asian countries. These hatcheries may maintain broodstock, produce juvenile animals of different stages and supply grow-out farms directly, or they are specialized in one or a few phases of seed production cycle such as spawning to produce eggs, egg incubation, early nursing, and or advanced nursing. Specific pathogen free stocks (SPF) have been developed and used in seed production for shrimp culture and the concept is being extended to production of other species.

There are some three hundred species currently being cultured and many new species have been explored experimentally for their farming potential in Asia. Plausible progress has been made in genetic improvement for some major farmed species such as common carp (China, Indonesia), crucian carp, *Carassius carassius* (China), tilapia and whiteleg shrimp, supported by both government and private sector investment. Some genetically improved farmed types, for example, GIFT (Genetically Improved Farmed Tilapia) tilapia (Eknath and Acosta, 1998; Gupta and Acosta, 2004b; World Bank, 2013), common carp and a number of improved farmed types of whiteleg shrimp, have been developed both within the region and in international programmes. These have been widely adopted and are playing important roles in maintaining continued increases in regional aquaculture production. However, some 40 percent of aquaculture species reported as cultured in the region are cultured as wild types and genetic improvement has yet to impact on aquaculture production significantly, representing a major opportunity to enhance production (FAO, 2019a).

1.9.3 Feed and feed ingredients

Feed availability and supply

Over the years, feed-based aquaculture, where the cultured organisms are provided with all or part of their nutritional needs from external feeds, has been undergoing intensification with more compound feed inputs of various forms (Tacon and Metian, 2008; Tacon *et al*., 2010). Total global usage of compound aquafeed was estimated at 49.6 million tonnes in 2016 and was expected to rise to 60.4 million tonnes by 2020 and 76.2 million tonnes by 2025, respectively (Tacon, 2018). The Asia-Pacific region, producing more than 90 percent of the global output of aquaculture, is the largest aquafeed producer and consumer. Aquafeed production has been increasing rapidly along with growth of the sector in the past two to three decades and likely will continue to increase.

Compound aquafeed is manufactured and generally available in most countries and territories in the region. Most farmers, both small-scale and large-scale, now buy their feeds commercially and the market is shared by just a few, large companies in each country. However, the region is importing a large amount of feed ingredients for animal feed production. The supply of high-quality ingredients for aquafeed production is a rising challenge, as there are shortages and competition for other uses. The use of locally available feed ingredients and alternative ingredients will be strategically important to the region and particularly for small-scale farmers who are at a disadvantage in accessing feed resources.

Farm-made feeds, to some extent, ease the problem of feed availability, yet quality and feed efficiency are questionable. Feed costs typically comprise 40 percent to 70 percent of production costs in semi-intensive, intensive and super-intensive aquaculture, and even more in some small-scale aquaculture farms where labour costs of family members are often not counted.

<u>Use of fish meal and fish oil</u>

The use of fish meal as fish oil as major ingredients for some culture commodities, such as shrimp and marine fish is one of the most controversial issues in relation to aquaculture feeds. In 2011, a total of 26.5 million tonnes of fish was converted into fish meal, of which 18 million tonnes were used for aquaculture (Guillen *et al*., 2019). Aquaculture has been the main user of fishmeal over the years, a global commodity in limited supply and often viewed as a disproportionate user of the global commodity by some critiques of aquaculture (Naylor *et al*., 1998; Naylor *et al*., 2000; Naylor *et al*., 2009). As is evident from the previous sections of this report, the Asia-Pacific region dominates global aquaculture production and China is the main driver as it contributes over 50 percent of global aquaculture production.

Currently, fish meal and fish oil used in aquafeeds are largely sourced from wild-captured fish but there is a consensus that this is not sustainable if aquaculture production continues to grow so alternative protein sources are needed (Gatlin III et al., 2007; Hasan et al., 2007; Tacon and Metian 2008; De Silva, Francis and Tacon, 2011; Tacon *et al*. 2010; Bulfon et al. 2013). Hua et al. (2019) suggested that beyond plant-based ingredients, there is potential to use food waste after biotransformation and/or bioconversion of raw waste materials, while microbial and macroalgal biomass have limitations regarding their scalability and protein content, respectively. These authors suggested that optimisation of alternative protein sources for aquafeeds be pursued to ensure a socially and environmentally sustainable future for the aquaculture industry.

It is important to notice that some recent developments in research and their application in industry have resulted in considerable reductions in the use of fish meal in aquatic feeds in developing countries (Han et al., 2018). While the Asia-Pacific region is the backbone of global aquaculture, in proportion to its production levels, its use of fish meal and fish oil is proportionately much less than, for example, production of salmon in temperate waters.

<u>Feed management</u>

Feed management essentially includes the choice of the appropriate feed for the cultured stock, based on its nutrient content and other quality parameters, and the manner, quantity and time of dispensation of the feed. FAO (2010) recognised seven primary issues that currently constrain feed use and management in aquaculture, namely: 1) limited access to information on feed and feed ingredients (availability, prices and quality); 2) poor feed preparation, processing, handling and storage at the farm level; 3) inadequate monitoring of feed and farm performances; 4) low impact of current dissemination strategies on improved feeding and feed management; 5) gaps in the understanding of the economic aspects of feed management; 6) health aspects and their implications for feed management; and 7) feed quality – lack of regulatory mechanisms. These issues have been gradually alleviated in the past ten years, yet they are all still persistent issues to some extent, especially in countries where the aquaculture industry is relatively new and for many small-scale farms.

Good farming and feed management practices at farm level that favour high eco-efficiency and feeding cost-effectiveness are not as widely known to farmers as they should be, while some common prevailing practices such as excessive protein input or feeding to satiation" may need to be rechecked and properly adjusted. It is often acknowledged that feeds used by many farms exceed the required protein requirement of the stocked species; possibly by three percent to four percent in protein content making the feed more costly. This tradition among farmers is hard to challenge and perhaps needs a concerted attempt by international, regional organisations and national extension service providers to draw the attention of farmers to curtail such practices. Also, in many farms the quantity of food dispensed exceeds the daily requirements of the stock.

Equally important is to avoid some inefficient practices of feed dispensation often seen in Asia-Pacific aquaculture. One such example is seen in carp feeding in India and Myanmar, where the feed is introduced into perforated polythene sacs, tied to posts in the pond and the fish extract the food through the perforations. This feeding method involves a lot of leaching of nutrients into the water and the fish are unable to access and utilize the food effectively and efficiently. Many such examples of relatively inefficient feed dispensation techniques used among rural farming communities are known (FAO, 2010), but the practices continue despite the inefficiencies.

There is no set feeding practice that will fit all situations for effective feed management but it is apparent that in general there is often over-feeding of the stock. The key to solving this problem will be through dialogue and education and it is important to give due attention to this.

1.9.4 Research

There have been wide-ranging research contributions made from the Asia-Pacific region to the development of the aquaculture sector. However, aquaculture research remains rather uncoordinated, especially at the regional and international level and often happens to be driven by institutional priorities or even the interests of individual researchers as well as determined by funding availability. Species that dominate production attract much of the research interest and resources, and research efforts are increasingly being coordinated at the national level. For example, China has established National Aquaculture Industry Technology Systems for farming of staple freshwater fish species, special freshwater fish species, marine fish species, crustacean and shellfish. Through these technology systems, research efforts are prioritized, streamlined and coordinated, facilitating participation by multiple stakeholders including government research institutes, universities, agro-industrial companies and farms. The research areas cover most aspects of the aquaculture industry including genetic resource appraisal, establishment of the genetic resource pool, genetic improvement of farmed types, nutrition and feeding, development of new or improvement of existing farming systems, biosecurity and disease control, culture environment control, aquatic food safety and quality, postharvest and processing and value chain development.

The importance of small-scale, homestead aquaculture practices in developing nations such as Bangladesh that bring about food security and nutritional security to small communities has been recognised (Nordhagen *et al*., 2020, Ratha, 2020, Haque *et al*., 2017). Equally, the significance of such practices from a gender equality perspective has been in focus (Brugere and Williams. 2017). There has also been a significant increase in investment and active involvement in aquaculture research and innovations by the private sector led by a few large agro-industrial companies in recent decades.

1.9.5 Animal health management support and services

Diseases pose severe threats to the aquaculture industry in the Asia-Pacific region and remain as one of the greatest challenges to the sustainability of the industry, particularly for the shrimp farming sector. Several transboundary aquatic animal diseases have swept the region over the past 30 years which have caused massive economic losses and social impacts. More recently, infectious myonecrosis in Indonesia and acute hepatopancreatic necrosis disease in Malaysia, Philippines, Thailand and Viet Nam have seriously affected shrimp farming (Senapin *et al.*, 2007; Flegel, 2012; Leaño and Mohan, 2012; Dabu et al., 2015). For finfish, the threat comes from tilapia lake virus (TiLV) which was first reported in the Asia-Pacific region in Thailand (Dong et al., 2017; Surachetpong et al., 2017), then in Taiwan Province of China (Yang, Chiu and Wu, 2017), Malaysia (Amal et al., 2018), the Philippines and India (NACA, OIE and FAO, 2017a). The spread of these transboundary aquatic animal diseases clearly demonstrates the vulnerability of the aquaculture industry, as well as wild fish populations, to disease emergence where impacts have been aggravated by a lack of preparedness and effective response whenever disease emergencies occur (Leaño, 2019).

In response to recent aquatic animal disease problems, aquaculture scientists in the region tried hard to develop methodologies and technologies for accurate and fast disease diagnosis, treatment through prudent application of chemicals and drugs, and prevention by vaccination and immuno-stimulation. Outstanding research achievements have been made in areas such as the biodiversity of parasites, infection modelling, life history and comprehensive control of parasites including *Dactylogyrus ctenopharyngodonis* and *D. lamellatus* affecting grass carp, *Enterogyrus coronatus* and *E. malmbergi* affecting tilapia. Progress has also been made on effector molecules and pathogenic mechanisms of microbial pathogens, the epidemiology of new and emerging shrimp viral diseases like viral covert mortality disease (Zhang et al., 2014) and Decapod iridescent Virus 1 (Qiu et al., 2018; Qiu *et al.*, 2019), invasion and replication of fish viral pathogens and their immune escape mechanisms, as well as the immune system composition and immune function of aquaculture species. With the continuous development of the industry and continuous diversification of cultivated species, the impact of viral diseases seems to be intensifying. It is expected that understanding these viral pathogens in terms of diagnosis, infection mechanisms and pathogenicity, can promote the development and progress of epidemiological and prevention strategies.

Many of the most serious disease issues affecting aquaculture, notably in the shrimp industry, have been associated with the translocation of live animals, including for broodstock and as seed. The accidental introduction of pathogens through such movements has caused massive damage to the industry. Although farmers eventually find strategies to reduce impact or "live with" disease, ongoing losses may remain large.

As new disease threats have emerged, the industry has been forced to adapt by improving management practices and modifying culture systems. This is perhaps most evident in the shrimp farming industry, where disease threats such as whitespot (WSSV) have driven extensive changes to grow-out production systems, forcing the abandonment of open water exchange in favour of closed systems, and now the early signs of a move towards recirculation, among many other changes. Hatchery practices have also improved with the adoption of routine laboratory testing of seed for disease and increasing use of specific pathogen free (SPF) stocks to reduce risk.

Disease threats have also driven extensive changes to government regulations concerning quarantine and health certification requirements for imported products. Instruments such as the *Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Animals and the Beijing Consensus and Implementation Strategy* (FAO/NACA, 2000) have provided a foundation for governments to strengthen regulatory safeguards on the movement of live animals. There has been extensive investment in capacity building in aquatic animal health with regards to personnel, institutions, surveillance and monitoring networks.

Reduction of the use of antimicrobials through alternative and better management practices has also contributed to the successful management of important diseases and production of safe aquatic products. These better management practices include the use of polyculture and green-water technology as well as alternatives to antimicrobials including effective microorganisms, probiotics and prebiotics (Pandiyan et al., 2013; Carbone and Faggio, 2016; Omar, Abdel-Salam and Mahmoud 2017; Chauhan and Singh, 2019), biofloc systems (Taw, 2015; Alimahmoudi, Azarm and Mohamadi, 2017), aquamimicry (Romano, 2017), the use of shrimp toilets for disposal of organic waste during grow-out culture operation (Khan, 2018; Kawahigashi, 2018), and recirculating aquaculture systems.

There has been a notable improvement in the increased awareness of use of antibiotics, and other chemicals in aquaculture practices, particularly in small scale farms that form the bulk of the sector in most of Asia. In general, there had been a decrease in the quantity and improvement of the mode of use of antibiotics and other additives in regional aquaculture systems. For example, Rico et al. (2013) reported that the total quantities of antibiotics applied by the catfish farmers, relative to production, were comparable or even lower than those reported for production of other animal commodities. Semi-intensive and intensive shrimp farms in China, Thailand and Viet Nam showed a decrease in the use of antibiotic treatments. Farmers generally did not exceed recommended dosages of veterinary medicines, and nationally or internationally banned compounds were (with one exception) reported neither by the surveyed farmers, nor by the surveyed chemical sellers. On the other hand, Ström et al., (2019) noted that in Viet Nam, antibiotics were used only by tilapia and catfish farmers but not shrimp farmers and that all farmers that were surveyed were aware of the risks associated with antibiotic use. It is also relevant to note that in general there had been an upsurge in the number of studies focusing on phytochemicals such as essential oils, saponins, flavonoids and phytosterols, discussing their effects on productive traits and the putative mechanisms of action, perhaps stimulating a gradual reduction in the use of antibiotics (Chakraborty et al., 2014).

There are generally institutions that are focused on aquatic animal health management across the region, often as integral parts of the national fisheries administration, the department of fisheries or government extension agencies. Their capacity has become stronger in providing aquatic animal health management support and services to farmers. Services and duties include disease diagnosis, surveillance, animal inspection and quarantine, regulating the use of drugs and remediating chemicals, as well as providing technical advice to farmers on disease prevention and treatment.

1.9.6 Insurance

Compared with other terrestrial food production sectors, aquaculture is more prone to risk factors such as natural disasters and disease outbreaks. Insurance is an important risk control mechanism. An FAO review in 2006 on aquaculture insurance (van Anrooy et al., 2006) indicated that large parts of Asia had barely been covered by aquaculture insurance services. The situation remains similar today as large insurance schemes have not yet been properly established in most Asian nations for most major cultured species.

Two exceptions are Japan and the Republic of Korea where aquaculture insurance has been developed thanks to favourable government policies and legal systems. Japan established a mutual insurance system where aquaculture entities can be insured to control operational risks. In 1964, Japan enacted the "Fishery Disaster Compensation Law", and in the same year, the National Federation of Fishery Masonic Associations was established to take charge of aquaculture insurance related work. The Fisheries Masonic Association was established by the Fisheries Freemasonry and is responsible for aquaculture insurance sales, underwriting, claims and customer services in various places. To achieve sustainable development of aquaculture insurance, the Japanese government has formulated financial policies that support premium subsidies, operating cost subsidies and reinsurance support as well as granting an average 40 percent premium subsidy to aquaculture entities participating in aquaculture insurance. At the same time, the Japanese government has established an aquaculture insurance reinsurance system to rationally diversify the operating risks of aquaculture insurance itself.

Republic of Korea has developed special laws and regulations for aquaculture insurance, including the "Aquaculture Insurance Law" and the "Aquaculture Insurance Law Implementation Order." These laws stipulate that the main operating bodies of aquaculture insurance in Korea are commercial insurance companies and the Central Committee of the Aquaculture Synergy Combination established under the "Aquaculture Industry Synergy Law" to carry out related work with commercial insurance and mutual insurance operation models. The main body of aquaculture participating in aquaculture insurance shall obtain relevant fishery qualifications and apply for insurance on a voluntary basis. In order to ensure a reasonable level of insurance premiums, the Korean Aquaculture Insurance Law Implementation Order stipulates that aquaculture insurance premium rates are implemented according to the region where they are launched, the subject matter of the insurance and the degree of risk. Through the establishment of the aquaculture insurance legal system, the rights, responsibilities, and behavioural boundaries of the parties to the aquaculture insurance have been clarified, all aspects of the aquaculture insurance have been guaranteed and the healthy development of the aquaculture insurance has been promoted. The Korean government has also introduced corresponding financial support policies for taxation and insurance compensation reserves of aquaculture insurance operating agencies. In order to guide the orderly development of aquaculture insurance, the Ministry of Agriculture, Forestry and Aquatic Food of the Republic of Korea is the national aquaculture insurance authority and an aquaculture insurance review committee has been set up to review the subject of aquaculture insurance, insurance rates and payment procedures.

Some progress on aquaculture insurance has been made in Indonesia. Since 2017, the government has provided aid for small-scale fish farmers through payment of a premium for “Fisheries Insurance for Small Fish Farmers”, or known as APPIK, to improve farming resilience. The insurance covers business failure and facility damage due to diseases and natural disasters. As of 2019, the government has paid the insurance premium for 15 026 fish farmers covering some 20 836 hectares of ponds for shrimp, milkfish, tilapia, and catfish culture. The APPIK program is targeted to cover five thousand hectares of land in 2020 so more farmers will benefit. Some more commodities are recommended to be covered by the aquaculture insurance scheme in 2021, including seaweeds, groupers, star pomfret, and white snapper (Rahman and Haryati, 2020).

Since 2012, China Fishery Mutual Insurance (CFMI) has launched a pilot mutual insurance programme for aquaculture. There are two main aquaculture insurance pilot models in China; mutual and commercial. Both receive significant insurance premium subsides from local governments. Commercial insurance could be a collaboration between local government and a private insurance company or between a private insurance company and a farming cooperative. The variety of insurance products piloted include indemnity-based and index-based types. For the first type, named-peril insurance is used, which usually covers natural disasters and some diseases. The index-based type includes wind speed, temperature and hydrological parametric insurance for some species such as sea cucumber, mitten crab, seaweed and oyster (Xinhua et al., 2017). In 2018, CFMI aquaculture insurance operated in eight Chinese provinces covering a total aquaculture area of about 33 000 ha with total insured value of about USD 60 billion.

1.10 Challenges and issues

Aquaculture development in the region is increasingly constrained by the limited availability of natural resources, including land and water so there is limited scope to increase aquaculture production in inland or coastal areas through expansion of culture areas. There are also restrictions over the use of farming land and open water bodies for aquaculture in many countries to protect crop production and other land and water uses.

Despite the improvement in efficiency of aquaculture feed and feeding, dependence on fish meal and fish oil persists. Other issues related to feed and feeding management in the region include the increasing reliance on terrestrial ingredients, competition for feed ingredients with other sectors, dependence on imported feed ingredients from other regions, lack of speciality feeds, inappropriate feeding practices and poor access of small-scale farmers to cost-effective quality feed.

It is not always possible to source high quality fish and shrimp seed with the desired genetics, specific pathogen free status, of uniform size at the right time and in the required quantities. Sourcing seed and broodstock from the wild for aquaculture of certain species is often associated with issues of uncertainty about stock quality, the risk of introducing diseases, overfishing of natural stocks and in general is regarded as unsustainable. There are also issues of broodstock quality, seed quality and disease risks specifically related to small-scale backyard hatchery production.

Compared with terrestrial agriculture, aquaculture is lagging behind in terms of genetic characterization, domestication and improvement. Many farmed species resemble their wild stocks with little to no genetic improvement and often experience genetic quality deterioration caused by reduced genetic biodiversity and inbreeding. Uptake of genetic improvement to develop better farmed types for aquaculture has been slow, especially for species with long life cycles and opportunities exist to enhance production efficiency through targeted genetic improvement. However, there is often a lack of attention to maintenance of genetic quality in seed supply systems, resulting in deterioration of performance of domesticated farmed types.

With fast growth of the sector, the region has made great progress in aquaculture research with increasing investment and research capacity. However, investment in aquaculture research in most countries in the region is probably inadequate and research efforts often lack strategic planning and effective coordination at national, regional and international level. Public access to private-sector research and innovations by large companies is often limited due to potential conflict of interests.

The region has been striving to establish extension networks for technology transfer with most nations having their institutional systems set up specifically for aquaculture extension, consisting of government agencies and extension officers at various administrative levels. Despite the progress, there is still a shortage of skilled extension workers and often good scientists do not appear to be good extensionists, hence research and field work are often uncoordinated. Small-scale farmers are especially disadvantaged in terms of access to the latest research information and innovations.

Diseases remain the major threat to the industry and this is aggravated by the lack of emergency preparedness and response in many countries when a new disease emerges. Prevention and spread of these emerging diseases remain a challenge to most countries, as proper biosecurity measures are still lacking especially at farm level.

Regulation has historically focused on microbial contamination and on anti-microbial residue levels in end products. Governments focus more on screening imported and exported products for harmful microbes and banned substances that pose risk to human health and for compliance with maximum residue limits (MRLs). The use of antimicrobials in aquaculture has been a persistent food safety and trade issue. Sanctions for non-compliance typically involve rejection of an individual shipment but have occasionally included trade embargos on exporting states. Over the past 30 years food safety standards and MRLs have been progressively tightened and compliance testing strengthened. As a result, the use of banned anti-microbial substances has declined substantially and adherence to MRLs has improved markedly, if not fully, and the proportion of shipments rejected has declined over time. In part, this can be attributed to exporting states proactively strengthening food safety regulations, inspection systems and licensing requirements to preserve market access. However, private sector exporters have also been proactive in establishing their own quality assurance and inspection systems.

More recently, there have been renewed concerns over antimicrobial usage in aquaculture due to the development of antimicrobial resistance (AMR), which may lead to multi-drug resistant, untreatable infections in humans and cultured animals. Many governments are currently revisiting controls on the use of anti-microbial substances. It is almost certain that controls will be tightened, but enforcement remains a challenge.

While it is possible to use anti-microbial substances in a responsible manner, in the Asia-Pacific region the aquaculture industry suffers from a lack of veterinary supervision, particularly (but not only) in a developing country context. Few farmers have access to the professional services required for an accurate diagnosis and appropriate treatment regimen. As a result, anti-microbial substances are sometimes used without professional oversight and in an ineffective manner. There is clear evidence of a rise in anti-microbial resistant strains of bacteria in aquaculture farms in the region, including multi-drug resistant strains. FAO, NACA and USAID are collaborating on the development of a regional framework for AMR surveillance in aquaculture and in a regional assessment of antimicrobial usage and associated risks in aquaculture. Similar work is also being conducted in the human health, agriculture, and terrestrial livestock sectors as part of a "one health" approach to the cross-sectoral problem.

Insurance schemes have not yet been established in most Asian nations for most major cultured species due mainly to the high-risk nature of the industry with risk factors which are often complex and unpredictable, difficulty in loss assessment, often low profitability of farming and insufficient institutional support.

Small scale farmers are often at a disadvantage in access to finance, feed, seed, market information, and technical services.

1.11 The way forward

Aquaculture resource management needs to fit into overall planning and management schemes for food security involving multiple food production sectors. Resource use should be optimized to give priority to those food production systems that are most relevant to food security, livelihoods and social development, environmental performance and of high resource efficiency. Aquaculture, with its strategic importance for food security, livelihood opportunities as well as comparable or better production and environmental performance than other food production sectors, deserves to be prioritised with strong policy support and investment.

Technology development and innovations to support sustainable intensification are fundamentally important to increase resource use efficiency. More support and investment both from public and private sectors in research and development are needed to advance aquaculture science and technology, stimulate innovations and develop farming systems that lead to higher production and economic efficiency, and better environmental performance and resilience.

Research in aquaculture needs to be strategically planned based on development objectives and priorities. Mechanisms need to be established for systematic assessment of research needs, on which research schemes are then formulated, research resources optimized and research efforts coordinated at national level. Regional and international collaborations need to be strengthened to facilitate implementation of research on common issues, information exchange and capacity building for researchers. Public private partnerships need to be strengthened and investment from both private and public sectors in aquaculture research need to be promoted. Outreach strategies and extension need to be integrated into research schemes and project life cycles.

With limitations in feed resources, particularly for small-scale, resource-poor farms in the region, there is a need to develop more cost-effective feeds and feeds based on local or alternative ingredients to improve feed availability and reduce feed costs. On the other hand, speciality feeds need to be developed to accommodate the diversity of culture species and culture environments. Continuing efforts are required to find economically viable solutions for fish meal and fish oil replacement in aquafeed. Greater effort is needed to develop and scale up the production of local feed ingredients and alternatives to fishmeal and fish oil.

Genetic improvement represents a major opportunity to increase aquaculture production. Appropriate approaches to, and adoption of, genetic improvement must be based on risk benefit analysis and a balance needs to be maintained between development of existing farming types and the development of new species determined by production enhancement potential. More appropriate strategies should be identified and adopted for initiation of breeding programmes with public support, private sector engagement and effective dissemination strategies envisaged from the start. The overall focus should be on the widespread delivery of improved farmed types to industry and long-term improvement in management approaches.

There is a continuous need to develop strategies, systems, management practices and products such as vaccines, immunostimulants, drugs and probiotics for disease prevention as well as treatments that fit into the conditions of aquaculture development in the region. There is a need to take a proactive approach to aquaculture biosecurity and emergency response, moving on from being reactive to being proactive for disease prevention and control. Thus, support for the government competent authorities and full cooperation of the private sector needs to be further strengthened in the overall management of aquatic animal health. There is also an urgent need to strengthen the local technical capacity and services to support small-scale farmers to effectively manage the health of cultured animals.

Governments and public agencies need to develop relevant policies, legal provisions and financial support to establish appropriate insurance schemes for aquaculture and expand their coverage through collaboration and partnership of both private and public sectors.

The majority of small-scale farmers need to be included in, and benefit from, all relevant development processes and capacity building for them which warrants continued and further strengthened institutional efforts to facilitate their access to resources, information, farming technologies and other services.

1.12 Aquaculture and Environmental Integrity

1.13 Status and trends

The rapid increase in aquaculture production over the past four decades has been fuelled by increased production inputs and resource use that inevitably result in increasing environmental footprints. For decades, the environmental impacts have been drawing criticism and stimulated debates and lobbying against aquaculture, particularly targeting intensive shrimp farming. The negative environmental impacts often under scrutiny include the destruction of mangrove forests in the early years of intensive shrimp culture, salinization and acidification of soils, pollution of water for human consumption, eutrophication of effluent receiving ecosystems, ecological impacts caused by use of chemicals and drugs, changes on landscape and hydrological patterns, and negative effect on fisheries (Martinez-Porchas and Martinez-Cordova, 2012). These aspects and the pros and cons of aquaculture impacts on biodiversity conservation were highlighted by Diana (2009) and De Silva (2012a). However, as expected the controversies on the use of fish meal and fish oil linger on (Cao et al., 2015; Han et al., 2018).

On the other hand, very recently Lebel, Lebel and Chuah (2019) pointed out that fish farms suffer significant losses from polluted run-off, entering water bodies where fish are grown. Mass mortality events in culture installations, such as cages, particularly due to external pollution, are at the core of the 'aquaculture as victim' discourse, while shrimp farming is the focus of the 'aquaculture as villain' discourse. A third discourse sees aquaculture as a benign technology and is used widely to describe fishpond culture systems, as well as sometimes promoting aquaculture in low-quality water bodies or as a part of integrated nutrient and waste re-use farming systems. This study pointed out that aquaculture farmers should be included as stakeholders in the management of watersheds and rivers, as well as in the negotiation and allocation of water resources, and emphasised a need for aquaculture development policies to pay closer attention to water quality and allocation issues.

In response to public concerns over the environmental impacts of aquaculture, policies, legal frameworks and regulatory mechanisms have been gradually established and strengthened in the region while various institutional instruments and tools have been devised to enforce environmental regulations and improve environmental integrity of aquaculture practices. The environmental performance of aquaculture operations in the region has been improved in the past decade and aquaculture practices are much more environmentally friendly than before.

There have been increasing efforts to integrate sectoral planning for aquaculture development and resource management involving policy development, spatial zoning, resource and business optimization, empowerment, and the inclusion of small-scale farmers. Environmental impact assessment (EIA) has become a prerequisite for permitting any commercial aquaculture operation above a certain size in major aquaculture-producing countries. Carrying capacity assessments are also carried out for aquaculture site selection and control of overall scale of farming operation in any environment. Environmental integrity is a primary concern in farm design, engineering and farming practices.

Control over the use of land and open water bodies for aquaculture has become increasingly strict in some countries such as China. In recent years, there has been large-scale removal of fish cages and pens in inland water bodies and coastal areas China as a measure to reduce organic matter loading into the natural environment and curb the eutrophication of natural water bodies as well as enhancing overall coastal zonal development. Clearance of mangroves for aquaculture has almost completely stopped in the region, while many countries and territories are reforesting coastal habitats to restore mangrove forests.

As described earlier in this report, there has been growing interest in polyculture, integrated agriculture-aquaculture, non-fed aquaculture, farming systems with capacity for water recirculation and nutrient recycling, integrated multi-trophic aquaculture and culture-based fisheries. The concepts are not new, but the practices are now being upgraded with improving nutrient use efficiency and minimizing effluent discharges as the core system functions and objectives, often supported by innovative engineering design and production control.

Feeding efficiency has always been a concern. Some innovative feeding practices have been tested and applied such as alternate feeding with changing ration sizes and alternate feeding with diets of different protein levels. Optical sensor assisted automatic feeders have become a technical option particularly for intensive aquaculture systems. They can monitor feeding conditions in real-time, automatically adjust feeding rates, prevent over-feeding and hence limit feed wastage.

There have been continuing efforts in the region in the past two decades to raise awareness and publicity regarding the adverse impacts and perceived impacts of aquaculture on natural resources with a backlash on bad practices affecting the productivity and sustainability of farms. Both public and private certification schemes have been developed, and compulsorily or voluntarily adopted across the region, which further standardize aquaculture products and farming practices. Farmers have realized that environmentally friendly practices improve their market access and profitability while supporting the long term sustainability of their farming operations.

1.14 Challenges and issues

The developing trend of intensification is an inevitable choice for aquaculture in the coming decades in the region and will increase demand for more intense resource inputs, in turn increasing environmental pressure. The sector must improve its productivity while at the same time improving its environmental performance (Waite et al., 2014). This has been, and will continue to be, a challenge for aquaculture development in the region.

Small-scale farms contribute greatly to aquaculture development in the region, yet they have less financial power and technological capacity to meet all requirements for environmental integrity. Support to small scale farmers should be further strengthened.

The great efforts and investments made by Asian aquaculture farmers to improve their environmental and social performance has not been rewarded with corresponding economic returns or market incentives. This means that a large number of small farmers have become more economically vulnerable.

1.15 The way forward

There are good reasons to believe that aquaculture in the region will continue to grow with better environmental performance, indicated by product safety and quality, resource use efficiency, less effluent discharges, minimal perturbation to natural ecosystems and biodiversity and improved productivity. To achieve sustainable growth, the sector needs broader application of risk assessment and management. Institutional capacity and sector governance needs to be continuously improved, research needs to be prioritized to fill the knowledge gaps in aquaculture-environment interactions needed for effective industry regulation, investment and policies for growth of environmentally friendly aquaculture practices needs to be increased and small-scale farmers need to be empowered.

Continued improvement of the environmental performance of aquaculture will require inputs from all stakeholders, particularly increasing the active role of consumers towards responsible consumption.

1.16 Markets and Trade

1.17 Status and trends

1.17.1 Background

Bush et al. (2019) affirmed the need for more rigorous and diverse future value chain research to improve understanding of aquaculture sector development as an increasingly important component of the global food system. Importantly, the study also noted that compared to other commodities, the share of globally produced aquatic food products that are traded internationally is high and growing, mostly due to globalisation and the geographical discrepancy between aquaculture production happening mostly in Asia, as well as aquatic food demand mostly in Europe, North America and Asia.

The Asia-Pacific region is a major market for aquatic products and plays an active role in both the regional and international trade of fishery products. Whether it is farmed or from the wild, fish continue to be one of the most traded food commodities in the world (Greentumble, 2016). The importation of high value, aquatic products has been increasing rapidly in several countries in the region over the last five years (FAO, 2019a). Five countries in the Asia-Pacific region are among the top ten importers of fishery products in the world including: China (third largest, USD 20.2 billion); Japan (fourth largest; USD 15.3 billion); Republic of Korea (fifth largest; USD 6 billion); Thailand (sixth largest; USD 3.9 billion); and Australia (ninth largest; USD 1.6 billion) (Statista, 2020). China, Hong Kong SAR and Taiwan Province of China also major importers.

Many countries in the region are producers of aquaculture and fishery products as well as being major exporters. China is the top exporter of fish and fishery products in the region, with export values amounting to USD 25 billion in 2018 (Statista, 2020) while Viet Nam (USD 7.7 billion) and India (USD 7 billion) are close behind.

The region is also an active player in both the production and international trade in seaweed. Global trade increased from USD 60 million in 1976 to more than USD 1 billion in 2016, with Indonesia, Chile and the Republic of Korea as the major exporters, while China, Japan and the United States of America are the leading importers (FAO, 2018).

The shrimp industry has the second highest total production value, after finfish, among all cultured produce in the Asia-Pacific region and was worth USD 31 billion in 2018, of which more than 80 percent was from culture of whiteleg shrimp (FAO, 2020a). It is also important to note that this species is one of the most important export products for some major producing countries in the region, including India, Indonesia, Thailand and Vietnam, as well as one of the most traded aquaculture commodities, globally, thereby continuing to increase its economic contribution to the region since its introduction.

Processing of fish products is concentrated in countries with lower labour costs and some countries including China, Thailand and Viet Nam have been importing fish and shrimp for processing and later re-exporting to other countries for final sale and consumption. Large retail and food service chains, often operating in multiple countries, are imposing new requirements on their suppliers for consistency in quality, food safety, traceability and sustainability.

As the demand for fish and fish products is income-sensitive for many consumers, the international fish trade largely depends on global economic conditions and follows prevailing global trade trends for other products. This means there was a decline in 2009 after the 2008 economic crisis, a rebound in 2010–2011 and moderate growth afterwards. In 2016 and 2017, the trade increased by seven percent compared to the year before, reaching a peak value of USD 152 billion in 2017 as economies strengthened, leading to increased demand and prices for fish products (FAO, 2018).

The increased global trade in aquatic food coupled with growing concerns over food safety has put developed countries under pressure to increase regulatory compliance over imports (Baylis, Noguiera and Pace, 2010). The demand from consumers for high quality and safe aquatic food products has paved the way towards the implementation of several aquaculture certification schemes. A great number of different food quality standards and certifications are relevant to the aquaculture sector and the requirements by importers also vary across countries. Although the focus of these certification schemes varies, the main concerns can be categorized into hygiene, social and environmental. More recent certification systems tend to include other factors surrounding the production process of the food products, reflecting the awareness of consumers on environmental and sustainable livelihood issues (Suzuki and Nam, 2013).

Despite this progress, importing country border rejections of exported aquatic food products occur intermittently and this has caused economic losses for exporting countries. While rising exports have been a source of growth for many developing countries in recent years, the rejection rate for commodities at the ports of developed countries has also been high (Suzuki and Nam, 2013). Aquatic food products coming from India and Viet Nam had the highest number of consignment rejections by the United States of America between January and May of 2017 (Behera, 2017). Export rejections from India were high, primarily due to the lack of proper infrastructure facilities with regard to adequate quality checks at various levels. Shrimp farmers who procure broodstock for cultivation also need to ensure the stock is free from viruses and contamination, and that the level of antibiotics in the water (where shrimp are cultivated) is within the permissible range. In the European Union on the other hand, rejections of Indian aquatic food exports have gone down consistently from 2013-2017 (Varma, 2017). However, after revision of the European Union quality standards, rejections of aquatic food exports could have been as high as 50 percent, compared to the earlier standards where only ten percent were affected.

1.17.2 Development of new niche, market-driven aquaculture practices

Within the last two decades major policy decisions were made when giant tiger prawn farms were severely impacted by the spread of white spot syndrome virus (WSSV) and yellow head virus to shift to farming the non-native, whiteleg shrimp based on the availability of specific pathogen free post larvae (SPF). The gradual establishment of suitable SPF whiteleg shrimp broodstock, spearheaded by Asia-Pacific region governments enabled the shrimp sector to get back on its feet and continue to contribute to the wellbeing of the sector. The introduction of whiteleg shrimp into the region has not resulted in major negative impacts on biodiversity and continues to be the most important facet of the aquaculture sector in the region contributing USD 25 billion in 2018 to local economies (Table 2, Figure 20) .

Also in the last two decades, important aquaculture practices have developed that cater for particular niche markets or needs. An example is the catfish farming sector, which was an almost completely export-oriented commodity, destined for western markets as a white fish substitute for cod. In spite of a tumultuous few years (De Silva and Phuong, 2011), the export value increased from USD 1.6 billion in 2015 to USD 2.3 billion in 2018, contributing significantly to export earnings by Viet Nam (VASEP, 2020).

The question is which or what is going to be the likely comparable development within the next decade or before. It could be a niche product such as soft-shell crab, again a commodity for the middle to upper class restaurant trade in countries with a strong Chinese ethnic community or could it be the giant freshwater prawn (*Macrobrachium rosenbergii*) being grown in culture-based fisheries in the region. Ideally, the commodity should not be a luxury food item and not ethnically driven so it has greater scope to emerge as a product that caters to wide market demand and consumer acceptance, with an export orientation to many Asian nations, or for that matter regionally and globally, as is the case with catfish from the Mekong Delta. What is probably needed is the transfer of the technology and ensuring that post-larvae for stocking the waters are available at the correct time in desired quantities. Or it could be the development and expansion of coastal aquaculture commodities such as sea cucumber which is increasingly sought after for its purported health enhancing properties.

However, in view of the huge consumer base in China, market opportunities within the country should also not be ignored so the development of mitten crab (Wang et al., 2016; Cheng, Wu and Li, 2018) and red swamp crayfish culture should be encouraged. Similar cases hold for other developing or emerging species in China, even though catering mainly for local consumers.

1.18 Challenges and issues

The aquaculture trade has become an important and integral part of international food supply systems, directly affected by economic development trends and the global trade environment. An increase in trade disputes has been evident in the last decade which has often resulted in interruptions to aquaculture trade.

Aquaculture food quality and safety have been significantly improved in the region thanks to the establishment, implementation and enforcement of relevant policies, legal provisions, regulations and standards, as well as the adoption of better management practices in farming and industrial chain management. However, food safety issues related to specific chemical residues and contaminants in aquaculture products have yet to be completely eradicated, which reduces consumer confidence and presents a persistent threat to the sustainability of aquaculture marketing as well as the reputation of the sector in international trade.

Diseases are major threats and perhaps the greatest challenge to the aquaculture industry. Disease outbreaks and the emergence of new diseases directly interrupting transboundary movements of aquaculture products are serious risk factors to aquaculture trade.

1.19 The way forward

The expectations of consumers for aquatic food are changing. Food safety and products that are free from contamination of hazardous materials were once the major and arguably the only concerns of consumers. However, this is now a basic requirement, while the way that products are produced and traded including farming practices, trading ethics and animal welfare are gradually becoming more important considerations determining product choice and willingness to pay.

Technology innovation and balanced development in aquaculture production, processing and food safety control are essential, to combat all these challenges for sustainable markets and trade in aquatic products. Adequate processing and distribution of aquatic products are both assurances for a successful and profitable aquaculture industry. Improvements in information flow between producers and consumers, increasing transparency of farming practices and industrial chain management, and product traceability are important for the development and sustainability of the trade in aquatic products, along with the establishment of modern logistics, wholesale markets, electronic trade networks and effective traceability systems.

1.20 Contribution of aquaculture to food security, social and economic development in achieving SDGs

1.21 Status and tends

1.21.1 Contribution to food security and nutrition

It is a well-accepted fact that aquaculture has contributed very significantly to food security, social and economic developments, globally and impacting on the developing world. In 2017, fish accounted for about 17 percent of total animal protein intake and seven percent of all protein intake, consumed globally. Moreover, fish provided about 3.3 billion people with almost 20 percent of their average per capita intake of animal protein (FAO, 2020b). Fish are some of the most efficient converters of feed into high quality food and their carbon footprint is generally lower than other animal production systems (Béné et al., 2015). These authors suggested that through fish-related activities (fisheries and aquaculture but also processing and trading), fish contribute substantially to the incomes and therefore to the indirect food security of more than ten percent of the world population, essentially in developing and emerging economies.

Global fish production has been rising continuously for decades, thanks to relatively stable capture fisheries production, reduced wastage and continued aquaculture growth. In 2018, it reached an all-time high of 179 million tonnes, of which 46 percent was generated by aquaculture and 87 percent was utilized for direct human consumption. This production resulted in a record-high average per capita consumption of 20.5 kg/yr in 2018 (FAO, 2020b). Since 1961, the rate of growth in global fish consumption has been twice as high as the rate of population growth, demonstrating that the fisheries and aquaculture sectors are crucial in meeting the FAO goal of a world without hunger and malnutrition (FAO, 2018). This development reached what could be considered a milestone in 2014 when aquaculture contributed more than 50 percent to global food fish consumption. In 2016, FAO elevated the recognition of the essential role of fisheries and aquaculture for food security and nutrition in the context of climate change, especially in the developing world.

The contribution of aquaculture to food security is even more significant in the Asia-Pacific region with its massive aquaculture production. Many Asian nations have a long tradition of aquaculture and consumption of aquatic food. On average, food fish supply per capita in the region was higher than the global level with Eastern Asia (39.5 kg/yr) twice as high as the global level (19.7 kg/yr) in 2016. However, there were major differences among nations and sub-regions in fish consumption in the Asia-Pacific region. For example, in 2016 Central Asia and Southern Asia only had per capita fish supplies of 2.7 kg/yr and 7.9 kg/yr, respectively, much lower than that of South-eastern Asia (33.7 kg/yr) and Eastern Asia (39.5 kg/yr) in the same year.

Eastern Asia

Aquaculture in East Asian countries has contributed greatly to food security, bringing previously high-priced species within the reach of ordinary consumers and meeting diverse dietary needs. It has also contributed to the economies of rural and remote areas by providing local employment. In terms of food security and nutrition, aquaculture is undoubtedly a more important contributor to people's diets in East Asia than in most parts of the world. In 2016, fish provided 25 percent of animal protein intake in Eastern Asia (Table 4).

Table 4. Average annual per capita fish consumption rates and fish protein intakes (kg/capita/yr) with relative protein intakes (percent) in Eastern Asia in 2016.

Country	Fish consumption rates (kg/capita/yr)	Fish protein intake (kg/capita/yr)	Fish protein intake/animal protein intake (percent)	Fish protein intake/total protein intake (percent)
China	38.9	9.1	23.6	9.4
China Hong Kong SAR	71.8	17.1	18.4	13.5
China Macao SAR	58.1	14.6	25.5	16.5
Taiwan Province of China	30.2	7.8	18.6	8.9
Japan	45.3	16.6	35.0	19.2
Korea, DPR	11.4	3.1	29.9	5.7
Korea, Republic of	56.5	16.4	35.8	17.4
Mongolia	0.5	0.2	0.4	0.2
Eastern Asia	39.5	9.9	25.0	10.4
World	19.7	5.4	17.5	6.9

In the 1990s the Chinese government set new priorities in agriculture development, shifting from increasing overall food production quantity to improving the living standards of rural populations through increasing their income. This allowed aquaculture development to play a more important role of increasing the income of rural households, while continuing to contribute to the supply of animal protein in the diet of the population.

As the main fishery and aquaculture countries in East Asiaern, the performance of China, Japan and Republic of Korea has been different in terms of per capita fish consumption over the last three decades (Figure 24). As world average annual per capita fish consumption rose steadily from 12.5 kg in 1985 to 19.7 kg in 2016, China's per capita consumption showed a rapid increase of more than 5 times, from 6.5 kg (only half of world average) in 1985 to 38.9 kg (almost double the world average) in 2016. At the same time, the annual per capita consumption rate in Japan decreased from more than 69.1 kg to 45.3 kg, while in the Republic of Korea it did not show a significant increase but varied slightly between 47.7 kg and 56.5 kg. Per capita fish consumption in Eastern Asia was much higher than the world average in all years and now stands at more than double the world average.

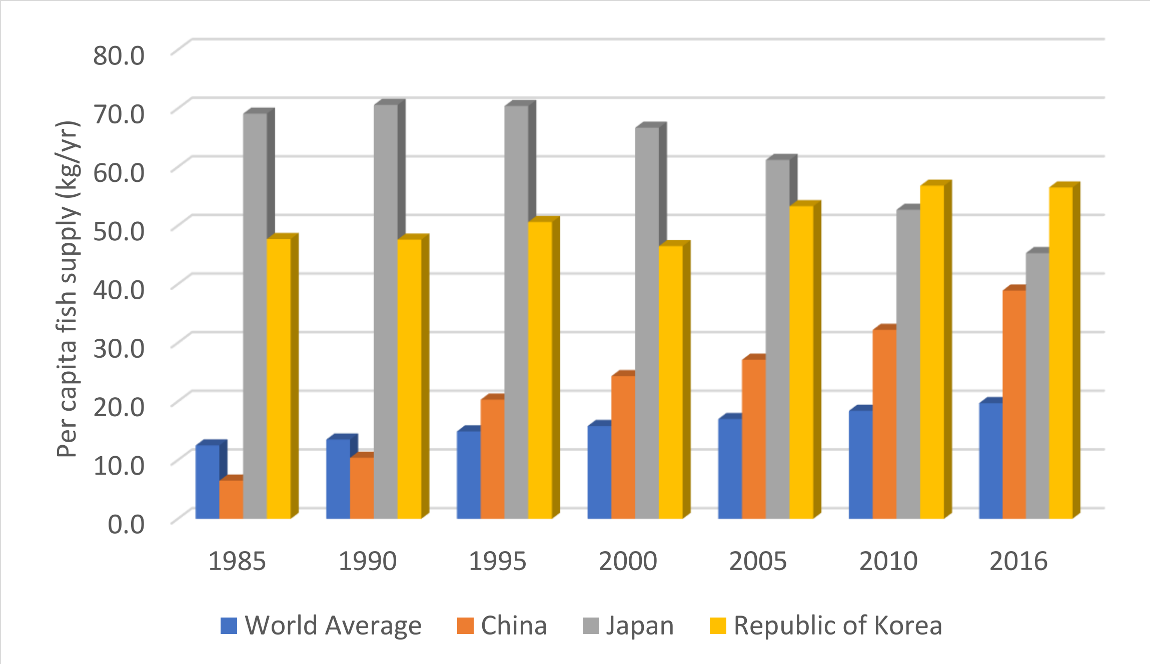

Figure 24. Per capita supply of fish and fishery products for selected countries in East Asia and globally in years between 1985 and 2016 (kg/yr)

Although per capita fish consumption in Japan and Republic of Korea was higher than in China over the period 1985 to 2016, the contribution of aquaculture to fish supply varied significantly between these countries (Table 5). As the per capita fish supply in China rose rapidly from 6.5 kg in 1985 to 38.9 kg in 2016, the ratio of aquaculture production to capture fishery production also rose from 0.75 to 2.63, signifying the greater contribution of aquaculture to fish consumption. Over the same period, the relative contribution of aquaculture to total fish supply in Japan and Republic of Korea, has increased slightly, but has been no more than 0.28.

China's contribution to world farmed fish production was steady at around 30 percent between 1960 to 1980 and started to increase rapidly after the 1980s, reaching nearly 70 percent in the mid-1990s and declined slightly to a little over 60 percent in the 2010s. China contributed almost or over half of world aquaculture production for all the major species groups except diadromous fish (Gui et al., 2018). Additionally, being the largest exporter of aquatic products in the world, China has also made great contributions to global food fish supply.

Table 5. Relative contribution of aquaculture and capture fisheries to total annual per capita fish supply in selected East Asian countries in years between 1985-2016

Country		1985	1990	1995	2000	2005	2010	2016
China	Supply (kg/yr)	6.5	10.4	20.3	24.3	27.1	32.2	38.9
	A:CF ratio	0.75	0.98	1.26	1.47	1.93	2.4	2.63
Japan	Supply (kg/yr)	69.1	70.6	70.4	66.7	61.2	52.7	45.3
	A:CF ratio	0.06	0.08	0.14	0.15	0.17	0.18	0.17
Republic of Korea	Supply (kg/yr)	47.7	47.6	50.6	46.5	53.3	56.8	56.5
	A:CF ratio	0.17	0.15	0.16	0.16	0.27	0.28	0.25
World average	Supply (kg/yr)	12.5	13.5	14.9	15.8	17.0	18.4	19.7

A: CF ratio: ratio of aquaculture to capture fisheries production

<u>South-Eastern Asia</u>

A detailed analysis on fish consumption in 2016 for the South-eastern Asia is presented in Table 6 which shows that fish accounted for more than 50 percent of total animal protein intake in Cambodia and Indonesia, and more than 20 percent in all countries except Timor-Leste in the sub-region. It is noteworthy that all the indicators exceed the corresponding values for the world, a trend that has been ongoing over the last few decades.

Table 6. Average annual per capita fish consumption rates and fish protein intakes (kg/capita/yr) with relative protein intakes (percent) in South-eastern Asia in 2016

Country	Fish consumption rates (kg/capita/yr)	Fish protein intake (kg/capita/yr)	Fish protein intake/animal protein intake (percent)	Fish protein intake/total protein intake (percent)
Brunei Darussalam	46.4	11.9	22.8	12.9
Cambodia	42.2	13.3	69.8	20.9
Indonesia	30.5	9.9	55.2	16.3
Lao PDR	25.4	7.6	46.5	10.7
Malaysia	57.3	16.8	38.9	21.6
Myanmar	47.8	16.6	45.8	19.4
Philippines	28.6	8.5	36.8	15.0
Singapore	49.1	12.3	21.8	14.2
Thailand	27.2	9.3	37.5	15.5
Timor-Leste	6.1	1.8	10.9	3.4
Viet Nam	35.6	9.9	31.3	12.2
South-eastern Asia	33.7	10.5	42.9	16.0
World	19.7	5.4	17.5	6.9

South Asia

In many parts of Southern Asia, meat is the main source of animal protein, the main exceptions being Bangladesh, Maldives and Sri Lanka. Livestock are often raised traditionally for self-consumption and marketing. Table 7 shows per capita fish supply in Southern Asian countries in 2016. Fish contributed 17.7 percent of total protein intake in 2016, comparable to that of the world average (17.5 percent). In Maldives and Sri Lanka, capture fisheries are practiced traditionally and are also the main source of fish. Aquaculture development is of recent origin, especially in the Maldives, and is still to develop and gain popularity. In Bhutan, suitable land for aquaculture is scarce and local taboos are restrictive towards the development of fish farming. Given these characteristics, aquaculture, which is relatively a very new activity has an important role to play in food security for the region.

Table 7. Average annual per capita fish consumption rates and fish protein intakes (kg/capita/yr) with relative protein intakes (percent) in Southern Asia in 2016

Country	Fish consumption rates (kg/capita/yr)	Fish protein intake (kg/capita/yr)	Fish protein intake/animal protein intake (percent)	Fish protein intake/total protein intake (percent)
Afghanistan	0.2	0.1	0.6	0.1
Bangladesh	23.8	6.9	61.1	12.4
Bhutan	5.9	2.0	12.8	2.9

India	6.6	1.9	16.6	3.4
Iran (Islamic Rep. of)	11.6	3.3	15.1	3.9
Maldives	142.3	47.3	70.0	48.8
Nepal	2.7	0.8	7.3	1.2
Pakistan	1.8	0.6	2.3	1.0
Sri Lanka	31.4	9.8	57.9	16
Southern Asia	7.9	2.3	17.1	4.0
World	19.7	5.4	17.5	6.9

Irrespective of the food habit, aquaculture increases the per capita availability of fish many times. It has also brought stability in the market in terms of prices and quantity available on a daily basis. The other advantage brought by aquaculture is supplying different species of fish with different quality (level of maturity) at low to high price points which is usually not available with meat and eggs.

Central Asia

Aquaculture in Central Asian countries is at an early development stage and fish consumption is low compared with the rest of the world. Per capita fish consumption was only 2.7 kg/yr in 2016 or about 14 percent of the world average, contributing only 2.3 percent of total animal protein intake.

Table 8. Average annual per capita fish consumption rates and fish protein intakes (kg/capita/yr) with relative protein intakes (percent) in Central Asia in 2016

Country	Fish consumption rates (kg/capita/yr)	Fish protein intake (kg/capita/yr)	Fish protein intake/animal protein intake (percent)	Fish protein intake/total protein intake (percent)
Armenia	6.6	1.9	4.3	2.1
Azerbaijan	2.7	0.8	2.8	0.9
Georgia	8.2	2.3	7.6	2.6
Kazakhstan	4.5	1.3	2.4	1.4
Kyrgyzstan	2.4	0.7	2.1	0.9
Tajikistan	0.4	0.1	0.5	0.2
Turkmenistan	3.4	1.0	2.9	1.2
Uzbekistan	2.3	0.7	2.5	0.9
Central Asia	2.7	0.8	2.3	1.0
World	19.7	5.4	17.5	6.9

Oceania

The fish consumption rate per capita in Oceania was higher than world average, while the contribution of fish to animal protein intake (11.0 percent) was lower than the world average (17.5 percent) in 2016 (Table 9). Aquaculture production in Oceania has been steadily increasing over the last ten years. However, it has yet to result in substantial quantities that would contribute significantly to food balance and capture fisheries remain the major contributor to food fish supply.

Table 9. Average annual per capita fish consumption rates and fish protein intakes (kg/capita/yr) with relative protein intakes (percent) in Oceania in 2016

Country	Fish consumption rates (kg/capita/yr)	Fish protein intake (kg/capita/yr)	Fish protein intake/animal protein intake (%)	Fish protein intake/total protein intake (%)
Australia and New Zealand	25.6	6.3	9.4	6.3
Melanesia	19.0	5.9	17.1	9.2
Micronesia	32.1	9.6	55.4	29.5
Polynesia	40.5	11.4	21.6	13.7
Oceania	24.3	6.3	11.0	7.0
World	19.7	5.4	17.5	6.9

1.21.2 Nutrition mainstreaming

There has been increasing awareness in recent years of the contribution that aquatic foods can make in meeting nutritional requirements, in particular, to provide micronutrients for vulnerable groups such as children and women of reproductive age. The use of aquaculture specifically to provide fish for nutritional programmes is not new. For example, Thailand's Village Fishpond Development Project (1978) and School Fishpond Programme (1992) provided both vocational training and improved the nutrition of local communities and students. Many community level development projects, such as NACA's work on culture-based fisheries, directly improve the nutritional status of communities. The impact may be direct, through provision of an affordable source of fish as a nutrient dense food, rich in protein, essential fatty acids, and micronutrients, or indirect through the generation of income that can be used to purchase food. The nutritional impact of aquaculture has not often been quantified, but there is an increasing trend to mainstream the collection of nutritional data in aquaculture projects.

Aquaculture plays particularly important roles in nutrition security for rural, poor communities where access to essential nutrients such as protein, vitamins and minerals is not readily available. Castine et al., (2017) highlighted the importance and significance of homestead pond aquaculture in Bangladesh that currently comprises polyculture of large fish species but provides an ideal environment to integrate a range of small fish species, which are consumed whole. These fish are rich in micronutrients and are an integral part of diets, particularly for the poor.

Kwasek *et al*., (2020) observed that fish is the dominant animal source food in many low- and middle-income countries in the global south and is available from both fisheries and aquaculture. The authors suggested that there is potential to modify the nutritional value of farmed fish through feeds and through production systems, illustrated by the common practice of supplementing omega-3 fatty acids in fish diets to optimize their fatty acid profile. Evidence has been recorded on the role that fish feeds can play to determine the nutritional composition of fish with respect to a number of key nutrients of interest for human health in low and middle-income country populations, including iron, zinc, vitamin A, vitamin D, selenium, calcium and omega-3 fatty acids. The authors observed that research on fortification of fish diets, particularly with vitamins and minerals, has not been directed toward human health but rather towards improving fish growth and health, emphasising the need to link the impact of fish feed enhancement with the health of humans consuming fish. On the other hand, human health risks associated with aquaculture feeds, that in turn will be manifested in the cultured stocks and finally in consumers, could emerge in conjunction with the adoption of fish diet manipulations and must be closely watched. These strategies may benefit the sector with monetary gain and economic viability but may not necessarily be the best option available, as community acceptance is foremost to ensure sustainability.

1.21.3 Contribution of aquaculture to economies

Aquaculture now features strongly in the development agendas of many governments in the Asia-Pacific region as it is considered as an important primary production sector to boost agricultural growth and related service sectors as well as earning foreign exchange.

Information on the relative contribution of capture fisheries and aquaculture to the GDP of the different nations in the region is not easily accessible or available. The relative contribution of capture fisheries and aquaculture sectors to the GDP of some nations of the Asia-Pacific region is given in Table 10. Even in China, which is the largest contributor to the aquaculture sector in the region and globally, the sector contributed only 0.73 percent (in 2013-2014) to its GDP, whereas the contributions to GDP in Bangladesh and Viet Nam in 2013–2014 were 2.81 percent and 3.85 percent, respectively. At the other extreme is the contribution of capture fisheries to the GDP of island nations. For example, in 2008 these ranged from 14.9 percent in Solomon Islands, to 57.7 percent in Kiribati and 62.8 percent in Marshall Islands (Lymer *et al*., 2008).

Table 10. Estimated contributions (percent) of capture fisheries and aquaculture to gross domestic product (GDP) in selected Asian countries, 2013–2014. After Subasinghe, 2017.

Country	Capture	Aquaculture
Bangladesh	0.382	2.807
China	0.208	0.730
Indonesia	0.441	1.187
Laos	0.000	1.387
Malaysia	0.247	0.305
Philippines	0.436	0.750
Thailand	1.683	0.652
Viet Nam	4.030	3.853

With the continuing growth of aquaculture in China, the total output value of aquaculture products reached USD 147 billion in 2018, which contributed 1.12 percent of national GDP in that year. It is noteworthy that aquaculture development will foster the development of related support and service sectors including input manufacturing, machinery, processing, trade, catering and construction. In 2018, the total output value from aquaculture and capture fisheries related supporting and service sectors reached USD 189 billion in China, which exceeded the total output value of aquaculture and capture fisheries of USD 186 billion (BOF/MARA, 2019). This suggests that the actual contribution of aquaculture industry to the national economy could be twice as much as the value of its production.

1.21.4 Contribution to poverty alleviation, employment and community development

Aquaculture contributes significantly to poverty alleviation through providing employment opportunities, income generation, providing nutrition security and improvement of the overall well-being of rural households and communities.

In 2018, the global aquaculture and fisheries sectors directly engaged an estimated 59.51 million people worldwide, of which about 20.53 million people (19.62 million in Asia) were employed in aquaculture and almost an equal number indirectly employed in related support and service sectors. Globally, women represented 19 percent of the work force in aquaculture (FAO, 2020c).

In China, the fishery sector provided jobs for more than 13 million people in 2018. More than half of the employment was full time, including 4.7 million jobs in aquaculture. In addition, 4.5 million people worked part time and more than 1.6 million were hired temporarily in aquaculture. The annual average net income for fishery workers was about USD 2,883 in 2018, much higher than that in other primary production sectors (BOF/MARA, 2019).

Many aquaculture farms in Asia are small-scale, farmer-owned, and farmer/family managed, and as such the gains from farming contribute more to household livelihoods, nutrition and income than to the communities where these are located. In effect, the community gains are indirect and occur mostly through providing goods and services, including labour when and if needed, to these farms. On the other hand, it has been shown that culture-based fisheries (CBF), a community managed, extensive aquaculture practice conducted in inland water bodies, provides direct monetary benefits to the communities involved as well as providing fish for household consumption, thereby improving their nutritional status (Saphakdy et al., 2009; Phomsouvanh, Saphakdy and De Silva, 2015).

1.21.5 Contribution to biodiversity conservation

Although all species used in aquaculture still occur in the wild, some are under threat (FAO, 2018). Aquaculture plays an important role in conservation of farmed species and farmed types and reduces fishing pressure on threatened species. One example that stands out is the development of grouper aquaculture for the live fish restaurant trade that is prevalent in many countries and territories in Asia including China, Singapore, China Hong Kong SAR and Taiwan Province of China. Grouper aquaculture supplies fish to restaurants, which in turn stimulated gradual growth of the grouper aquaculture sector, spearheaded by businesses in the region (Rimmer and Glamuzina, 2019**)**. As a result, illegal and destructive fishing methods have almost completely disappeared and no longer negatively impact the biodiversity of coral reefs, providing the opportunity for reefs to gain their original status, while the contribution of grouper aquaculture continues to increase.

Several nations in the Asia-Pacific region, through aquaculture practices, are making a positive impact towards addressing the dwindling population numbers of aquatic animals that are listed as threatened and or endangered by IUCN. Foremost amongst these are sea turtles in Myanmar, such as loggerheads (*Caretta caretta*), green turtles (*Chelonia mydas*), hawksbills (*Eretmochelys imbricata*), olive ridleys (*Lepidochelys olivacea*) and leatherbacks (*Dermochelys coriacea*) (Ministry of Agriculture, Livestock and Irrigation, 2018). Myanmar is making a concerted effort to conserve the natural breeding grounds of these turtle species, as well as establishing hatcheries for the purpose of releasing artificially produced young turtles to the sea. Meanwhile, China has been implementing large-scale programmes of releasing aquatic animal seed into major rivers and coastal areas for decades. The seed are produced in hatcheries from broodstock caught either from the wild or raised in captivity and the species include endangered species and species of important economic value. Similar conservation efforts have also been made in other countries in the region including Cambodia and Thailand. Such activities have contributed to conserve endangered species and enhance wild populations (Miao, De Silva and Davy, 2010). However, these initiatives often do not get noticed or credited by global and regional critics of the aquaculture sector so it is important to emphasise that aquaculture in general has an important secondary function by contributing towards biodiversity conservation.

1.22 Challenges and issues

The contribution of aquaculture towards the achievement of SDG targets has been increasingly recognized. However, some of the issues that hamper aquaculture development in the region, such as the vulnerability of small-scale farms, environmental concerns in the process of much-needed production intensification, practice ethics, issues in value chains and services still need to be addressed in the process to transform aquaculture to achieve SDGs. In addition, inadequate inclusiveness of, and inequality among, stakeholders, genders and different social groups in decision making, resource access and benefit sharing, challenge sectoral sustainability.

Gender equality has been advocated and promoted in aquaculture in the region. Women actively participate in all segments of value chains and production activities, and play key roles in farming, local trade, postharvest and the processing industry. However, women’s opportunities in aquaculture have not kept pace with rapid growth of the sector. When aquaculture intensifies and scales up, women tend to be displaced or relegated to the lowest paid, low-grade work and few women are senior staff, owners, managers and executives in the larger enterprises (Brugere and Williams, 2017).

Rapid urbanization in the last two to three decades stimulates the migration of rural populations to urban centres and these tend to be young people in their prime. This has caused demographic changes in coastal fisheries communities (Siar and Kusakabe, 2020) and is probably also a common occurrence in other agricultural, rural communities. Consequently, aquaculture, especially small-scale operations, are impacted by a shortage of skilled young professionals and labour that could impact the potential for these communities to benefit from nutrition security, improved livelihoods and community development opportunities.

1.23 The way forward

Aquaculture will continue to play an increasingly important role in the transformation of food systems in the Asia-Pacific region and remains at the centre of efforts to achieve SDG targets, particularly in poverty alleviation, ending hunger, ensuring health and well-being, sustainable use of water, gender equality and empowerment of women, responsible consumption and production, as well as the conservation and sustainable use of the oceans, seas and marine resources for sustainable development.

Transforming aquaculture to achieve SDGs demands holistic approaches involving multiple stakeholders in strategy formation, action planning, resource optimization and implementation. Equality and inclusiveness need to be integrated into policies and observed in all development processes.

1.24 External pressures on the sector

1.25 Status and trends

1.25.1 COVID-19

It is apparent that COVID-19 has caused extensive damage to supply chains on both the supply and demand side, including:

- Curtailment of consumer spending due to business closures and job losses.
- Disruption of normal production cycles and management operations at farm level and in linked industries due to lockdown measures.
- Significantly increased production costs and reduced economic returns.
- Disruption of food processing and packing facilities due to public health measures.
- Severe disruption of the restaurant trade due to lockdowns.
- Air freight disruption, due to wholesale grounding of commercial airline fleets.

The extent of impacts seem to vary by sub-sector. Export-oriented industries producing high-value live or chilled products such as shrimp, abalone and tuna were heavily impacted by the loss of air freight links. The impact on shipping, distribution and marketing of frozen or processed products is not yet clear. Domestically-oriented aquaculture production is likely to face less disruption, particularly regarding low-cost, consumer staples. However, there has been a large reduction in economic activity across the board and the entire industry will be affected.

1.25.2 Impacts of climate change

Climate change is a serious threat to the aquaculture sector that will have profound direct and indirect impacts on the industry. Direct impacts include the biological tolerance and health status of farmed organisms, in unstable culture environments, or through saline intrusion or inundation of low-lying culture areas. Indirect impacts include access to feed supplies, regulatory restrictions on greenhouse emissions, trade links and markets, economic disruption, consumer demand and purchasing power.

To date, the known impacts on the sector are limited (Barange *et al.*, 2018). While the increasing frequency of major weather events such as storms has been linked to climate change, other likely present-day impacts include the frequency of red tides and harmful algal blooms. There are reports of ocean acidification affecting cultured molluscs in terms of shell deposition, growth, health status and survival (Clements and Chopin, 2016) but it is presently difficult to separate the impacts of climate-induced acidification from other sources, both anthropogenic and natural, that occur in coastal environments.

It has been reported that between 1998 and 2017, more than 526 000 people died worldwide and there were losses of USD 3.47 trillion because of more than 11 500 extreme weather events (Sarkar, S. 2018). The intensity, number and frequency of occurrence of extreme weather events in South-eastern Asian maritime states has been increasing in the past decade. A study found that eight of the ten cities most at risk from such events are in the Philippines which had "poor institutional and societal capacity to manage, respond and recover from natural hazard events" (Verisk Maplecroft, 2015). For example, Typhoon Haiyan killed 6 300 people in 2013 in the Philippines which is impacted by more than 20 typhoons a year (D'Urso, 2015). All such extreme events will undoubtedly impact on existing coastal aquaculture activities, but it is difficult to predict the exact economic losses as well as losses in livelihoods that are dependent on aquaculture, nor is it easy to develop mitigating measures to combat such impacts.

The Asia-Pacific region covers all climatic regimes, from temperate to tropical, and includes many island states, land locked states and maritime states. As such the whole range of climate change impacts could be felt, albeit to varying degrees. Average temperatures in South-eastern Asia have been rising since the 1960s and according to the Global Climate Risk Index, four of the region's countries, Viet Nam, Myanmar, the Philippines, and Thailand, are among the top ten nations that have been most negatively impacted by climate change in the past 20 years (Spiess, 2018). Pickering et al. (2012)

addressed the vulnerabilities of aquaculture in the tropical Pacific to climate change, although the small island states have very marginal or limited aquaculture practices and the climate change impacts were likely to be more on other life associated aspects in the islands, including capture fisheries. De Silva and Soto (2009) and De Silva (2012b) evaluated climate change impacts and challenges for aquaculture in detail and considered the pros and cons of mitigating measures that could be adopted to safeguard livelihoods and the aquaculture sector. What is evident is that each case must be considered in isolation and that it is not possible to have a “one size fits all” scenario.

Recently, Reid et al. (2019) dealt with climate change and aquaculture and considered the adaptation potential and biological responses and resources, respectively. What transpired from these analyses was that adaptation potential, the biological response and resources needed to combat climate change impacts are remarkably diverse and that no one solution is available. Impact mitigation can be done through environmental control with engineering and management solutions to reduce exposure to stressors, and epigenetic adaptation to improve the stress tolerance of cultured species. It was pointed out that research advances need to deal with the complexity of multiple stressors to understand how climate change affects aquaculture. Research will benefit most from a combination of empirical studies, modelling approaches and observations at the farm level. Ultimately, for aquaculture sectors to move beyond short-term coping responses, governance initiatives incorporating the changing needs of stakeholders, users and culture ecosystems are required to facilitate planned climate change adaptation and mitigation.

Ahmed and Glaser (2016), considering the importance and the high degree of vulnerability of coastal farming and particularly the shrimp farming sector in Bangladesh, made the observation that a plausible adaptation strategy to mitigate climate change impacts may be to adopt Integrated Multi-Trophic Aquaculture (IMTA), although it is generally considered as an approach to coping with environmental issues. The authors suggested that open water IMTA in coastal Bangladesh would be a novel process of growing different finfish and shellfish with seaweeds in an integrated farm. Furthermore, the authors believed that IMTA is considered an ecosystem approach, adaptation strategy to climate change which could generate environmental and economic benefits. Various types of IMTA have been demonstrated and expanded in China (Fang and Zhang, 2015, Fang et.al., 2016).

Ahmed, Thompson and Glaser (2019) pointed out that aquaculture is often at risk from a combination of climatic variables, including cyclones, drought, floods, temperature irregularities, ocean acidification, rainfall variations, salinity changes and sea level rise. For aquaculture growth to be sustainable its environmental impacts must reduce significantly and adaptation to climate change will also be needed to produce more fish without environmental impacts. Possible adaptation strategies include integrated aquaculture, recirculating aquaculture systems (RAS) and an expansion of aquatic food farming. However, it is not certain how many of the above mitigating strategies could be adopted or added to existing aquaculture practices in the region, particularly whether they will be economically viable, as apart from shrimp aquaculture, the other major species cultured in the region are relatively low value.

Leung and Bates (2013) evaluated disease outbreak severity across different latitudes and concluded that disease progresses more rapidly at lower latitudes and results in higher cumulative mortality, particularly at the early stages of development and in shellfish. They also pointed out that tropical countries suffer proportionally greater losses in aquaculture during disease outbreaks and have less time to mitigate losses. Furthermore, there is the possibility that some infectious diseases may increase with climate change-related weather abnormalities, particularly extreme temperatures. As the Asia-Pacific region is the backbone of global aquaculture where aquaculture is spread across a wide range of climatic regimes and latitudes, aquaculture stakeholders must be proactive in developing suitable strategies to mitigate these potentially negative consequences.

The climate change impacts on fisheries and aquaculture were discussed at a workshop held in June 2012, Noumea, New Caledonia (Johnson, Bell and De Young, 2013). The workshop mainly concerned priority adaptations for economic development and government revenue, food security and sustainable livelihoods for Melanesian, Micronesian and Polynesian nations. From the aquaculture viewpoint, climate change was likely to decrease the efficiency of mariculture, while the productivity of freshwater aquaculture was expected to be enhanced by higher water temperatures and greater rainfall allowing tilapia and milkfish to grow faster in ponds and for ponds to be built in more areas, including at higher elevations in the case of tilapia farming. *Macrobrachium* prawn aquaculture was also likely to benefit in the short term, but increasing temperatures are likely to have negative effects on prawn farming in the longer term. The range of potential impacts to mariculture and the implications for their future plans and opportunities for diversifying livelihoods away from coastal fisheries and into mariculture were considered as well as potential benefits of enhanced freshwater aquaculture for inland communities in Papua New Guinea, Solomon Islands and Fiji, that are expected to receive more rainfall. It was thought that milkfish has real expansion potential and for higher islands, tilapia is the only viable option for efficient expansion of freshwater aquaculture. It was agreed that care was needed to reconcile the production of these fish for food security with biodiversity conservation. Two FAO regional consultative workshops were convened respectively in Kathmandu in 2011 and Bangkok in 2018. The former was mainly to raise awareness and sharing of knowledge over the climate changes and its potential impact on capture fisheries and aquaculture. The Bangkok workshop focused more on the progress made by countries and international organizations in addressing climate change impacts on fisheries and aquaculture, and recommendations for further strategy and actions to build the climate resilience of fisheries and aquaculture in the Asia-Pacific region (Wongbusarakum *et al*., 2019).

1.26 Challenges and issues

With the development of IT technology, the region has made great progress in providing access to farmers for essential information including extreme weather events, market conditions, production supplies and support services. However, disaster preparedness in general has not been adequate in the region, indicated by the lack of systematic mechanisms for disaster surveillance, early warning and mitigation. In addition, aquaculture insurance has not been properly established and the farming sector is vulnerable to external risk factors.

The impact of COVID-19 is unprecedented, profound, and likely to be long lasting. The responses to mitigate the impact on aquaculture supply chains have so far been ineffective with insufficient institutional support and a lack of coordination among multiple stakeholders.

1.27 **The way forward**

Significant government involvement is required to build capacity in prevention and impact mitigation from natural disasters and in response to other external factors that affect aquaculture. This should include building information infrastructure and establishing effective surveillance and early warning systems for unusual and extreme weather events, hydrological situations and unexpected changes in environmental water quality. There should also be information systems to collect, analyse and disseminate information on disease prevalence, as well as market dynamics of both supplies and products. Some standard operational procedures specifically for emergency response to disasters need to be developed and farmers need to be properly informed and trained. Insurance schemes need to be improved through government assistance and public private partnerships to adequately cover the aquaculture sector.

Knowledge on the impact of climate change on aquaculture is still limited. There is a need to develop methods and procedures for evaluation of aquaculture damage and losses due to natural disasters, and research into both direct and indirect impacts of climate change on aquaculture. This would help improve understanding of climate change impact mechanisms and strengthen climate change adaptation and impact mitigation.

In facing the current challenges brought by COVID-19, governments should set priorities to restore interrupted supply chains through assistance to farmers, facilitation of logistical support and international trade collaboration.

1.28 Governance and management of the sector

1.29 Status and Trends

1.29.1 Regulatory frameworks

After four decades of fast growth, aquaculture has become one of the most important food production and agri-business sectors in many Asia-Pacific countries. Governments set both policy and resource priorities for its development with progressively improving sector governance to ensure its sustainability.

A recent consultation organized by FAO and NACA on strengthening aquaculture governance in Asia-Pacific concluded that administrative, legislative and regulatory frameworks for aquaculture development have been established in major aquaculture producing countries in the region, with relevant policies, laws, regulations and standards being formed and institutional mechanisms developed for implementation and enforcement (Miao and Yuan, 2021).

Regulatory work covers important aspects of aquaculture including the allocation of water space and land area as well as other issues including resource use, carrying capacity, environmental impact assessments, licencing, feed and feed management, use of chemicals and drugs, effluent discharges and imports of exotic species. Sustainability issues are also important such as resource utilization, technology adoption, environmental impacts, food safety, biosecurity, economic performance and social responsibilities.

1.29.2 Aquaculture certification

The development and application of best management practices (BMPs) and good aquaculture practices (GAPs) with participatory approaches, as well as the empowerment of small-scale farmers through organizing them into clusters and collective farming, have become prominent in the region especially in Southern and South-eastern Asia and greatly improved overall management and regulation of the industry. Certification has been widely applied to aquaculture of various species, aquaculture products, farming systems, production processes and value chains. Market incentives associated with certification have gradually been recognized and certification has increasingly become a persuasive form of market governance that helps improve aquaculture sustainability in the region.

1.29.3 Networking

When it was realised in the second half of the last century that aquaculture is a major pathway to reduce gaps between demand and supply of fish to feed growing populations and improve nutrition, actions were initiated to transform aquaculture to a major food production sector. The project Network of Aquaculture Centres in Asia (NACA) was initiated in 1979 with the objective to establish a platform to address the need for the coordination of cooperative research, training, and information exchange in a collective effort to promote aquaculture development on a regional basis, especially with emphasis on sharing available resources in accordance with the concept of technical cooperation among developing countries. By the end of the project, implemented by FAO and UNDP, NACA had become an intergovernmental organization that has been sustained for over two and half decades, now with 20 member governments.

Many nations and governments in the Asia-Pacific region and international organizations such as FAO and UNDP have played major roles in supporting this network that has become a model for the nations and comparable organisations in the other continents that are striving towards achieving a similar goal to drive sector performance.

Other regional collaboration mechanisms and networks that have been playing important roles in coordinating regional efforts for aquaculture development include the Southeast Asia Fisheries

Development Center (SEAFDEC), the Asia-Pacific Fishery Commission (APFIC), the Bay of Bengal Inter Governmental Organization (BOB-IGO) and the Mekong River Commission (MRC).

1.30 Challenges and Issues

Many countries in the region have made great efforts and remarkable achievements in aquaculture governance. However, despite the importance and contribution of aquaculture to food security, Béné *et al*. (2015) pointed out that limited attention has been given so far to fish as a key element in food security and nutrition strategies at national level while in wider development discussions and interventions, the overall potential for improving food security and nutrition embodied in the strengthening of the fishery and aquaculture sectors has been missed and must be rectified. Some countries, especially those where aquaculture is still at an early stage of development, still lag behind in policy formation, establishment of legal frameworks, institutional arrangements and development of relevant regulations and standards. In some countries where policies have been developed, the implementation is somehow hampered or delayed by lack of human resources and financial support. In addition, the numerical dominance by small-scale farms in the region, many of which are still resource poor, imposes difficulties in monitoring and enforcement of aquaculture regulations.

Many nations in the region such as Japan, Republic of Korea, and Mongolia in East Asia, Brunei, Singapore and Timor-Leste in Southeast Asia, Bhutan and Afghanistan in South Asia are not members of the NACA network. Some of these need to secure quality and safe aquatic food supplies from both domestic and international markets, while others would benefit from the development of aquaculture for rural nutritional security, poverty alleviation and revenue generation. The diverse and complementary needs among nations can be more effectively addressed through a common collaboration platform such as NACA at a regional level. For example, Timor-Leste has a 706 km coast-line with the potential to develop coastal aquaculture and would benefit from joining the NACA network to take advantage of the training and knowledge sharing facilities it offers on a regular basis.

Many other networks have been established in the region, aiming to facilitate collaboration in education, technology transfer, communication and trade. However, investment of both monetary and human resources into these networks seems to be insufficient, which constrains network maintenance and effective operation.

1.31 The way forward

Aquaculture governance will become even more important in the future as the industry has to move forward to be more resource efficient, environmentally friendly, economically profitable and socially responsible. Meanwhile resource competition, environmental pressure and social and economic conflicts are likely to get more intense in the coming decades. The region needs to invest more in capacity building to develop human resources and provide sufficient financial support to make aquaculture governance effective and efficient. Small-scale farms, especially those that are resource-poor, need assistance to access resources, technical capacity building and community management.

The region needs more investment in aquaculture technology extension and various networks to transform research into productivity and develop aquaculture in the region as a whole.

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

1.33 Status and trends

FAO's five strategic objectives relating to food security and nutrition, poverty alleviation in rural areas, resilient livelihoods, and sustainable management and efficient use of natural resources are featured across the SDGs and lie at the heart of its work in practice. They contribute to the eradication of hunger, food insecurity and malnutrition, increase and improve provision of goods and services from agriculture, forestry and fisheries in a sustainable manner, reduce rural poverty, enable more inclusive and efficient agricultural and food systems at local, national and international levels and increase the resilience of livelihoods to threats and crises (FAO, 2017b).

The Sustainable Development Goals are a universal set of targets agreed by 194 United Nations member states to guide their development policies and initiatives over the next 15 years (FAO, 2017b). The SDGs apply equally to developed and developing countries and the framework of targets and indicators provides the basis for stimulating initiatives, monitoring performance and levering compliance. The 2030 Agenda focuses on the elimination of hunger and reduction of poverty and inequality (opportunity, resource access, gender, youth) in all their forms. It is associated with a financing framework (The Addis Ababa Action Agenda) that recognizes the need not just for innovation and business development but also social protection. It commits to support the Paris Agreement on Climate Change, by promoting and facilitating energy efficiency and clean energy. It seeks to increase resilience to climate change, extreme weather and natural disasters, as well as market volatility and political instability. It also seeks to reduce the pressure of human economic activity on the natural environment by stressing the need not just for habitat and ecosystem protection, but also increased resource use efficiency and sustainable production and consumption thereby spreading responsibility for delivering sustainability across all economic players (FAO, 2017b).

Almost all the SDGs, and many associated targets (more than 34), are relevant to aquaculture development. Existing guidance and initiatives designed to promote sustainable aquaculture (including the Code of Conduct for Responsible Fisheries and associated Technical Guidelines; the Bangkok Declaration & Phuket Consensus; the Blue Growth Initiative) will broadly support delivery of the SDGs (FAO, 2017b). Aquaculture in the Asia-Pacific region has achieved outstanding growth in the past three decades with an average annual rate of nearly ten percent. As a result, the region is now contributing more than 90 percent of global aquaculture production. Fish now supply over 20 percent of the animal protein in the diets of the Asia-Pacific population and 60 percent of this is from aquaculture. In addition, the Asia-Pacific region is the most important supplier to the global seafood trade and its aquaculture production accounts for the majority of the traded seafood commodities (FAO, 2020c). It is expected that increased population growth and further economic development will lead to increased fish consumption and as a consequence, the global demand for food fish is expected to increase by between 30 million tonnes and 40 million tonnes by 2030 from the current level. Achieving 60 percent growth in the next 15 years will not only be required for the aquaculture sector to meet the increasing fish demand but will also have enormous implications for the livelihoods of the many rural populations in Asia-Pacific countries (FAO, 2020c).

The aquaculture sector is increasingly being required to meet stringent environmental standards, biosecurity safeguards and food safety standards, so improved governance of the sector is needed to ensure its sustainable growth (FAO RAP, 2019). FAO and NACA organized a Regional Consultation on a Strategy and Action Plan for Sustainable Intensification of Aquaculture in the Asia-Pacific Region in 2014 in Bangkok, Thailand. The development of the regional strategy and action plan was intended to promote the concerted efforts of member governments, regional and international organizations, donor and development agencies and the industrial sector to support the sustainable intensification of aquaculture and to prioritize necessary actions at regional and national levels to support sustainable intensification of aquaculture in the region. The well-articulated regional strategy and action plan set a clear vision and goals for the development of the aquaculture sector, an appropriate strategy and an implementable action plan defining the roles of different stakeholders in supporting sustainable intensification of aquaculture. The widely endorsed regional strategy and action plan can guide government policy adjustment and facilitate the mobilization of investment needed to support the sustainable intensification of aquaculture in the region. Forty representatives of the governments of 16 countries in Asia, five regional and international organizations and five development agencies (donor agencies) participated in the consultation (FAO, 2016).

Intensification of aquaculture has been an ongoing process in the Asia-Pacific region. Its aim is to increase the productivity of aquaculture through the use of external inputs (materials, energy, investment) and resources (water, feed ingredients) and the application of new technologies and improved management practices. Intensification of aquaculture has been a major contributor to rapid aquaculture production growth in the Asia-Pacific region in the past two decades, which has contributed significantly to food and nutrition security and livelihoods in the region. Sustainable intensification of aquaculture has been included as the Asia-Pacific regional initiative of FAO's global blue growth initiative (BGI). However, the impacts of intensification have attracted considerable public concern regarding the long-term sustainability of the sector.

Table 11. Contribution of Asia-Pacific region aquaculture to the United Nations SDGs

Sustainable Development Goals (FAO, 2017b)		**Contributions**
1	End poverty in all its forms everywhere	It is widely recognized that aquaculture significantly contributes to sustainable development in rural communities and plays a vital role in ensuring food security, poverty alleviation, and economic resilience (IUCN). Aquaculture related activities support the livelihoods of more than 120 million people worldwide, the majority of them living in developing countries. Ensuring responsible and sustainable value chains will benefit the poorest and most vulnerable in society, further enabling fisheries to provide economic resilience (COFI, 2021).
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
10	Reduce inequality within and among countries	
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Aquaculture is crucial in the fight against hunger and an important enabler of food security and nutrition. Fish consumption continues to rise, providing nutritious food for the world's growing population. Among these, 3.3 billion people consume almost 20 percent of their average per capita intake of animal protein from fish and fish products. Aquaculture presents unique opportunities to fulfil the pillars of food security as the world's population continues to expand (FAO, 2020c). Nearly two-thirds of the world's hungry are in the Asia-Pacific region. They are among 815 million people worldwide who do not consume enough nutritious food for an adequate supply of dietary energy. On 17 October 2016, Her Royal Highness Maha Chakri Sirindhorn of Thailand become FAO Special Ambassador for Zero Hunger. Her Royal Highness has dedicated many Royal Projects to combat hunger and improve nutrition in Thailand and in other countries of Asia and the Pacific.
3	Ensure healthy lives and promote wellbeing for all at all ages	Aquaculture plays an important role for food security and nutrition for humankind. Fish as a source providing construction materials for RNA, DNA, numerous other biomolecules, cells, muscle tissues, bones, and organs that perform numerous different structural and functional roles with prevention and reduction of disease. It is an excellent food providing all the essential amino acids, essential n-3 fatty acids, vitamins, and minerals. Fish protein is highly digestible and of high biological value. Fish contains biomolecules that enhance performance ability physically and mentally. Fish is a good food for early development.

		Fish is a food for the brain and health that can also be proved from the present review. The human mind is the medium through which the civilization was developed and through which any goal and success can be achieved. Fish is an important functional food for an efficient and quality life (Sarojnalini and Hei, 2019).
5	Achieve gender equality and empower women and girls	Women engage in all stages of the fisheries value chain and make up around fifty percent of those employed in the marketing and post-harvest processing of fish. Efforts to empower women by enhancing full access to and equal opportunities in the fisheries and aquaculture sector may serve as a catalyst for combating systemic gender inequalities and achieving greater inclusiveness (FAO, 2020c). The Global Conference on Gender in Aquaculture and Fisheries is one the major platforms of aquaculture contribution to SDG 5. The 7th Global Conference on Gender in Aquaculture and Fisheries (GAF7) was organized by the Gender in Aquaculture and Fisheries Section of the Asian Fisheries Society (AFS), the Asian Institute of Technology and the Network of Aquaculture Centres in Asia-Pacific in 2018 (Williams *et al*. 2019). It followed 28 years of women and gender symposia and workshops supported by the AFS and its Indian Branch. GAF7 created a platform for sharing the latest gender in fisheries and aquaculture research, learning new methods and approaches, launching new training products and crafting a vision for the future of our research field.
12	Ensure sustainable consumption and production patterns	Fish offer opportunities for sustainable food systems, with a lower carbon footprint than alternative animal source foods. The implementation of appropriate policies that foster sustainable consumption and production practices in fisheries and aquaculture will support the move towards more sustainable patterns of consumption and production and achieve sustainable management and efficient use of natural resources (FAO, 2020c).
13	Take urgent action to combat climate change and its impacts	In 2016, FAO and NACA organized a regional workshop on Environmental Monitoring & Early Warning Systems for Fisheries & Aquaculture in the Lower Mekong River Basin to address current state of monitoring systems and potential for future development. FAO and NACA and partners co-organized the Global Conference on Climate Change Adaptation within Fisheries and Aquaculture-FishAdapt in Bangkok, Thailand during 8-10 August 2016 to share on the ground experiences in undertaking climate change vulnerability assessments and implementing adaptation actions within fisheries and aquaculture sector and dependent communities.
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	From 2016-2019, the International Ocean Institute -Thailand in collaboration with FAO, NACA, SEAFDEC and partners co-organized sustainable fisheries and aquaculture component under the 4-week flagship regional training programme "Ocean Governance Framework: Implementation of UNCLOS and Its Related Instruments for the Southeast Asian Seas and the Indian Ocean" in Thailand. There are about 18-20 trainees attending the training course each year from the Southeast Asian and the South Asian countries.
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	The State of the World's Aquatic Genetic Resources for Food and Agriculture, with information on nearly 700 farmed species, including wild relatives and farmed types, based on information from 92 country reports and submissions from international organizations. FAO's current biosecurity work is largely focused on human and farmed animal health, and does not include study of associated species impacts in the wild, and related implications for biodiversity more generally. An expanded portfolio of work could include the human and animal disease burden from exotic, endemic and emerging diseases that can be linked to movement of species, changing climate, antibiotic/antimicrobial-resistant infections and shifts in aquaculture and trade practices, which are also known to impact biodiversity more generally (COFI, 2021).

17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Targets and goals can only be achieved by working together. This includes partnerships between the private and public sector, with academia, civil society and non-governmental organizations (NGOs) but also across national borders and through multilateral efforts and solutions. It also foresees international cooperation in fisheries management, in regional fisheries bodies to promote the application of the FAO Code of Conduct for Responsible Fisheries and its associated guidelines, plans of action and agreements (COFI, 2021). The Asia-Pacific Fishery Commission (APFIC) was founded in 1948 to promote the full and proper use of living aquatic resources in the region from the Indian Ocean to the Pacific Ocean. The Commission assists member countries to achieve their objectives by helping with the development and management of fishing and culture operations, processing and marketing. APFIC works to improve understanding, awareness and cooperation concerning fisheries issues in the Asia-Pacific region. Twenty-one countries are now members of the Commission, which maintains its Secretariat at the FAO Regional Office for Asia and the Pacific in Bangkok, Thailand. This is a main multi-stakeholder partnership to enhance national and regional partnerships for sustainable development in the Asia-Pacific region. The FAO Regional Conference for Asia and the Pacific (APRC) is a forum to discuss current country and regional priorities and pressing issues in the region such as the impact of COVID-19, the state of agriculture, natural resources management, food security and nutrition. It is also an opportunity to highlight examples of partnerships, innovation and digital technologies that are helping to improve food security and nutrition across the region as well as regional and global policy and regulatory matters.

1.34 Salient issues

Being the most populous region of the world with heavy demands on natural resources, Asia will face great challenges to maintain the growth of its aquaculture sector and to meet increasing demand for fish inside and outside the region in the coming decades (FAO, 2016). Sustainable intensification of aquaculture is now recognized as the major approach to achieve sustainable growth of the sectora in the region. Six strategic objectives are as follows: establish/maintain an enabling environment; establish good governance, effective planning and management; improve management along the aquaculture value chain; strengthen supporting services; increase social responsibility and equitable benefits; and, strengthen the focus on increasing resilience of aquaculture farmers.

The Blue Growth Initiative is an innovative, integrated and multi-sectoral approach to the management and use of aquatic resources. It aims to restore the productive potential of the oceans and inlands waters by strengthening policy, responsible management regimes and practices to reconcile economic growth and food security with the conservation of natural ecosystems that support that productive potential. Blue growth is seen as a critical pathway for countries to achieve the Sustainable Development Goals by shared synergies with the objectives and precepts of the 2030 Agenda, so further implementation of the Blue Growth Initiative will aid in monitoring and progressing the SDGs. This is through application of binding and non-binding FAO instruments, to establish the necessary mechanisms and procedures to monitor and report on Members' progress towards achieving the SDGs (FAO, 2020c).

The Asia-Pacific region is witnessing considerable advancements in innovative approaches that combine agriculture and aquaculture leading to improved livelihoods for smallholders. Innovative integrated agro-aquaculture is recognized as an effective approach to promote aquaculture for improved efficiency and sustainable growth by the Chinese government. The Chinese Academy of Fishery Sciences (CAFS) and its subsidiary institutions have been supporting the innovation and dissemination of integrated agro-aquaculture farming technology and management practices across China and have made great achievements. CAFS will closely collaborate with FAO to support the dissemination and scaling up of successful stories in Asia. There is an increasing potential to promote such systems in a number of Asia-Pacific countries including Indonesia, Viet Nam, Bangladesh, Philippines, Lao PDR and Myanmar, but also in other areas of the world. South-South Cooperation is a very appropriate platform to scale up innovative rice-fish and other integrated agro-aquaculture farming systems (UN China, 2017).

1.35 The way forward

It is estimated that fish consumption in the Asia-Pacific region will increase by 30 percent by 2030. With capture fish production unlikely to increase, it is estimated that aquaculture production will need to increase by 50 percent by 2030 from the current level. At the same time, the aquaculture sector is facing serious challenges, the foremost being the impact of climate change and climate variability, urbanization and related social and economic changes, increasing intra-regional trade and increasing public concern over the environment and food safety (FAO, 2016). It appears that for Asian aquaculture to be more efficient and sustainable, continuing efforts towards intensification of the sector should pay more attention not only to increasing resource-use efficiency but also to reducing environmental impacts to a minimum. If the benefits of aquaculture should also be made equitable it is paramount that both small-scale and large-scale aquafarmers and industrialists coexist, sharing profits and enjoying benefits. In a market economy world, this can only be achieved through better governance by enacting people-centred and poverty-addressing, policies and regulatory frameworks (FAO, 2017b).

Aquaculture is projected to be the prime source of seafood by 2030, as demand grows from the global middle class and wild capture fisheries approach their maximum take. When practiced responsibly, fish farming can help provide livelihoods and feed a global population that will reach nine billion by 2050. But for an aquaculture system to be truly sustainable, it must have environmental sustainability. Aquaculture should not create significant disruption to the ecosystem or cause a loss of biodiversity or substantial pollution impact. Aquaculture must also be economically sustainable, generating viable businesses with good long-term prospects and be socially responsible, contributing to community well-being (World Bank, 2013).

NACA proposed future actions by setting up a regional climate change impact assessment, showing the possible effects of climate change on aquaculture in different countries over the next 15 years (increased temperature, change in rainfall pattern, storm intensity and frequency, increased CO_2, and sea level rise). Aquaculture farmers would have access to information to make informed choices about how they should be adapting their aquaculture production systems to climate change. It is necessary to define adaptation strategies for the main environmental, disease and genetic threats caused by climate change, to inform and guide the aquaculture community and to communicate the results of the vulnerability assessment and adaptation planning and strategies at all levels. Implementing pilot projects on adaptation and providing capacity building required to manage aquaculture systems and establish early warning systems, disaster risk reduction, preparedness and response plans on climate change or disaster impacts including aquatic disease outbreaks.

1.36 Conclusions

It is evident that the Asia-Pacific region continues to play a dominant role in the aquaculture sector globally and China remains the largest contributor to production and largest consumer while many other Asian nations are making greater contributions to regional aquaculture with fast production growth. Aquaculture is critically important for global food security, improved nutrition, poverty alleviation, employment and rural development. However, the rate of growth of the sector in the region has declined over the years, which has largely resulted from much reduced growth rate of aquaculture production in China because of shifting sectoral development priorities, from quantity to more focused on quality and efficiency. New initiatives embedded in policies, governance, technology development and services will have to be undertaken for the aquaculture sector to keep the pace with the growing demand for fish in the region, and also as a major supplier to the world. Aquaculture needs to be further integrated into national strategies for food and nutrition security with the policy and resource priorities given to ensure its sustainable growth.

It should be recognized that apart from seaweeds, Chinese carps, molluscs and a few new emerging species such as swamp red crayfish and mitten crab that are almost exclusively farmed in China, two non-native species, the whiteleg shrimp and tilapia play very important roles in aquaculture production in the region. It is also important to recognise that over the last decade there has not been an upsurge in the emergence of aquaculture of new species or species groups of regional significance.

The aquaculture sector in the region has attempted to embrace practices that contribute to overall sustainability and environmental integrity. In this regard aquaculture farmers in the region have attempted to minimise waste from the farming systems and utilise effluents as nutrient sources for secondarily farmed aquatic species and or land-based agriculture. In addition, there is evidence to show that over the last decade or more aquaculture practices in the region have reduced their dependence on antibiotics and other chemicals while awareness has increased, all contributing towards sustainability of the sector. Farming practices in the Asia-Pacific region, have made suitable management changes rather effectively, at times in cooperation between public and private sectors. Such initiatives perhaps will stand in good stead for other regions too.

Farming systems in the region have been improving and evolving towards more resource efficiency, environmental integrity, productivity and better climate resilience in response to the increasing scarcity of land and water resources, climate change challenges and increasingly high environmental and social standards. More will be achieved in future through improvements in existing farming systems and technology combining aspects of traditional and modern practices. Technological, management and governance efforts are ensuring that aquaculture remains within the carrying capacity of inland and coastal ecosystems. Recirculating aquaculture and offshore cage culture, although not yet fully developed in the region and facing some development constraints, are among the technology options that need to be further pursued. However, such developments have to be adaptive to the regional diverse resource settings and business contexts.

One area of plausible development is "Integrated Multi-Trophic Aquaculture (IMTA)". Although there are indications that here China (Zhang et al., 2018) may take the lead, it is a development that should be adopted and accelerated regionally. Research and adoption of culture-based fisheries, an extensive form of aquaculture that is community based, to augment the food fish supply to poor, rural communities and increase household incomes has also been an important initiative of the region.

Impacts of climate change are likely to be associated with hazardous extreme weather events as well as sea level rise. Key recommendations for mitigating the impacts of climate change on existing farming practices in the region, such as adoption of modification of existing farming facilities and management practices, integrated aquaculture such as IMTA and the production of salinity tolerant strains need to be given urgent attention.

It has been pointed out that aquaculture, often criticised for impacting on biodiversity and environmental integrity, has not been well recognised for its positive impacts on biodiversity. Examples from the region have been brought forward, specifically with initiatives taken in relation to the live food fish restaurant trade and aquatic biodiversity conservation and enhancement supported by aquaculture activities.

Research and development have contributed greatly to aquaculture growth in the region although it might have been sometimes driven by institutional priority or individual interest. The need for strengthening coordination and collaboration at national level is imperative. Collaboration at sub-regional, regional level need to be strengthened in establishing and co-financing aquaculture research and development of regional importance, such as genetic improvements of species that are strategically important for aquaculture development in the region, aquaculture environmental control and manipulation, biosecurity and aquatic animal health management and marketing.

It is recommended that governments strengthen their support to existing regional networking mechanisms such as NACA to facilitate the collaboration in aquaculture research, knowledge and information sharing, technology dissemination, sectoral policy and strategy development and regional capacity building in the region.

The Asia-Pacific region will need to continuously sustain a stable aquaculture growth as a vitally important food production sector for greater contribution to the attainment of relevant SDG targets in the decade to come, although probably at a lower growth rate than that in the previous decade. This is likely to be achieved mainly through sustainable intensification supported by better governance and sector management, technology development, farming innovations and genetic improvement of farmed types.

11. References

Abery, N.W., Sukadi, F., Budhiman, A.A., Kartamihardja, E.S., Koeshendrajana, S. & De Silva, S.S. 2005. Fisheries and cage culture of three reservoirs in west Java, Indonesia; a case study of ambitious development and resulting interactions. *Fisheries Management and Ecology*, 12: 315-330. (also available at https://doi.org/10.1111/j.1365-2400.2005.00455.x)

Ahmed, N. & Diana, J. S. 2015.Threatening "white gold": Impacts of climate change on shrimp farming in coastal Bangladesh. *Ocean & Coastal Management* 114: 42-52. (also available at https://doi.org/10.1016/j.ocecoaman.2015.06.008**)**

Ahmed, N. & Diana, J. S. 2016. Does climate change matter for freshwater aquaculture in Bangladesh? *Regional Environmental Change* 16:1659–1669

Ahmed, N. & Glaser, M. 2016. Can "Integrated Multi-Trophic Aquaculture (IMTA)" adapt to climate change in coastal Bangladesh? *Ocean & Coastal Management* 132: 120-131. (also available at doi: 10.1016/j.ocecoaman.2016.08.017)

Ahmed, N., Thompson, S. & Glaser, M. 2019. Global aquaculture productivity, environmental sustainability, and climate change adaptability. *Environmental Management*, 63:159–172 (also available at https://doi.org/10.1007/s00267-018-1117-3)

Alday-Sanz, V., Brock, J., Flegel, T. W., McIntosh, R., Bondad-Reantaso, M. G., Salazar, M. & Subasinghe, R. 2018. Facts, truths and myths about SPF shrimp in aquaculture. *Reviews In Aquaculture*, 12 (1); 76-84. doi: 10.1111/raq.12305

Alimahmoudi, M., Azarm, H.M. & Mohamadi, Y. 2017. Biofloc new technology and shrimp disease in super-intensive aquaculture. *International Journal of Fisheries and Aquatic Research*, 2:17-21. (also available at http://www.fishjournals.com/archives/2017/vol2/issue2/1-1-32)

Amal, M.N.A., Koh, C.B., Nurliyana, M., Suhaiba, M., Nor-Amalina, Z., Santha, S., Diyana-Nadhirah, K.P., Yusof, M.T., Ina-Salwany, M.Y. & Zamri-Saad, M. 2018. A case of natural co-infection of tilapia lake virus and *Aeromonas veronii* in a Malaysian red hybrid tilapia (*Oreochromis niloticus x O. mossambicus*) farm experiencing high mortality. *Aquaculture* 485: 12–16. (also available at https://doi.org/10.1016/j.aquaculture.2017.11.019)

Anh, P. T., Kroeze, C., Bush, S. & Arthur, P. J. M. 2010. Water pollution by Pangasius production in the Mekong Delta, Viet Nam: causes and options for control. *Aquaculture Research* 2010, 1-21. doi:10.1111/j.1365-2109.2010.02578.x

Asian Development Bank. 2013. *Food security in Asia-Pacific*. Mandaluyong City, Philippines: Asian Development Bank. 108 pp. (also available at https://www.adb.org/sites/default/files/publication/30349/food-security-asia-pacific.pdf)

Aslan, L.O.M., Bolu, L.O.R., Ingram, B.A., Gooley, G.J. & De Silva, S.S. 2015. Mariculture in SE Sulawesi, Indonesia: Culture practices and the socio economic aspects of the major commodities. *Ocean and Coastal Management* 116: 44-57. (also available at http://dx.doi.org/10.1016/j.ocecoaman.2015.06.028.).

Aye, K. M., Lay, K. K., Win, H. & De Silva, S. S. 2007. A new freshwater aquaculture practice that has successfully targeted a niche export market with major positive societal impacts: Myanmar. *Aquaculture Asia Magazine. August-September 2007*: 22-27.

Badiola, M, Mendiola, D & Bostock, J. 2012. Recirculating Aquaculture Systems (RAS) analysis: main issues on management and future challenges. *Aquacultural Engineering* 51: 26–35.

Barange, M. Bahri, T., Beveridge, M.C.M., Cochrane, K., Funge-Smith, S. and Poulain, F. (Eds), 2018. *Impacts of climate change on fisheries and aquaculture: Synthesis of current knowledge, adaptation and mitigation options.* FAO Fisheries and Aquaculture Technical Paper 627. 628pp. (also available at http://www.fao.org/3/i9705en/I9705EN.pdf)

Baylis, K., Noguiera, L. & Pace, K. 2010. Food import refusals: evidence from the European Union. *American Journal of Agricultural Economics*, 93: 566-572. (also available at https://doi.org/ 10.1093/ajae/aaq149.

Beard T.D. Jr, Arlinghaus, R., Cooke, S.J., McIntyre, P., De Silva S., Bartley D. & Cowx, I.G. 2011. Ecosystem approach to inland fisheries: research needs and implementation strategies. *Biology Letters* 7(4), 481–483 (also available at doi: 10.1098/rsbl.2011.0046).

Behera, N. 2017. Seafood food exports to the US face quality issues. [online] *Business Standard, India*. [Cited xx month 2020] https://www.business-standard.com/article/markets/aquatic food-exports-to-the-us-face-quality-issues-117062700079_1.html

Belton, B., Haque, M.H., Little, D.C. & Sinh, L.X. 2011. Certifying catfish in Viet Nam and Bangladesh: Who will make the grade and will it matter? *Food Policy* 36: 289–299. doi:10.1016/j.foodpol.2010.11.027

Belton, B., Little, D. C. & Sinh, L.X. 2013. The social relations of catfish production in Viet Nam. *Geoforum*, 42: 567-577. doi:10.1016/j.geoforum.2011.02.008

Béné, C, Barange , M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G.-I. & Williams, M. 2015. Feeding 9 billion by 2050 – Putting fish back on the menu. *Food Security*, 7: 261-274. (also available at DOI 10.1007/s12571-015-0427-z)

Beveridge, M.C.M., Ross, L.G. & Kelly, L.A. 1994. Aquaculture and biodiversity. *Ambio* 23:497–502

BOF/MARA. 2019. *China Fishery Statistics Yearbook 2019*. Bureau of Fisheries, Ministry of Agriculture and Rural Affairs, P. R. China.. Beijing, China Agriculture Press.

Bossier, P. & Ekasari, J. 2017. Biofloc technology application in aquaculture to support sustainable development goals. *Microbial Biotechnology* 10: 1012–1016.

Braidotti, G. 2019. Aquaculture's ancient roots recognized. Fish September 2019, Fisheries research Development Corporation News pp.17.

Bregnballe, J. 2015. A Guide to Recirculation Aquaculture: An introduction to the new environmentally friendly and highly productive closed fish farming systems. Food and Agriculture Organization of the United Nation, Rome, Italy and EUROFISH International Organisation, Copenhagen, Denmark. 95 pp. http://www.fao.org/3/i4626e/i4626e.pdf

Brown T.W., Boyd C.E. & Chappell J.A. 2012. Approximate water and chemical budgets for an experimental, in-pond raceway system. *Journal of the World Aquaculture Society* 43: 526-537.

Brugere, C. & M. Williams. 2017. *Profile: Women in Aquaculture*. [online] Selangor, Malaysia, Genderaquafish.org. [Cited xx month 2020] https://genderaquafish.org/portfolio/women-in-aquaculture/

Buddhiman & De Silva, S. S. 2005. Fisheries and cage culture of three reservoirs in west Java, Indonesia; a case study of ambitious developments and resulting interactions. *Fisheries Management and Ecology* 12: 315-330.

Builth, H., Kershaw, A. Peter, White, C., Roach, Anna, Hartney, L., McKenzie, M., Lewis, T., & Jacobsen, G. 2008. Environmental and Cultural Change on the Mt. Eccles Lava-Flow Landscapes of Southwest Victoria, Australia. *The Holocene* 18(3): 413–24.

Bulfon, C., Volpatti , D. & Galeotti, M. 2013. Current research on the use of plant-derived products in farmed fish. *Aquaculture Research* 46: 513–551. (also available at https://doi.org/10.1111/are.12238)

Bunlipatanon, P., Songseechan, N., Kongkeo, H., Abery, N.W. & De Silva S. S. 2013. Comparative efficacy of trash fish versus compounded commercial feeds in cage aquaculture of Asian seabass (*Lates calcarifer*) (Bloch) and tiger grouper (*Epinephelus fuscoguttatus*) (Forsskål). *Aquaculture Research* 45; 373-388. (DOI: 10.1111/j.1365-2109.2012.03234.x)

Bush, S.R., Belton, B., Little, D.C. & Islam, M.S. 2019. Emerging trends in aquaculture value chain research. *Aquaculture* 498: 428–434. (also available at https://doi.org/10.1016/j.aquaculture.2018.08.077)

Bush, S. R., Khiem, N. & Sinh, L.X. 2009. Governing the environmental and social dimensions of pangasius production in Viet Nam: a review_ *Aquaculture Economics & Management*, 13:271–293, DOI: 10.1080/13657300903351594

Cao, L., Naylor, R., Henriksson, P., Leadbitter, D., Metian. M., Troell, M. & Zhang, W. 2015. China's aquaculture and the world's wild fisheries. *Science*, 347: 133–135 (also available at DOI: 10.1126/science.1260149).

Carbone, D. & Faggio, C. 2016. Importance of prebiotics in aquaculture as immunostimulants, effects on immune system of *Sparus aurata* and *Dicentrarchus labrax*. *Fish and Shellfish Immunology*, 54:172-178. (also available at https://doi.org/10.1016/j.fsi.2016.04.011)

Castine, S.A., Bogard, J.R., Barman, B.K., Karim, M., Hossain, Md M., Kunda, M., Haque, A.B.M., Phillips, M.J. & Thilsted, S.H. 2017. Homestead pond polyculture can improve access to nutritious small fish. *Food Security* 9:785–801. (also available at DOI 10.1007/s12571-017-0699-6)

Chakraborty, S. B., Horn, P. & Hancz, C. 2014. Application of phytochemicals as growth-promoters and endocrine modulators in fish culture. *Reviews in Aquaculture* (2014) 6, 1–19. (also available at https://doi.org/10.1111/raq.12021)

Chan, C.Y., Tran, N., Dao, C.D., Sulser, T.B., Phillips, M.J., Batka, M., Wiebe, K. & Preston N. 2017. Fish to 2050 in the ASEAN region. Penang, Malaysia: World Fish and Washington DC, USA: International Food Policy Research Institute (IFPRI). Working Paper: 2017-01. 36 pp.

Chandrasoma, J. & Pushpalatha, K. B.C. 2018. Fisheries enhancements in inland waters in Sri Lanka with special reference to culture based fisheries: current status and impacts. *Sri Lanka Journal of Aquatic Sciences* 23(1): 49-65. (also available at http://doi.org/10.4038/sljas.v23i1.7546)

Chauhan, A. & Singh, R. 2019. Probiotics in aquaculture: a promising emerging alternative approach. *Symbiosis*, 77:99-113. (also available at https://link.springer.com/article/10.1007/s13199-018-0580-1)

Chen, J., Guang, C., Xu, H., Chen, Z., Xu, P., Yan, X., Wang, Y. & Liu, J. 2008. Marine fish cage culture in China. In A. Lovatelli, M.J. Phillips, J.R. Arthur and K. Yamamoto (eds). FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11 March 2006. FAO Fisheries Proceedings. No. 11. Rome, FAO. 2008. pp. 285–299.

Cheng, Y., Wu, X. & Li, J. 2018. Chinese mitten crab culture: current status and recent progress towards sustainable development. In: Jian-Fang Gui, Qisheng Tang, Zhongjie Li, Jiashou Liu and Sena S De Silva (eds.), *Aquaculture in China: Success Stories and Modern Trends*, pp.335-371. Wiley, UK. (also available at https://doi.org/10.1002/9781119120759.ch3_2)

China Fishery Mutual Insurance, 2019. Summary report on core business of China Fishery Mutual Insurance in 2018 (Chinese). http://www.cfmi.org.cn/index.php?m=content&c=index&a=lists&catid=140

Clements, J.C. & Chopin, T. 2016. Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies. *Reviews in Aquaculture* 9, 326-341. (also available at https://doi.org/10.1111/raq.12140)

COFI. 2021. *The 34th Session of the Committee on Fisheries, 1-5 February 2021. FAO's Contribution of Fisheries and Aquaculture towards Achieving the 2030 Agenda.* Rome, FAO. 21 pp.
(also available at http://www.fao.org/3/ne713en/ne713en.pdf)

Connor, W.E. 2000. Importance of n–3 fatty acids in health and disease. *American Journal of Clinical Nutrition* 71 (1 Supplement): 171S-175S.

Cui, W. & Ning, B. 2019. Development and application of crab culture in the development of Chinese mitten crab industry of Shanghai. *Aquaculture Research*. 50:367–375. (also available at https://doi.org/10.1111/are.13920)

Cunnane, S.C. & Stewart, K. M. (ed.) 2010. Human Brain Evolution: The influence of Freshwater and Marine Food Resources. John Wiley and Sons, New Jersey, 209 pp.

Dabu, I.M., Lim, J.J., Arabit, P.M.T., Orense, S.J.A.B., Tabardillo Jr., J.A., Corre, V.L. & Maningas, M.B.B. 2015. The first record of acute hepatopancreatic necrosis disease in the Philippines. *Aquaculture Research*, 48:792-799. (also available at https://doi.org/10.1111/are.12923)

Dasgupta, S., Laplante B., Meisner, C., Wheeler, D. & Yan, J. 2007. The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis. World Bank Policy Research Working Paper 4136, Washington, DC.

David, B., Bryce, B. & McNiven, I.J. 2006. The Social Archaeology of Australian Indigenous Societies. Canberra: Aboriginal Studies Press

De Schryver, P., Crab, R., Defoirdt, T., Boon, N. & Verstraete, W. 2008. The basics of bio-flocs technology: the added value for aquaculture. *Aquaculture* 277: 125–137.

De Silva, S.S, Subasinghe, R.P., Bartley, D.M. & Lowther, A. 2004. *Tilapias as alien aquatics in Asia and the Pacific: a review.* FAO Fisheries Technical Paper. No. 453. Rome, FAO. 2004. 65p.

De Silva, S.S., Amarasinghe, U.S. & Nguyen, T.T.T. (Eds), 2006. Better- approaches to culture-based fisheries development in Asia. ACIAR Monograph 120, 96 pages

De Silva, S.S. & Phillips, M.J. 2007. A Review of Cage Aquaculture: Asia (excluding China), FAO Fisheries Technical Paper No. 498, pp 18-48.

De Silva S.S & Soto, D. 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. *FAO Fisheries Technical Paper*, 530: 137-215.

De Silva, S.S. & Turchini, G.M. 2009. Use of wild fish and other aquatic organisms as feed in aquaculture – a review of practices and implications in the Asia-Pacific.In M.R. Hasan and M. Halwart (eds). Fish as feed inputs for aquaculture: practices, sustainability and implications. FAO Fisheries and Aquaculture practice Technical Paper.No. 518. Rome, FAO. pp. 63–127.

De Silva, S.S. & Davy, F.B., 2010. Aquaculture successes in Asia, contributing to sustained development and poverty alleviation. In: Success Stories in Asian Aquaculture (S.S. De Silva, F.B. Davy, eds.), pp.08- 21. Springer-IDRC-NACA.

De Silva, S.S., Francis, D. & Tacon, A.G.J. 2011. Fish oil in aquaculture; in retrospect. In Turchini, Giovanni M., Ng, Wing-Keong and Tocher, Douglas R. (ed), *Fish oil replacement and alternative lipid sources in aquaculture feeds*, CRC Press, Boca Raton, Flo., pp.1-20. (also available at https://dro.deakin.edu.au/view/DU:30031360)

De Silva, S.S. & Phuong T. N. 2011. Striped catfish farming in the Mekong Delta, Vietnam: a tumultuous path to a global success. *Reviews in Aquaculture* 3: 45-73. (also available at doi: 10.1111/j.1753-5131.2011.01046.x).

De Silva S.S. 2012a. Aquaculture: a newly emergent food production sector-and perspectives of its impacts on biodiversity and conservation. *Biodiversity and Conservation* 21 (12): 3187-3220. (also available at https://link.springer.com/article/10.1007/s10531-012-0360-9)

De Silva, S.S. 2012b. Climate change impacts: challenges for aquaculture. In: *Farming the Waters for People and Food* (eds. R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan & P. Sorgeloos). pp. 75-122. Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand. 22–25 September 2010. FAO, Rome and NACA, Bangkok.

De Silva S. S., Ingram, B.A. & Wilkinson, S. (eds.), 2015. Perspectives on culture-based fisheries development in Asia. Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand. 123pp.

Deckere, de E., Korver, O., Verschuren, P.M. & Katan, M.B., 1998. Health aspects of fish and n-3 polyunsaturated fatty acids from plant and marine origin. *European Journal of Clinical Nutrition* 52: 749-753.

Diana, J.S. 2009. Aquaculture production and biodiversity conservation. *BioScience* 59: 27–38. (also available at https://doi.org/10.1525/bio.2009.59.1.7)

Dien, L. D., Hiep L. H., Hao N. V., Sammut J. & Burford M. A. 2018. Comparing nutrient budgets in integrated rice-shrimp ponds and shrimp grow-out ponds. *Aquaculture* 484 (2018): 250–258. https://doi.org/10.1016/j.aquaculture.2017.11.037

Dong, H.T., Siriroob, S., Meemetta, W., Santimanawong, W., Gangnonngiw, W., Pirarat, N., Khunrae, P., Rattanarojpong, T., Vanichviriyakit, R. & Senapin, S. 2017. Emergence of tilapia lake virus in Thailand and an alternative semi-nested RT-PCR for detection. *Aquaculture*, 476: 111-118. (also available at https://doi.org/10.1016/j.aquaculture.2017.04.019)

D'Urso, J. 2015. Southeast Asia faces increasingly intense climate events: analysts. [online] Thomson Reuters Foundation. [Cited xx month 2020] https://www.reuters.com/article/us-climatechange-events-asia/southeast-asia-faces-increasingly-intense-climate-events-analysts-idUSKBN0MS5IR20150402

Eknath, A.E. & Acosta, B.O. 1998. *Genetic improvement of farmed tilapias (GIFT) project: final report, March 1988 to December 1997*. International Center for Living Aquatic Resources Management, Makati City, Philippines. 75 pp.

Fang, J. & Zhang, J. 2015. Types of integrated multi-trophic aquaculture practiced in China. *World Aquaculture*, 46: 26-30.

Fang, J., Zhang, J., Xiao, T., Huang, D., & Liu, S. 2016. Integrated multi-trophic aquaculture (IMTA) in Sanggou Bay, China. *Aquaculture Environment Interactions* 8, p. 201-205. (also available at doi: 10.3354/aei00179).

FAO. 2010. Report of the FAO Expert Workshop on On-farm feeding and feed management in aquaculture. Manila, the Philippines, 13–15 September 2010. *FAO Fisheries and Aquaculture Report*. No. 949. Rome, FAO. 2010. 37p. (also available at http://www.fao.org/3/i1915e/i1915e.pdf)

FAO. 2015. *Report of the APFIC/FAO Regional Consultation: Improving the contribution of culture-based fisheries and fishery enhancements in inland waters to Blue Growth*, 25–27 May 2015, Jetwing Blue Hotel, Negombo, Sri Lanka. RAP Publication 2015/08, 52 p. (also available at http://www.fao.org/3/i5152e/i5152e.pdf)

FAO. 2016. *Regional strategy and action plan for sustainable intensification of aquaculture in the Asia-Pacific region*. Bangkok, FAO. 68 pp. (also available at http://www.fao.org/3/i5466e/i5466e.pdf)

FAO. 2017a. *Regional review on status and trends in aquaculture development in Asia-Pacific – 2015* by Rohana Subasinghe. FAO Fisheries and Aquaculture Circular 1135/5. Rome, Italy**.** 32 pp. (also available at http://www.fao.org/3/i6875e/i6875e.pdf**)**

FAO. 2017b. *The 2030 Agenda and the Sustainable Development Goals: The challenge for aquaculture development and management*, by John Hambrey. FAO Fisheries and Aquaculture Circular No. 1141, Rome, Italy. 63 pp. (also available at http://www.fao.org/3/i7808e/i7808e.pdf)

FAO. 2018. *The State of World Fisheries and Aquaculture 2018 – Meeting the sustainable development goals*. Rome**,** FAO**.** 211 pp. (also available at http://www.fao.org/3/I9540EN/i9540en.pdf)

FAO. 2019a. *The State of the World's Aquatic Genetic Resources for Food and Agriculture*. FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome. 253 pp. (also available at http://www.fao.org/3/CA5256EN/CA5256EN.pdf)

FAO. 2019b. Wongbusarakum, S., De Jesus-Ayson, E.G., Weimin, M. & DeYoung, C. 2019. Building Climate-resilient Fisheries and Aquaculture in the Asia-Pacific Region – FAO/APFIC Regional Consultative Workshop. Bangkok, Thailand, 14-16 November 2017. Bangkok, FAO. (also available at http://www.fao.org/3/ca5770en/CA5770EN.pdf)

FAO. 2020a. Fishery statistical collections. Global aquaculture production. In: FAO Fisheries and Aquaculture Department [online] Rome. http://www.fao.org/fishery/statistics/global-aquaculture-production/en. Updated in 2020.

FAO. 2020b. Fishery statistical collections. Consumption of fish and fishery products. In: FAO Fisheries and Aquaculture Department [online] Rome. http://www.fao.org/fishery/statistics/global-consumption/en

FAO. 2020c. *The State of World Fisheries and Aquaculture 2020. Sustainability in action.* Rome. 208 pp. (also available at https://doi.org/10.4060/ca9229en)

FAO/NACA, 2000. The Asia Regional Technical guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and The Beijing Consensus and Implementation Strategy. *FAO Fisheries Technical Paper* No. 402. Rome, FAO. 53p. (also available at http://www.fao.org/3/x8485e/x8485e00.htm)

FAO/NACA, 2011. Regional Review on Status and Trends in Aquaculture Development in Asia-Pacific – 2010. http://www.fao.org/3/i2311e/i2311e.pdf

FAO RAP. 2019. *Asia-Pacific region must move to strengthen governance of aquaculture for sustainable development.* [online] Bangkok, FAO Regional Office for Asia and the Pacific. [Cited xx month 2020] http://www.fao.org/asiapacific/news/detail-events/en/c/1245728/.

Fiedler, J. L., Lividini, K., Drummond, E. & Thilsted S.H. 2016. Strengthening the contribution of aquaculture to food and nutrition security: The potential of a vitamin A-rich, small fish in Bangladesh. *Aquaculture* 452: 291–303. http://dx.doi.org/10.1016/j.aquaculture.2015.11.004

Fitzsimmons, K. & Martinez-Garcia, R. 2013. *Why tilapia is becoming the most important food fish on the planet.* Proceedings of the 9th International Symposium on Tilapia in Aquaculture (Eds. Liu L. and Fitzsimmons K). AquaFish Cooperation Research Support Program, Shanghai Ocean University, Shanghai. (also available at https://www.academia.edu/23491108/Why_tilapia_is_becoming_the_most_important_food_fish_on_the_planet)

Flegel, T.W. 2012. Historic emergence, impact and current status of shrimp pathogens in Asia. *J. Invert. Pathol.*, 110:166-173. (also available at doi: 10.1016/j.jip.2012.03.004)

Fry, J.P., Love, D.C., MacDonald, G.K., West, P.C., Engstrom, P.M., Nachman, K.E. & Lawrence, R.S. 2016. Environmental health impacts of feeding crops to farmed fish. Environment International 91: 201–214. http://dx.doi.org/10.1016/j.envint.2016.02.022

GAA. 2019. What is the environmental impact of aquaculture? Aquaculture 101 Series, Global Aquaculture Alliance, New Hamphsire, USA. https://www.aquaculturealliance.org/blog/what-is-the-environmental-impact-of-aquaculture/

Gatlin III, D.M., Barrows, F.T., Brown, P., Dabrowski, K., Gaylord, T.G. & Hardy, R.W. 2007. Expanding utilization of sustainable plant products in aquafeeds: a review. *Aquaculture Research* 38: 551-579. (also available at https://doi.org/10.1111/j.1365-2109.2007.01704.x)

Gitterle, T. & Diener, J. 2014. Genetic improvement programs for shrimp vary between Asia, Americas. [online] *Global Aquaculture Advocate*. [Cited xx month 2020] https://www.aquaculturealliance.org/advocate/genetic-improvement-programs-for-shrimp-vary-between-asia-americas/

Godfrey, M. 2015. China's AQSIQ releases aquatic food import rejections. Aquatic food source. https://www.aquatic foodsource.com/news/supply-trade/china-s-aqsiq-releases-aquatic food-import-rejections

Government of Cambodia, 2010. *The Strategic Planning Framework for Fisheries 2010–2019*. Phnom Penh, Ministry of Agriculture, Forestry and Fisheries. 57 pp. (also available at http://extwprlegs1.fao.org/docs/pdf/cam143042.pdf)

Gozlan, R.E. 2008. Introduction of non-native freshwater fish: is it all bad? *Fish and Fisheries* 9:106–115

Greentumble. 2016. Negative and positive environmental impacts of aquaculture. [online] *Greentumble*. [Cited xx month 2020] https://greentumble.com/environmental-impacts-of-aquaculture/

Gui, J. F., Tang Q, S., Li, Z. J., Liu, J. S, De Silva, S. S. 2018. Aquaculture in China - Success Stories and Modern Trends. Wiley-Blackwell. 720 pp.

Guillen, J., Natale, F., Carvalho, N., Casey, J., Hofherr, J., Druon, J-N., Fiore, G., Gibin, M., Zanzi, A., & Martinsohn, J.T. 2019. Global seafood consumption footprint. *Ambio* 48:111–122. (also available at https://doi.org/10.1007/s13280-018-1060-**9)**

Gupta, M.V. & Acosta, B.O. 2004a. A review of global tilapia farming practices. *Aquaculture Asia Magazine,* 10(7): p. 7-16.

Gupta, M.V. & Acosta, B.O. 2004b. From drawing board to dining table: the success story of the GIFT project. *NAGA World Fish Center Quarterly*, 27: p. 4-14

Han, D., Shan, X., Zhang, W., Chen, Y., Wang, Q., Li, Z., Zhang, G., Xu, P., Li, J., Xie, S., Mai, K., Tang, Q. & De Silva, S. S. 2018. A revisit to fishmeal usage and associated consequences in Chinese aquaculture. *Reviews in Aquaculture* 10 (2):493-507. (also available at https://doi.org/10.1111/raq.12183)

Haque, A. B. M. M. and Dey, M. M. 2017. Impacts of community-based fish culture in seasonal floodplains on income, food security and employment in Bangladesh. *Food Security* 9:25–38. (also available at DOI 10.1007/s12571-016-0629-z)

Haque, S.M., Satu, S.B., Rahman, M.M., Egna, H.S., Salger, S. & Borski, R.J. 2017. Improving the Livelihood for Marginalized Women's Households in Southwest Bangladesh through Aquaculture. *Asian Fisheries Science Special Issue* (30S):313 - 326.

Harmeling, S. & Eckstein, D. 2012. Global Climate Risk Index 2013: Who suffers most from extreme weather events? Weather-related Loss Events in 2011 and 1992 to 2011. *German watch*, Bonn.

Hasan, M.R. 2012. Transition from low-value fish to compound feeds in marine cage farming in Asia. FAO Fisheries and Aquaculture Technical Paper. No. 573. Rome, FAO. 2012. 198 pp

Hasan, M.R., Hecht, T., De Silva, S.S. & Tacon, A.D.J. (Eds.) 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development.* FAO Fisheries Technical Paper, 497. Rome, Italy. 501 pp. (also available at http://www.fao.org/3/a1444e/a1444e00.htm)

Hasan, M.R. & Halwart, M. (eds). 2009.Fish as feed inputs for aquaculture: practices, sustainability and implications. FAO Fisheries and Aquaculture Technical Paper. No. 518. Rome, FAO. 2009. 407p

Henriksson, P.J.G., Murray, F.J, Little, D.C., Dalsgaard, A. & den Brink PJ.V. 2013. Use of veterinary medicines, feed additives and probiotics in four major internationally traded aquaculture species farmed in Asia. *Aquaculture* 412–413: 231–243

Hua, K., Cobcroft, J.M., Cole, A., Condon, K., Jerry, D.R, Mangott, A., Praeger, C., Vucko, M.J., Zeng, C., Zenger, K. & Strugnell, J.M. 2019. The future of aquatic protein: implications for protein sources in aquaculture diets. *One Earth,* 1: 316-329. (also available at https://doi.org/10.1016/j.oneear.2019.10.018)

IISD. 2014. *The role of seafood in global food security.* Summary of the 15th meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea: 27-30 May 2014. Winnipeg, Canada, The International Institute for Sustainable Development. 20 pp. (also available at https://www.un.org/depts/los/general_assembly/contributions_2014/FAO%20contribution%20UN%20SG%20OLOS%20report%20Part%20I%20FINAL.pdf).

IUCN. 2017 *Marine Protected Areas: Exploring Potential Opportunities and Synergies.* Gland, Switzerland, International Union for Conservation of Nature. 16 pp. (also available at https://www.iucn.org/sites/dev/files/content/documents/aquaculture_and_marine_protected_areas.pdf)

Jacquet, J. & Pauly, D. Ainsley, D., Holt, S., Dayton, P. & Jackson, J. 2010. Aquatic food stewardship in crisis. *Nature (Opinion*), 467|2 September 2010:28-29.

Jahangiri, L. & Ángeles, E.M. 2018. Administration of probiotics in the water in finfish aquaculture systems: A review, *Fishes 2018*, 3, pp. 33; doi:10.3390/fishes3030033

Jannathulla, R., Rajaram, V., Kalanjiam, R., Ambasankar, K., Muralidhar, M. & Dayal, J.S. 2019. Fishmeal availability in the scenarios of climate change: Inevitability of fishmeal replacement in aquafeeds and approaches for the utilization of plant protein sources. *Aquaculture Research* 50 (12): 3493-3506. DOI: 10.1111/are.14324

Jennings, S., Stentiford, G.D., Leocadio, A.M., Jeffery, K. R., Metcalfe, J. 2016. Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment. *Fish and Fisheries* 17 (4); 893-918.

Johnson, J., Bell, J. & De Young, C. 2013. *Priority adaptations to climate change for Pacific fisheries and aquaculture: reducing risks and capitalizing on opportunities. FAO/Secretariat of the Pacific Community Workshop, 5-8 June 2012, Noumea, New Caledonia.* FAO Fisheries and Aquaculture Proceedings No. 28. Rome, FAO. 109 pp. (also available at http://www.fao.org/3/i3159e/i3159e00.htm)

Jonell, M., Phillips, M.J., Ronnback, P. & Troell, M. 2013. Eco-certification of Farmed Aquatic food: Will it Make a Difference? *AMBIO* 42: 659–674. DOI 10.1007/s13280-013-0409-3

Jones, R.J. & Steven, A.L. 1997. Effect of cyanide on corals in relation to cyanide fishing on reefs. *Marine and Freshwater Research* 48:517–522

Ju, Rui-Ting, Li, Xiao, Jiang, Jia-Jia, Wu, Jihua, Liu, Jianguo, Strong, Donald R. & Li Bo. 2020. Emerging risks of non-native species escapes from aquaculture: Call for policy improvements in China and other developing Countries. Journal of Applied Ecology 57: 85–90. DOI: 10.1111/1365-2664.13521

Kawahigashi, D. 2018. New paradigm in controlling EMS/AHPNS in intensive *P. vannamei* Boone 1931 culture ponds. *Asian Fisheries Science*, 31S:182-193. (also available at https://doi.org/10.33997/j.afs.2018.31.S1.013)

Khan, M.I.R. 2018. Shrimp toilet: a novel way for disposal of organic wastes in aquaculture systems. *Aqua International*, September 2018:52-54.

Kongkeo, H., Wayne, C., Murdjani, M., Bunliptanon, P. & Chien, T. 2010. Current practices of marine fin fish cage culture in China, Indonesia, Thailand and Viet Nam. Marine Finfish Aquaculture Network. Marine Aquaculture Network Aquaculture. *Aquaculture Asia Magazine* XV No. 2, April-June 2010 pp. 32-40.

Kreft, S., Eckstein, D., Junghans, L., Kerestan, C . & Hagen, U. 2014. Global climate risk index 2015: Who suffers most from extreme weather events? Weather-related Loss Events in 2013 and 1994 to 2013. *German watch*, Bonn.

Kwasek, K., Thorne-Lyman, A. L. & Phillips, M. 2020. Can human nutrition be improved through better fish feeding practices? a review paper, Critical Reviews in Food Science and Nutrition, 60 (22): 3822-3835. (also available at DOI: 10.1080/10408398.2019.1708698)

Ladan, J. & Esteban, M. A., 2018. Administration of Probiotics in the Water in Finfish Aquaculture Systems: A Review. Fishes 2018, 3, 33; doi:10.3390/fishes3030033

Lao PDR, Ministry of Agriculture & Forestry 2010. *Agricultural Master Plan, 2011 to 2015*. Vientiane, Lao PDR. 122 pp.

Leaño, E.M. & Mohan, C.V., 2012. Early mortality syndrome threatens Asia's shrimp farms. *Global Aquaculture Advocate*, 15(4): 38-39. (also available at https://www.aquaculturealliance.org/advocate/early-mortality-syndrome-threatens-asias-shrimp-farms/)

Leaño, E.M., 2019. Transboundary aquatic animal diseases: history and impacts in the ASEAN aquaculture. In: E.A. Tendencia, L.D. de la Pena and J.M.V. dela Cruz (editors). *Aquatic Emergency Preparedness and Response System for Effective Management of Transboundary Disease Outbreaks in Southeast Asia (AEPRS*). SEAFDEC Aquaculture Department, Tigbauan, Iloilo, Philippines. p. 72-79. (also available at https://repository.seafdec.org.ph/bitstream/handle/10862/3466/LeanoEM2019.pdf;jsessionid=49C8BD1BAF6FAE07C7701A1E40EBA4CE?sequence=1)

Lebel, L., Lebel, P. & Chuah, J. 2019. Water use by inland aquaculture in Thailand: stakeholder perceptions, scientific evidence, and public policy. *Environmental Management* 63:554–563 (also available at https://doi.org/10.1007/s00267-019-01143-0)

Leung, T.L.F. & Bates, A.E. 2013. More rapid and severe disease outbreaks for aquaculture at the tropics: implications for food security. *Journal of Applied Ecology*, 50: 215–222 (also available at https://doi.org/10.1111/1365-2644.12017)

Li, D., Xie, C., He, X., Tan, R., Zhang, Z. & Gao, Y. 2018a. *The success of yellow catfish aquaculture in China: from rare wild fish to popular farmed fish.* In: Jian-Fang Gui, Qisheng Tang, Zhongjie Li, Jiashou Liu and Sena S De Silva (eds.), Chinese Aquaculture: Success Stories and Modern Trends, p. 463- 487. Wiley, UK.

Li, D., Xie, C., He, X.,Qi, C. & Liang, X. 2018b. *Channel catfish culture.* In: Jian-Fang Gui, Qisheng Tang, Zhongjie Li, Jiashou Liu and Sena S. De Silva (eds.), Chinese Aquaculture: Success Stories and Modern Trends, p. 679-698. Wiley, UK.

Li, W., Cheng, X., Xie, J., Wang, Z. & Yu, D. 2019. Hydrodynamics of an in-pond raceway system with an aeration plug-flow device for application in aquaculture: an experimental study. *Royal Society Open Science*, 6: 182061. (also available at http://dx.doi.org/10.1098/rsos.182061)

Limsong, S., Sitha, H., Sary, O., Vutha, O., Mohan, C.V. & De Silva S. S. 2013. Introduction of culture based fishery practices in small water bodies in Cambodia: issues and strategies. *Aquaculture Asia Magazine* XVIII (4): 12-17. (also available at https://enaca.org/publications/magazine/2013/introduction-cbf-cambodia-2013.pdf)

Lio-Po, G. D., Leaño, E. M., Usero, R. C., & Guanzon, N. G., Jr. 2002. *Vibrio harveyi* and the 'green water culture' of *Penaeus monodon*. In Y. Inui & E. R. Cruz-Lacierda (Eds.), Disease Control in Fish and Shrimp Aquaculture in Southeast Asia – Diagnosis and Husbandry Techniques: Proceedings of the SEAFDEC-OIE Seminar-Workshop on Disease Control in Fish and Shrimp Aquaculture in Southeast

Asia – Diagnosis and Husbandry Techniques. SEAFDEC Aquaculture Department, Iloilo, Philippines. pp. 172-180.

Little, D.C., Bush, S.R., Belton, B., Phuong, N.T., Young, J.A. & Murray, F.J. 2012. Whitefish wars: Pangasius, politics and consumer confusion in Europe. Marine Policy 36: 738–745

Liu, H. and Su, J.L. 2017. Vulnerability of China's nearshore ecosystems under intensive mariculture development. Environmental Science and Pollution Research, 24: 8957–8966

Lymer, D., Funge-Smith, S., Clausen, J., & Miao, W., 2008. Status and potential of fisheries and aquaculture in Asia and the Pacific 2008. *RAP Publication 2008/02*. Rome, FAO and Bangkok, APFC. (also available at http://www.fao.org/3/i0433e/I0433E00.htm)

Malindine, J. 2019. Prehistoric aquaculture: origins, implications, and an argument for Inclusion. *Journal of Culture and Agriculture* 41(1): 68-73.

Martinez-Porchas, M. & Martinez-Cordova, L.R. 2012. World aquaculture: environmental impacts and troubleshooting alternatives. *The Scientific World Journal*, 2012: 389623. (also available at https://doi.org/10.1100/2012/389623).

McGinley. 2011. Invasive species. In: C.J. Cleveland (Ed.), Encyclopedia of Earth, Environmental Information Coalition, National Council for Science and the Environment, Washington DC, USA.

Miao, W., De Silva, S. & Davy, B. 2010. *Inland fisheries resource enhancement and conservation in Asia.* FAO Regional Office for Asia and the Pacific, Bangkok. RAP Publication 2010/22, 189 pp. (also available at http://www.fao.org/3/i1984e/i1984e.pdf)

Miao, W. & Yuan, D. eds. 2021. *Regional Consultative Workshop: Strengthening Aquaculture Governance for Sustainable Development in Asia-Pacific: Bangkok, Thailand, 5-6 November 2019*. Bangkok, FAO. 174 pp. (also available at http://www.fao.org/publications/card/en/c/CB4463EN/)

Minchin, D. 2009. Introduction of exotic species. In: J.H. Steele *et al.* (Editors), Encyclopedia of Ocean Sciences, Elsevier, London, United Kingdom. p. 332-334

Ministry of Agriculture, Livestock and Irrigation. 2018. *Fishery statistics.* Ministry of Agriculture, Livestock and Irrigation, Republic of the Union of Myanmar. 75 pp.

Mous, P.J., Pet-Soede, L., Erdmann M., Cesar H.S.J., Sadovy, Y. & Pet, J.S. 2000. Cyanide fishing on Indonesian coral reefs for the live food fish market- what is the problem? *SPC Live Reef Fish Information Bulletin* 7:20–27

Moyle, P.B. & Leidy, R.A. 1992. Loss of biodiversity in aquatic ecosystems; evidence from fish faunas. In: Fielder PL, Jain SK (eds) Conservation biology: the theory and practice of nature conservation. Chapman and Hall, London, pp 129–161

NACA, OIE & FAO, 2017. *Quarterly Aquatic Animal Disease Report (Asia and Pacific Region)*, 2016/3, July – September 2016. NACA, Bangkok, Thailand and OIE-RRAP, Tokyo, Japan. 77 pp. (also available at https://rr-asia.oie.int/wp-content/uploads/2019/09/qaad-2016-4q.pdf)

Naylor, R.L., Goldburg, R.J., Mooney, H., Beveridge, M.C.M., Clay, J., Folke, C., Kautsky, N, Lubchenco, J., Primavera, J. & Williams, M. 1998. Nature's subsidies to shrimp and salmon farming. *Science*, 282: p. 883–884 (also available at DOI: 10.1126/science.282.5390.883)

Naylor, R.L., Goldburg, R.J., Primavera, J., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M. 2000. Effect of aquaculture on world fish supplies. *Nature* 405:1017–1024. (also available at https://www.nature.com/articles/35016500)

Naylor, R.L., Williams, S.L & Strong, D.R. 2001. Aquaculture—a gateway for exotic species. *Science* 294:1655–1666

Naylor, R.L., Hardy, R.W., Bureau, D.P., Chiu, A., Elliott, M., Farrell, A.P., Forster, I., Gatlin, D.M., Goldburg, R.J., Hua, K. & Nichols, P.D. 2009. Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy of Sciences* 106: 15103-15110. (also available at https://doi.org/10.1073/pnas.0905235106)

Newton, R., Telfer, T. & Little, D. 2014. Perspectives on the utilization of aquaculture coproduct in Europe and Asia: Prospects for value addition and improved resource efficiency. *Critical Reviews in Food Science and Nutrition* 54:4: 495-510, DOI:10.1080/10408398.2011.588349

Ngoc, P.T.A., Meuwissen, M.P.M., Le, T. C., Verreth, J.A.J., Bosma, R H., & OudLansink, A.G.J.M. 2016. Economic feasibility of recirculating aquaculture Systems in Pangasius Farming. *Aquaculture Economics & Management* 20 (2):185–200.

Nguyen, Lam Anh, Vinh, Dang H., Bosma, R., Verreth, J., Leemans Rik & De Silva, S S. 2014**.** Simulated impacts of climate change on current farming locations of striped catfish (*Pangasianodon hypophthalmus*; Sauvage) in the Mekong Delta, Viet Nam. *Ambio* 43**:** 1059-1068. DOI 10.1007/s13280-014-0519-6

Nguyen, Lam Anh, Phan, B. V., Tung, Bosma, R., Verreth J., Leemans Rik, De Silva, S.S.& Lansink, A.O. 2018. Impact of climate change on the technical efficiency of striped catfish (*Pangasianodon hypophthalmus*) farming in the Mekong Delta, Viet Nam. *Journal of the World Aquaculture Society 49 (Issue 3):* 570-580.. DOI: 10.1111/jwas.12488

Nguyen, S.H., Bui, A.T., Le, L.T., Nguyen, T.T.T. & De Silva, S.S. 2001. The culture-based fisheries in small, farmer-managed reservoirs, in two provinces of northern Vietnam: an evaluation based on three production cycles. *Aquaculture Research* 32: 975- 990. (also available at https://doi.org/10.1046/j.1365-2109.2001.00633.x)

Nguyen, T. Thuy, Nguyen T. Loc, Lindberg, J. E. & Ogle, B. 2007. Survey of the production, processing and nutritive value of catfish by-product meals in the Mekong Delta of Viet Nam. *Livestock Research for Rural Development* 19 (9): 5 pp.

Nguyen, T. T. 2010. Evaluation of Catfish (Pangasius hypophthalmus) By-Products as Protein Sources for Pigs in the Mekong Delta of Viet Nam (Vol.69). PhD. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden

Nordhagen, A., Rizwan, A.A.M., Aakre, I., Reksten, A.M., Pincus, L.M., Bøkevoll, A. Mamun, A., Thilsted, S.H., Htut, T., Somasundaram, T. & Kjellevold, M. 2020. Nutrient composition of demersal, pelagic, and mesopelagic fish species sampled off the coast of Bangladesh and their potential contribution to food and nutrition security - The EAF Nansen Programme. *Foods,* 9 (6): 730-749. (also available at https://doi.org/10.3390/foods9060730)

Olsen, R. L. & Hasan, M.R. 2012. A limited supply of fishmeal: Impact on future increases in global aquaculture production. Trends in Food Science & Technology (2012), http://dx.doi.org/10.1016/j.tifs.2012.06.00

Omar, W.A., Abdel-Salam, R.G. and Mahmoud, H.M. 2017. The use of effective microorganisms (EM) as a probiotic on cultured Nile tilapia; *Oreochromis niloticus*. *Egyptian Journal of Zoology*, 67:67-90. (also available at DOI: 10.12816/0037795)

Osborne, Z. 2018. The environmental hazards of intensive shrimp farming on the mekong delta. Viet Nam either has to change the way it approaches shrimp farming or face the loss of hundreds of hectares of land. Pacific Standard. https://psmag.com/.amp/environment/the-environmental-impacts-of-shrimp-farming-in-Viet Nam

Pandiyan, P., Balaraman, D., Thirunavukkarasu, R., George, E.G.J., Subramaniyan, K., Manikkam, S. & Sadayappan, B. 2013. Probiotics in aquaculture. *Drug Invention Today*, 5:55-59. (also available at https://doi.org/10.1016/j.dit.2013.03.003)

Paunovic, M., Cakic, P., Hegedi, A. Kolarevic S. J., & Lenhardt, M. 2004. A report of *Eriocheir sinensis* (H. Milne Edwards, 1854) (Crustacea: Brachyura: Grapsidae) from the Serbian part of the Danube River. *Hydrobiologia* 529: 275–277.

Pet-Soede, L. & Horuodono, S. 2004.SARS and the live food fish trade in Indonesia: some anecdotes. *SPC Live Reef Fish Information Bulletin* 12:3–9

Phan, L.T., Bui, T.M., Nguyen, T.T.T., Gooley G.J., Ingram B.A., Nguyen H.V., Nguyen, P.T. & De Silva, S.S.. 2009. Current status of farming practices of striped catfish, *Pangasianodon hypophthalmus*, in the Mekong Delta, Viet Nam. *Aquaculture* 296: 227–236.

Phomsouvanh, A., Saphakdy B. & De Silva S.S. 2015. Production trends, monetary returns and benefit sharing protocols from the extensive aquaculture practice of culture-based fisheries in rural communities in Lao PDR. *Aquaculture* 439: 29-38. (also available at http://dx.doi.org/10.1016/j.aquaculture.2015.01.022)

Phu, Tran M., Phuong, Nguyen T., Dung Tu T., Hai, Dao M., Son, Vo N., Rico, A., Clausen, J. H., Madsen, H., Murray, F. & Dalsgaard, A. 2015. An evaluation of fish health-management practices and occupational health hazards associated with Pangasius catfish (*Pangasianodon hypophthalmus*) aquaculture in the Mekong Delta, Viet Nam. *Aquaculture Research* 2015: 1–17. doi:10.1111/are.12728

Pickering, T., Ponia, B., Hair, C.A., Southgate, P. & De Silva, S.S., 2012. Vulnerability of aquaculture in the tropical Pacific to climate change. In: *Vulnerability of Tropical Fisheries and Aquaculture to Climate Change* (Bell, J.D., Johnson, J.E., Hobday, A.J., Eds.), 637-741. South Pacific Commission, Noumea, New Caledonia.

Pomeroy, R.S., Parks, J.E. & Balboa, C.M. 2006. Farming the reef: is aquaculture a solution for reducing fishing pressure on coral reefs? *Marine Policy* 30:111–130

Pullin, R.S.V. (ed.). 1988. *Tilapia genetic resources for aquaculture*. ICLARM Conference Proceedings 16, Manila, Philippines. 108 pp.

Pullin, R.S.V. & Capili, J.B. 1988. *Genetic improvement of tilapia: problems and prospects*. In R.S.V. Pullin, T. Bhukaswan, K. Tonguthai & J.L. Maclean, eds. The Second International Symposium on Tilapia in Aquaculture, pp. 259-266. Bangkok, Thailand, Department of Fisheries and Manila, Philippines, International Centre for Living Aquatic Resources Management.

Pushpalatha, K.B.C. & Chandrasoma, C. 2010. Culture-based fisheries in minor perennial reservoirs in Sri Lanka: variability in production, stocked species and yield implications. *Journal of Applied Ichthyology* 26: 98–103. (also available at https://doi.org/10.1111/j.1439-0426.2009.01361.x)

Qiu, L., Chen, M.M., Wang, R.Y., Wan, X.Y., Li, C., Zhang, Q.L., Dong, X., Yang, B., Xiang, J.H. & Huang, J. 2018. Complete genome sequence of shrimp hemocyte iridescent virus (SHIV) isolated from white leg shrimp, *Litopenaeus vannamei*. *Archives of Virology*, 163(3):781-785. (also available at doi: 10.1007/s00705-017-3642-4)

Qiu, L., Chen, X., Zhao, R.H., Li, C., Gao, W., Zhang Q.L., Huang J. 2019. Description of a Natural Infection with Decapod Iridescent Virus 1 in Farmed Giant Freshwater Prawn, *Macrobrachium rosenbergii* . *Viruses*, 11(4): 354. (also available at doi: 10.3390/v11040354)

Rahman, M. R., & Haryati, S. 2020. Ministry develops aquaculture micro insurance for fish farmers. [online] *Antaranews.com*. [Cited xx month 2020] https://en.antaranews.com/news/151084/ministry-develops-aquaculture-micro-insurance-for-fish-farmers#.XvA5DbT9558.twitter

Ratha, B. C. 2020. Standard Operating Procedure: Inclusion of small fish in Supplementary Nutrition Programme (SNP). Pilot study in Odisha, India (Odia version). Penang, Malaysia: WorldFish. Guidelines

Reid, G.K., Gurney-Smith, H.J., Marcogliese, D.J., Knowler, D., Benfey, T., Garber, A. F., Forster, I., Chopin, T., Brewer-Dalton, K., Moccia, R. D., Flaherty, M., Smith C. & De Silva, S.S. 2019. Climate change and aquaculture: considering biological response and resources. *Aquaculture Environment Interactions* 11*: 569–602.* (also available at doi: 10.3354/aei00332)

Rico, A., Phu, T. M., Satapornvanit, K., Min, J., Shahabuddin, A, M., Hendriksson, P.J.G, Murray, F.J., Little, D.C., Dalsgaard, A. & Van den Brink, P.J. 2013. Use of veterinary medicines, feed additives and probiotics in four major internationally traded aquaculture species farmed in Asia. *Aquaculture* 412, 231-243 (also available at https://doi.org/10.1016/j.aquaculture.2013.07.028)

Rimmer, M.A. & Glamuzina, B. 2019. A review of grouper (Family Serranidae: Subfamily Epinephelinae) aquaculture from a sustainability science perspective. *Reviews in Aquaculture* 11: 58–87. (also available at https://doi.org/10.1111/raq.12226)

Romano, M. 2017. Aquamimicry: a revolutionary concept for shrimp farming. [online] *Global Aquaculture Advocate*. [Cited xx month 2020]. https://www.aquaculturealliance.org/advocate/aquamimicry-a-revolutionary-concept-for-shrimp-farming/

Rückert, S., Klimpel, S., Al-Quraishy, S., Mehlhorn, H. & Palm Harry W. 2009. Transmission of fish parasites into grouper mariculture (Serranidae: *Epinephelus coioides* (Hamilton, 1822)) in Lampung Bay, Indonesia. *Parasitology Research* 104:523–532. DOI 10.1007/s00436-008-1226-7

Rudnick, D.A., Hieb, K., Grimmer, K.F.& Resh, V.H. 2003.Patterns and processes of biological invasion: The Chinese mitten crab in San Francisco Bay. *Basic and Applied Ecology* 4: 249–262.

Sadovy, Y.J., Donaldson, T.J., Graham, T.R., McGilvray, F., Muldoon, G.J., Phillips, M.J., Rimmer, M.A,. Smith, A. & Yeeting, B. 2003. While stocks last: the live reef food fish trade, Asian Development Bank, Manila

Sadovy, Y.J. 2005. Trouble on the reef: the imperative for managing vulnerable and valuable fisheries. *Fish and Fisheries* 6:167–185

Salin, K.R. & Ataguba, G.A. 2018. Aquaculture and the environment: towards sustainability. In: F. I. Hai *et al*. (eds.), Sustainable Aquaculture, Applied Environmental Science and Engineering for a Sustainable Future, https://doi.org/10.1007/978-3-319-73257-2_1

Saphakdy, B., Phomsouvanh, A. Davy, B., Nguyen, T.T.T. & De Silva, S.S. 2009. Contrasting community management and revenue sharing practices of culture-based fisheries in Lao PDR. *Aquaculture Asia Magazine* XIV (3): 2-6.

Sarkar, S. 2018. South and Southeast Asia most at risk by climate change. [online] Eco-business [Cited xx month 2020] https://www.eco-business.com/news/south-and-southeast-asia-most-at-risk-by-climate-change/

Sarojnalini, C. & Hei, A. 2019. Fish as an Important Functional Food for Quality Life. In: *Functional Foods* edited by Vasiliki Lagouri. Intech Open. 19 pp. (also available at https://www.intechopen.com/chapters/65354).

Scales, H., Balmford, A. & Manica, A. 2007. Monitoring the live reef food fish trade: lessons learned from local and global perspectives. SPC Live Reef Fish Inf Bull 17:36–44

Schafer, H. 2018. *Finishing the job of ending poverty in South Asia*. [online] Washington DC, World Bank. [Cited xx month 2020]. https://blogs.worldbank.org/endpovertyinsouthasia/finishing-job-ending-poverty-south-asia

Senapin, S., Phewsaiya, K., Briggs, M. & Flegel, T. W. 2007. Outbreaks of infectious myonecrosis virus (IMNV) in Indonesia confirmed by genome sequencing and use of an alternative RT-PCR detection method. *Aquaculture,* 266: 32–38. (also available at https://doi.org/10.1016/j.aquaculture.2007.02.026)

Siar, S.V. & Kusakabe, K., (eds.) 2020. *Demographic change in Asian fishing communities – Drivers, outcomes and potential impacts.* Bangkok, FAO. 124 pp. (also available at https://doi.org/10.4060/cb1752en)

Smith, I.R. & Pullin R.S.V. 1984. Tilapia production booms in the Philippines. *ICLARM Newsletter* 7: 7- 9.

Spiess, R. 2018. *Natural disasters - flooded out.* [online] Globe. [Cited xx month 2020] https://southeastasiaglobe.com/flooding-will-devastate-se-asia-in-near-future/

Statista. 2020. Leading importers of fish and fishery products worldwide in 2018. [online] *Statista, Fisheries & Aquaculture*. [Cited xx month 2020] https://www.statista.com/statistics/268266/top-importers-of-fish-and-fishery-products/n

Ström, G.H., Hanna, B., Barnes, A.C., Da, C.T., Nhi, N.H.Y., Lan, T.T., Magnusson, U., Haldén, A. N. & Boqvist, S. 2019. Antibiotic use by small-scale farmers for freshwater aquaculture in the Upper Mekong Delta, Viet Nam. *Journal of Aquatic Animal Health*, 31: 290-298 (also available at DOI: 10.1002/aah.10084)

Subasinghe, R. P., Bueno, P., Phillips, M. J., Hough, C., McGladdery, S. E. & Arthur, J. R. (Eds). 2001. *Proceedings of the Conference on Aquaculture in the Third Millennium.* Bangkok, NACA. 471 pp. (also available at https://enaca.org/?id=413)

Subasinghe, R.P., Arthur, J.R., Bartley, D.M., De Silva, S.S., Halwart, M., Hishamunda, N., Mohan, C.V. & Sorgeloos, P. 2012. *Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand, 22–25 September 2010.* FAO, Rome and NACA, Bangkok. 896 pp. (also available at http://www.fao.org/3/i2734e/i2734e00.htm)

Sun, S.-X., Hua, X.-M., Deng, Y.-Y., Zhang, Y.-N., Li, J.-M., Wu, Z., Limbu, S. M. et al. 2018. Tracking pollutants in dietary fish oil: from ocean to table. *Environmental Pollution* 240: 733-744.

Surachetpong, W., Janetanakit, T., Nonthabenjawan, N., Tattiyapong, P., Sirikanchana, K. and Amonsin, A., 2017. Outbreaks of tilapia lake virus infection, Thailand, 2015-2016. *Emerging Infectious Diseases*, 23: 1031-1033. (also available at doi: 10.3201/eid2306.161278)

Suzuki, A. & Nam, V.H. 2013. Status and constraints of costly port rejections: a case from the Vietnamese frozen aquatic food export industry. *IDE Discussion Paper* No. 395, Institute of Developing Economies JETRO, Chiba, Japan. 44 pp. (also available at https://ideas.repec.org/p/jet/dpaper/dpaper395.html)

Swadling, P. 1977. The implications of shellfish exploitation for New Zealand prehistory. Mankind 11: 11–8.

Tacon, A.G. & Metian, M. 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. *Aquaculture* 285: 146-158. (also available at https://doi.org/10.1016/j.aquaculture.2008.08.015)

Tacon, A.G., Metian, M., Turchini, G.M. & De Silva, S.S. 2010. Responsible aquaculture and trophic level implications to global fish supply. *Reviews in Fishery Science* 18: 94-105. (also available at https://doi.org/10.1080/10641260903325680)

Tacon, A.G.J. 2018. Global trends in aquaculture and compound aquafeed production. *World Aquaculture*, June 2018, pp. 33-46. (also available at http://www.aquahana.com/wp-content/uploads/2018/06/TaconWAS.pdf)

Tal, Y., Schreier, H.R., Sowers , K.R., Stubblefield, J.D., Place , A.R. & Zohar, Y. 2009. Environmentally sustainable land-based marine aquaculture. Aquaculture 286: 28–35

Taw, N. 2015. Biofloc technology: possible prevention for shrimp diseases. [online]. *Global Aquaculture Advocate*. [Cited xx month 2020] https://www.aquaculturealliance.org/advocate/biofloc-technology-possible-prevention-for-shrimp-diseases/

Tran, L.H., Fitzsimmons, K.M. & Lightner, D.V. 2014. Tilapia can enhance water conditions, help control EMS in shrimp ponds. Global Aquaculture Advocate, January/February: 26-27.

UN. 2017. UN's FAO Promotes Advancements of Innovative Agro-aquaculture Systems to Enhance Blue Growth in Asia-Pacific. [online] Kunming, United Nations in China. [Cited xx month 2020] http://www.un.org.cn/info/6/571.html.

UNESCAP. 2019. *Economic and social survey of Asia and the Pacific 2019 - Ambitions beyond growth.* Bangkok, United Nations. 177 pp. (also available at https://www.unescap.org/sites/default/d8files/knowledge-products/Economic_Social_Survey%202019.pdf)

UNESCAP. 2020. *Aging societies*. [online] Bangkok, United Nations. [Cited xx month 2020]. https://www.unescap.org/our-work/social-development/ageing-societies

Usher, S., Haslam, R.P., Ruiz-Lopez, N., Sayanova, O. & Napier, J.A. 2015. Field trial evaluation of the accumulation of omega-3 long chain polyunsaturated fatty acids in transgenic Camelina sativa: Making fish oil substitutes in plants. *Metabolic Engineering Communications* 2: 93–98. http://dx.doi.org/10.1016/j.meteno.2015.04.002

van Anrooy, R., Secretan, P.A.D., Lou, Y., Roberts, R. & Upare, M. 2006. Review of the current state of world aquaculture insurance. *FAO Fisheries Technical Paper.* No. 493. Rome, FAO. 2006. 92p. (also available at http://www.fao.org/3/a0583e/a0583e00.htm)

Varma, M.S., 2017. Good news: Rejection rate of Indian sea food exports by the European Union declines. [online]. *Financial Express*, India. [Cited xx month 2020] https://www.financialexpress.com/india-news/good-news-rejection-rate-of-indian-sea-food-exports-by-the-european-union-declines/671995/

VASEP. 2020. Vietnam Association of Seafood Exporters and Producers. [online] [Cited xx month 2020] http://seafood.vasep.com.vn

Verisk Maplecroft. 2015. *Which cities are most exposed to natural hazards? Natural Hazards Risk Atlas 2015*. [online] Verisk Maplecroft. [Cited xx month 2020] https://www.maplecroft.com/insights/analysis/which-cities-are-most-exposed-to-natural-hazards/

Waite, R., Beveridge, M., Brummett, R., Castine, S., Chaiyawannakarn, N., Kaushik, S., Mungkung, R., Nawapakpilai, S. & Phillips, M. 2014. Improving productivity and environmental performance of aquaculture. Working Paper, Installment 5 of *Creating a Sustainable Food Future*. Washington, DC. World Resources Institute. 58 pp. (also available at https://files.wri.org/d8/s3fs-public/WRI14_WorkingPaper_WRR5_final.pdf)

Wang, Q., Cheng, L., Liu, J., Li, Z., Xie, S. & De Silva, S.S. 2015. Freshwater Aquaculture in PR China: Trends and Prospects. *Reviews in Aquaculture* 7 (4); 283-302. (also available at https://doi.org/10.1111/raq.12086)

Wang, Q., Liu, J., Zhang S., Lian, Y., Ding, H., Du, X., Li, Z. & De Silva S.S. 2016. Sustainable Farming Practices of the Chinese Mitten Crab (*Eriocheir sinensis*) around Hongze Lake, Lower Yangtze River Basin, China. *AMBIO*, 45; 361-373. (also available at DOI.10.1007/s13280-015-0722-0)

Wang, Q., Ding, H., Tao, Z. & Ma, D. 2018. Crayfish (*Procambarus clarkii*) cultivation in China: a decade of unprecedented development. In: Jian-Fang Gui, Qisheng Tang, Zhongjie Li, Jiashou Liu and Sena S De Silva (eds.), *Chinese Aquaculture: Success Stories and Modern Trends*, pp. 628-653. Wiley, UK.

Wikipedia. 2020a. *Land use statistics by country*. [online] [Cited xx month 2020] https://en.wikipedia.org/wiki/Land_use_statistics_by_country

Wikipedia. 2020b. *List of countries by total renewable water resources*. [online] [Cited xx month 2020] https://en.wikipedia.org/wiki/List_of_countries_by_total_renewable_water_resources

Williams, M.J., Gopal, N., Rejula, K., Pedroza-Gutiérrez, C., Nietes, A., Satapornvanit, P.R., Ananthan, P.S., Badayos-Jover, M.B., Roxas, A., Sijitha, M.C.X., Pierce, J. & Afrina Choudhury. 2019. *Long Report GAF7: Expanding the Horizons The 7th Global Conference on Gender in Aquaculture & Fisheries*. Gender in Aquaculture and Fisheries Section of the Asian Fisheries Society, Malaysia. pp. 57. (also available at https://www.genderaquafish.org/wp-content/uploads/2019/08/GAF7_Long-Report.pdf)

Wongbusarakum, S., De Jesus-Ayson, E.G., Weimin, M. & De Young, C. 2019. *Building Climate-resilient Fisheries and Aquaculture in the Asia-Pacific Region – FAO/APFIC Regional Consultative Workshop. Bangkok, Thailand, 14-16 November 2017*. Bangkok, FAO. 242 pp. (also available at http://www.fao.org/3/ca5770en/CA5770EN.pdf)

World Bank. 2013. *Fish to 2030: Prospects for fisheries and aquaculture*. Agriculture and Environmental Services Discussion Paper 03. World Bank Report number 83177-GLB, Washington, DC, 81 pp. (also available at https://documents1.worldbank.org/curated/en/458631468152376668/pdf/831770WP0P11260ES003000Fish0to02030.pdf)

World Bank. 2020. World Development Indicators. [online] Washington, World Bank [Cited xx month 2020]. http://data.worldbank.org/data-catalog/world-development-indicators

Xinhua, Y., Pongthanapanich, T., Zongli, Z., Xiaojun, J. & Junchao, M. 2017. Fishery and aquaculture insurance in China. *FAO Fisheries and Aquaculture Circular* No. 1139, Rome, Italy. 31 pp. (also available at http://www.fao.org/3/i7436e/i7436e.pdf)

Yang S.M., Chiu, C.C. & Wu, L. 2017. *Taiwan reports tilapia lake virus*. [online] Taipei, Focus Taiwan News Channel [Cited xx month 2020] http://focustaiwan.tw/news/asoc/201706140010.aspx

Zhang, J., Ge, C., Fang, G. & Tang Q. 2018. Multi Trophic Mariculture practices in coastal waters. In: Jian-Fang Gui, Qisheng Tang, Zhongjie Li, Jiashou Liu and Sena S De Silva (eds.), *Chinese Aquaculture: Success Stories and Modern Trends*, pp.543-554.. Wiley, UK.

Zhang, Q.L., Liu Q., Liu S., Yang H.L., Liu S, Zhu L.L., Yang B, Jin J.T., Ding L.X., Wang X.H., Liang Y, Wang Q.T. & Huang J., 2014. A new nodavirus is associated with covert mortality disease of shrimp. *J Gen Virol.* 95, 2700–2709. (also available at doi: 10.1099/vir.0.070078-0)

Zhang, S. Y., Li, G., Wu, H. B., , Liu, X. G., , Yao, Y. H., Tao, L. & Liu, H., 2011. An integrated recirculating aquaculture system (RAS) for land-based fish farming: The effects on water quality and fish production. *Aquacultural Engineering* 45: 93– 102

ANNEX 1. FAO STATISTICAL DATA

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

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

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

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

i) the legal status, institutionalization and resource allocation;
ii) development of national statistical standards in line with international standards;
iii) adequate and stable staffing plus an effective mechanism for data collection, compilation, storage, dissemination and reporting; (FAO, 2020c)
iv) improvement in the coverage of farmed species in trade statistics, with the clear separation of farmed vs wild species;
v) improvement in the coverage and accuracy of employment data, disaggregated by sex, occupational status and age.

ANNEX 2. Some relevant geographic and socio-economic data on Asia-Pacific countries and territories

Country/territory	Land area (2019, km²)	Population (2019)	Population density (people/km²)	GDP (2019, USD million)	GNI per capita (2019, USD)	HDI (2017)	ADR of the old (percent, 2017)
Eastern Asia							
China	9 388 210	1 397 715 000	149	14 342 903	10 410	0.752	14.85
China, Hong Kong SAR	1 050	7 507 400	7 150	366 030	50 840	0.933	22.58
China, Macao SAR	30	640 445	21 067	53 859	78 640	0.914	12.74
Japan	364 560	126 264 931	346	5 081 770	41 690	0.909	45.03
Korea, Democratic People's Republic of	120 410	25 666 161	213	17 364	n.a.	n.a.	13.58
Korea, Republic of	97 489	51 709 098	530	1 642 383	33 720	0.903	19.16
Mongolia	1 553 560	3 225 167	2	13 853	3 780	0.741	6.08
South-Eastern Asia							
Brunei Darussalam	5 270	433 285	82	13 469	32 230	0.853	6.34
Cambodia	176 520	16 486 542	93	27 089	1 480	0.582	6.86
Indonesia	1 811 570	270 625 568	149	1 119 191	4 050	0.694	7.90
Lao People's Democratic Republic	230 800	7 169 455	31	18 174	2 570	0.601	6.39
Malaysia	328 550	31 949 777	97	364 702	11 200	0.802	9.07
Myanmar	653 080	54 045 420	83	76 086	1 390	0.578	8.50
Philippines	298 170	108 116 615	363	376 796	3 850	0.699	7.57
Singapore	709	5 703 569	8 045	372 063	59 590	0.932	17.92
Thailand	510 890	69 625 582	136	543 650	7 260	0.755	15.95
Timor-Leste	14 870	1 293 119	87	1 674	1 890	0.625	---
Viet Nam	310 070	96 462 106	311	261 921	2 540	0.694	10.24

Country/territory	Land area (2019, km²)	Population (2019)	Population density (people/km²)	GDP (2019, USD million)	GNI per capita (2019, USD)	HDI (2017)	ADR of the old (percent, 2017)
Southern Asia							
Afghanistan	652 860	38 041 754	58	19 101	540	0.498	4.76
Bangladesh	130 170	163 046 161	1 253	302 571	1 940	0.608	7.66
Bhutan	38 144	763 092	20	2 447	2 970	0.612	7.12
India	2 973 190	1 366 417 754	460	2 875 142	2 130	0.640	9.04
Iran, Islamic Republic of	1 628 760	82 913 906	51	445 345	5 420	0.798	7.68
Maldives	300	530 953	1 770	5 729	9 650	0.717	5.68
Nepal	143 350	28 608 710	200	30 641	1 090	0.574	9.18
Pakistan	770 880	216 565 318	281	278 222	1 530	0.562	7.40
Sri Lanka	62 710	21 803 000	348	84 009	4 020	0.770	15.27
Central Asia and Caucasus							
Armenia	28 470	2 957 731	104	13 673	4 680	0.755	16.34
Azerbaijan	82 670	10 023 318	121	48 048	4 480	0.757	8.51
Georgia	69 490	3 720 382	54	17 743	4 740	0.780	22.54
Kazakhstan	2 699 700	18 513 930	7	180 162	8 810	0.800	10.74
Kyrgyzstan	191 801	6 456 900	34	8 455	1 240	0.672	7.05
Tajikistan	138 790	9 321 018	67	8 117	1 030	0.650	5.66
Turkmenistan	469 930	5 942 089	13	40 761	6 740	0.706	6.60
Uzbekistan	425 400	33 580 650	79	57 921	1 800	0.710	6.62
Australia and New Zealand							
Australia	7 692 020	25 364 307	3	1 392 681	54 910	0.939	23.68
New Zealand	263 310	4 917 000	19	206 929	42 670	0.917	23.60
Melanesia							
Fiji	18 270	889 953	49	5 536	5 860	0.741	9.53
New Caledonia	18 280	287 800	16	n.a.	0	0.000	14.74

Country/territory	Land area (2019, km²)	Population (2019)	Population density (people/km²)	GDP (2019, USD million)	GNI per capita (2019, USD)	HDI (2017)	ADR of the old (percent, 2017)
Papua New Guinea	452 860	8 776 109	19	24 970	2 780	0.544	6.32
Solomon Islands	27 990	669 823	24	1,425	2 050	0.546	6.08
Vanuatu	12 190	299 882	25	917	3 170	0.603	7.36
Micronesia							
Guam	544	167 294	308	5 920	n.a.	n.a.	14.53
Kiribati	810	117 606	145	195	3 350	0.612	6.37
Marshall Islands	180	58 791	327	221	4 860	0.708	---
Micronesia, Fed. States of	700	113 815	163	402	3 400	0.627	7.75
Nauru	20	12 581	629	118	14 230	n.a.	n.a.
Northern Mariana Is.	460	57 216	124	1 323	n.a.	n.a.	n.a.
Palau	460	18 008	39	284	17 280	0.798	n.a.
Polynesia							
American Samoa	200	55 312	277	636	n.a.	n.a.	n.a.
French Polynesia	3 660	279 287	76	n.a.	n.a.	n.a.	n.a.
Samoa	2 830	197 097	70	851	4 180	0.713	9.70
Tonga	717	104 494	146	450	4 300	n.a.	9.97
Tuvalu	30	11 646	388	47	5 620	n.a.	n.a.

Source: World Bank, 2020.

GDP: Gross Domestic Product; GNI: Gross National Income; HDI: Human Development Index; ADR: Age dependency ratio, old (% of working-age population)

n.a.: data not available

Annex 3. Land and renewable water resources in some Asia-Pacific countries and territories

Country/territory	Cultivated land (km²)	Cultivated land (%)	Arable land (km²)	Arable land (%)	Permanent crops (km²)	Permanent crops (%)	Other lands (km²)	Other lands (%)	Total area (km²)	Date	Total renewable water resources (km³)
World	17 235 800	11.6	15 749 300	10.6	1 549 600	1	131 701 100	88.4	149 000 000		54 727.8
Asia-Pacific (est.)	5 934 628	16.6	5 060 272	14.1	852 934	2.4	29 988 882	83.7	35 826 422		16 305.6
% A-P in the world total	34	n.a.	32	n.a.	55	n.a.	23	n.a.	24		29.7
Eastern Asia											
China	1 238 013	12.9	1 084 461	11.3	153 552	1.6	8 358 947	87.1	9 596 960	2011	2 840.0
China, Hong Kong SAR	68	6.1	n.a.	n.a.	n.a.	n.a.	706	91.2	774	2015	0.9
China, Macau SAR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	28	100	28	2005	
China, Taiwan Province	8 216	22.7	6 117	16.9	2 099	5.8	27 977	77	36 193	2011	67.0
Japan	47 250	12.5	44 226	11.7	3 024	0.8	327 751	87.5	377 915	2011	430.0
Korea, Democratic People's Republic of	29 124	21.4	15 808	19.5	13 316	1.9	91 414	78.6	120 538	2011	77.2
Korea, Republic of	17 347	17.5	15 254	15.3	2 193	2.2	82 373	82.5	99 720	2011	68.7
Mongolia	6 256	0.4	6 256	0.4	0	0	1 557 860	99.6	1 564 116	2011	34.8
South-Eastern Asia											
Brunei	156	3.0	110	2.08	46	0.87	5 115	97.05	5 270	2011	8.5
Cambodia	42 716	23.6	41 087	22.7	1 629	0.9	138 319	76.4	181 035	2011	476.1
Indonesia	478 055	25.1	247 598	13	230 457	12.1	1 426 514	74.9	1 904 569	2011	2 019.0
Lao People's Democratic Republic	16 340	6.9	14 682	6.2	1 658	0.7	220 460	93.1	236 800	2011	327.0
Malaysia	73 568	22.3	9 567	2.9	64 001	19.4	256 279	77.7	329 847	2011	580.0
Myanmar	126 524	18.7	111 639	16.5	14 885	2.2	550 054	81.3	676 578	2011	1 168.0
Philippines	108 000	36.0	54 600	18.2	53 400	17.8	192 000	64	300 000	2011	479.0
Singapore	20	2.9	10	1.47	10	1.47	663	97.06	683	2005	0.6

Thailand	203 188	39.6	158 035	30.8	45 153	8.8	309 932	60.4	513 120	2011	457.2
Timor-Leste	2 231	15.0	1 502	10.1	729	4.9	12 643	85	14 874	2011	7.9
Viet Nam	108 302	32.7	68 227	20.6	40 075	12.1	222 908	67.3	331 210	2011	884.1
Southern Asia											
Afghanistan	78 916	12.1	77 612	11.9	1 304	0.2	673 314	87.9	652 230	2011	24.8
Bangladesh	97 268	65.5	87 615	59	9 653	6.5	51 192	34.5	148 460	2011	1 227.0
Bhutan	1 113	2.9	998	2.6	115	0.3	37 281	97.1	38 394	2011	34.7
India	1 891 761	57.0	1 753 694	52.8	138 067	4.2	1 395 502	43	3 287 263	2011	1 911.0
Iran, Islamic Republic of	197 794	12.0	178 006	10.8	19 788	1.2	1 450 401	88	1 648 195	2011	137.0
Maldives	130	43.3	40	13.33	90	30	170	56.67	300	2005	0.0
Nepal	23 993	16.3	22 227	15.1	1 766	1.2	123 188	83.7	147 181	2011	622.5
Pakistan	227 686	28.7	219 724	27.6	7 962	1.1	568 409	71.3	796 095	2011	246.8
Sri Lanka	23 944	36.5	13 579	20.7	10 365	15.8	41 666	63.5	65 610	2011	52.8
Central Asia and Caucasus											
Armenia	5 257	17.7	4 693	15.8	564	1.9	24 486	82.3	29 743	2011	7.8
Azerbaijan	22 083	25.5	19 745	22.8	2 338	2.7	64 517	74.5	86 600	2011	77.7
Georgia	5 298	7.6	4 043	5.8	1 255	1.8	64 402	92.4	69 700	2011	61.6
Kazakhstan	242 516	8.9	221 059	8.9	0	0	2 482 384	91.67	2 724 900	2011	66.0
Kyrgyzstan	21 400	7.1	13 400	6.7	8 000	0.4	178 551	92.9	199 951	2011	23.6
Tajikistan	10 087	7.0	8 790	6.1	1 297	0.9	134 013	93	144 100	2011	21.9
Turkmenistan	20 496	4.2	20 008	4.1	488	0.1	467 604	95.8	488 100	2011	105.5
Uzbekistan	48 766	10.9	45 187	10.1	3 579	0.8	398 634	89.1	447 400	2011	48.9
Australia and New Zealand											
Australia	487 695	6.3	479 954	6.2	7 741	0.1	7 253 525	93.7	7 741 220	2011	492.0
New Zealand	5 642	2.1	4 838	1.8	806	0.3	263 196	97.9	268 838	2011	333.5
Norfolk Island	0	0.0	0	0	0	0	35	100	35	2005	---
Melanesia											
Fiji	2 507	13.7	1 647	9	860	4.7	15 767	86.3	18 274	2011	28.6
New Caledonia	100	0.5	59	0.32	41	0.22	18 475	99.46	18 575	2005	---
Papua New Guinea	10 182	2.2	3 240	0.7	6 942	1.5	452 658	97.8	462 840	2011	801.0
Solomon Islands	1 040	3.6	202	0.7	838	2.9	27 856	96.4	28 896	2011	45.0
Vanuatu	1 451	11.9	195	1.6	1 256	10.3	10 738	88.1	12 189	2011	10.0
Micronesia											
Kiribati	411	50.7	22	2.74	389	47.95	400	49.31	811	2011	---

Marshall Islands	100	55.6	20	11.11	80	44.44	80	44.45	181	2005	---
Micronesia, Fed. States	361	51.4	40	5.71	321	45.71	341	48.58	702	2011	---
Nauru	0	0.0	0	0	0	0	21	100	21	2005	---
Northern Mariana Islands	83	17.4	62	13.04	21	4.35	394	82.61	477	2005	---
Palau	60	13.1	40	8.7	20	4.35	398	86.95	458	2005	---
Polynesia											
American Samoa	50	25.0	20	10	30	15	149	75	199	2005	---
Cook Islands	60	25.0	40	16.67	20	8.33	178	75	237	2005	---
French Polynesia	290	7.0	29	0.7	261	6.3	3 877	93	4 167	2011	---
Samoa	299	10.6	79	2.8	220	7.8	2 532	89.4	2 831	2011	---
Tonga	280	37.5	166	22.2	115	15.3	467	62.5	747	2011	
Tuvalu	17	66.7	0	0	17	66.67	9	33.33	26	2005	---
Wallis and Futuna	118	42.9	20	7.14	98	35.71	157	57.15	274	2005	---

Sources: Wikipedia, 2020a; Wikipedia 2020b
n.a.: data not available

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

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

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