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Overview and issues of aquaculture in the Asia-Pacific Fishery Commission region

CONTENTS

1 AQUACULTURE PRODUCTION OF MAJOR COMMODITY GROUPS

Production from aquaculture in the Asia-Pacific region reached 104.7 million tonnes in 2018. 44.8 percent of this total production is from finfish, a further 30.8 percent comprises aquatic plant production, molluscs 15.4 percent and crustaceans 8.0 percent. The proportions of each major group has remained relatively stable over the last 20 years, although the actual volume of total production has increased over 200 percent in 20 years and 64 percent in 10 years (Table 1).

Table 1. Percentage contribution and change in production of major aquaculture commodity groups in Asia and the Pacific 1998-2018

ISCAAP Division	1998 (tonnes)	2008 (tonnes)	2018 (tonnes)	% of 1998 total	% of 2008 total	% of 2018 total	% Increase 1998 to 2018
Aquatic plants	9,196,153	17,113,578	32,245,995	27.0	26.8	30.9	251
Crustaceans	1,024,921	4,453,058	8,315,332	3.0	7.0	8.0	711
Diadromous fishes	656,043	1,113,729	1,949,856	1.9	1.7	1.9	197
Freshwater fishes	14,958,602	27,224,990	42,492,142	43.9	42.6	40.7	184
Marine fishes	633,227	1,421,516	2,195,731	1.9	2.2	2.1	247
Molluscs	7,479,184	11,951,859	16,184,269	21.9	18.7	15.5	116
Miscellaneous aquatic animals	151,019	614,948	915,038	0.4	1.0	0.9	506
Miscellaneous aquatic animal products	604	26,177	26,799	0.0	0.0	0.0	4,336
Total	**34,099,753**	**63,919,854**	**104,325,162**	**100**	**100**	**100**	**206**

Source: Data from FAO FishStatJ, 2020

A great variety of aquatic species are being grown in aquaculture with 254 species reported, with an aquaculture production greater than 1.0 tonne in the Asia-Pacific region. 20 species or species groups contribute 74 percent of the production of the region (Table 2).

Table 2: Top twenty species and species groups contributing to Asia-Pacific aquaculture production (% of total Asia-Pacific production in 2018)

Aquatic plants	%	Finfish	%	Molluscs and crustaceans	%
Japanese kelp	10.9	Grass carp	5.4	Cupped oysters nei	4.9
Eucheuma seaweeds nei	8.8	Silver carp	4.5	Whiteleg shrimp	3.8
Gracilaria seaweeds	3.3	Common carp	3.7	Japanese carpet shell	3.9
Wakame seaweed	2.2	Bighead carp	3.0	Scallops nei	1.8
Nori nei seaweed	1.9	Catla	2.9	Red swamp crawfish	1.6
Elkhorn sea moss	1.5	Nile tilapia	2.7		
		Carassius spp	2.6		
		Striped catfish (Pangasius)	2.3		
		Roho labeo	1.9		
TOTAL	**28.6**		**29.0**		**16.0**

Source: Data from FAO FishStatJ, 2020

Nine finfish species provide 29.1 percent of the regional total. All of these are freshwater species, although some tilapia are culture in brackishwater. Six marine aquatic plant species account for Japanese kelp, Euchema spp., Gracilaria spp., Wakame and Nori seaweeds. Three marine molluscs groups and two crustacean species (grown in brackish or freshwater) provide 16.1 percent of the regional total. A further 234 species or species groups account for the remaining 26 percent of production.

Overall, 48.4 percent of aquaculture production is from marine waters with 63 percent of this being aquatic plants, a further 31 percent are molluscs (Table 3). Finfish represent only 4.2% and crustaceans 2.8 percent of marine aquaculture production by volume in the region.

Table 3: Production of aquaculture by major groups according to the production environment (2018)

ISCAAP Group	Brackish water (BW)	Fresh water (FW)	Marine (MW)	Grand Total	BW %	FW %	MW %
Aquatic plants	116,603	69,590	32,059,802	32,245,995	0.4	0.2	99.4
Crustaceans	4,592,954	3,579,207	143,172	8,315,332	55.2	43.0	1.7
Diadromous fishes	1,120,821	598,533	230,503	1,949,856	57.5	30.7	11.8
Freshwater fishes	318,211	42,173,786	146	42,492,142	0.7	99.3	0.0
Marine fishes	297,279	21,017	1,877,435	2,195,731	13.5	1.0	85.5
Molluscs	49,182	206,927	15,928,160	16,184,269	0.3	1.3	98.4
Miscellaneous aquatic animals	50	527,583	387,405	915,038	0.0	57.7	42.3
Miscellaneous aquatic animal products		703	26,096	26,799	0.0	2.6	97.4
Grand Total	**6,495,099**	**47,177,345**	**50,652,718**	**104,325,162**	6.2	45.2	48.6

Source: Data from FAO FishStatJ, 2020

Conversely, freshwater aquaculture constitutes 45.4 % of production in the Asia-Pacific and 90.7 percent of this is finfish. Crustaceans are 7.5 percent of production.

Brackishwater production is surprisingly limited, but reflects the limited space available in brackishwater lagoons and coastal aquaculture areas, accounting for only 6.3 percent of total aquaculture production in the region. is dominated by crustaceans (70.9 percent) with finfish providing 26.6 percent.

99.4% of aquatic plants are cultured in the marine environment and 99.3 percent of fish species in freshwaters. Diadromous fish are cultured across all three environments. 42.8% of crustaceans are cultured in freshwater and 55.5% in brackishwater.

85.6 percent of marine finfish are cultured in marine waters, the rest in brackishwater. 98.4% of molluscs are cultured in marine waters.

2 AQUACULTURE INNOVATIONS FOR IMPROVED SUSTAINABILITY

Aquaculture has come a long way. It has benefited humankind by supplying food and sustaining livelihoods, especially where there has been limited access to fish from the wild or availability of high value l species. Projected population growth and improving living standards indicate that global demand for food fish will increase by 20 percent (additional 30 million tonnes) from the level in 2016. With limitations on capture fisheries production and projected increasing demands for fish, the current aquaculture industry is anticipated to play a much more important role in food and nutrition security, livelihood development and national economy.

The sustainable growth of aquaculture sector has to be secured, but the sector is also facing a rapid changing external environment along with new challenges. The sector needs to produce more fish to meet the increasing demand with limited natural resources such as land and water and to increase the economic return from the culture operation.

The aquaculture sector in Asia-Pacific has largely evolved from the traditional farming practices with gradual intensification in production and improvements in management sophistication. The intensification of production operations through higher density stocking and increased material inputs allows significant increases in productivity, however, when intensification goes beyond environment carrying capacity and its negative impacts are not effectively mitigated, the sustainability of the aquaculture operations is seriously threatened. More and more stringent environmental and social standards demand significant improvement in sectoral performance in environmental and social benefits for better public acceptance. This requires transformative changes of aquaculture farming systems and technologies.

Increasingly, aquaculture operations are facing more stringent requirement in environmental, social and food quality and safety standards, which is largely the result of greater consumer awareness and heightened concern and which are transmitted to producers through trade.

In addition, increasingly frequent natural disasters and extreme weather largely associated with climate change further increase the vulnerability of the aquaculture sector.

To sustain its growth, a number of pressing, often interlinked and mostly complex issues, need to be addressed. This section reviews some of the key issues facing the aquaculture sector in the APFIC region and some potential steps that can be taken to support or improve its sustainability.

The aquaculture sector needs to be more dynamic and vibrant to ensure continued development and adoption of innovative technology and farming systems to address the new and multi-faceted challenges to the sustainable growth for greater contribution to the attainment of SDGs related to food security and nutrition, poverty alleviation and sustainable resources utilization.

Innovative technology for genetic improvement and refined seed production technologies and practices need to be made available and widely adopted for species that are popularly cultured or of good market potential for much improved production performance and quality of products.

Culture practices need to be refined or altered to meet the changing market demand for the products such as balanced marketing, scheduled supply and good quality and safety and other challenges such as mitigation of risks associated with climate change impacts and reduced carbon emission and harmful effluent from aquaculture operation. System performance improvements may be technologically sophisticated or and include:

- Integration or co-culture of other organisms of different trophic levels (e.g. Integrated Multi-Trophic Aquaculture or IMTA; rice-fish systems)
- Improved feeds and alternative feed ingredients
- Genetic improvements and selective breeding, improved hatchery mass-production technologies

- Sector=wide and on-farm biosecurity measures and health monitoring; reduced used of antimicrobials.
- Water quality improvements, effluent treatment, water recirculation and biofloc systems

Many of the higher technology approaches also benefit from the application of Information and Communication Technology and big data:

- Precision aquaculture, monitoring and automation allowing monitoring, documentation and control of biological, chemical and physical processes as well as behaviour of fish in the fish farm and integrating the various data into a handy digital tool for farm operation by the manager (for instance, to control aeration, feeding and water exchange in response to changing water quality parameters).
- Tracking diseases, and assisting biosecurity measures
- Environmental monitoring, zoning, early warning
- Input sourcing
- Improving traceability and food safety
- Marketing of aquaculture products
- Linking producers and consumers

Dissemination and scaling up the innovative technologies, systems and practices at national and regional levels can be facilitated through cooperation. There are challenges as the willingness to share competes with commercial interests, but overall there is a strong need to put farmers in touch with viable options to improve their system productivity, environmental footprint, profitability and resilience. Networking and collaborations between research and extension institutions and private sector can facilitate this and is in line with FAO's commitments to its member countries.

Innovations should be quickly and widely applied to solve existing problems and mitigate or prevent imminent risks. The pathways to wide application are through commercialization and government-assisted (and/or civil society organization-facilitated) dissemination and adoption by farmers.

These pathways require innovative financing coupled to innovative policy. These feed into each other with policy providing the incentive and enabling environment for R & D that yield innovations; innovations can inform and support policy making and improve the effectiveness of policy.

3 RELIABLE SUPPLY OF QUALITY SEED AND GENETIC IMPROVEMENT

The importance of quality seed supply to the performance of aquaculture operation is generally recognized. However, being a more recently developed food production sector, seed production for aquaculture lags far behind husbandry of land-based animals particularly in Asia.

There are several issues with the aquaculture seed production in Asia, which significantly compromise the quality (i.e. viability, vigour, growth rate, resistance or tolerance to disease, etc) of the seed. Hundreds of species of aquatic animal are currently being cultured in Asia. Except for tilapia and few carp species, seed are produced from non-domesticated broodstock without systematic selective breeding. Many hatcheries for aquaculture do not follow good practices in broodstock development and management, selection of breeders and nursery operation. Very often, broodstock are simply selected from growout pond without knowing the genetic background.

In past decades, Asian aquaculture sector has made significant progress in reducing the dependence of aquaculture on seed from wild with the success in induced spawning that enabled artificial and mass seed production of most cultured species.

There are several challenges facing aquaculture which highlight the importance of seed quality in the performance of culture operation.

- Species diversification
- Commercialization and mainstreaming markets require large size, uniformity and scheduled delivery of farmed products.
- Intensification requires good attributes of seed against health threats.
- Increasing need for biosecurity but lack of available quality seed in–country (e.g. although specific pathogen free (SPF) and specific pathogen resistant (SPR) seed) can drive extensive transboundary movement of seed (sometimes illegal) with inadequate biosecurity controls.
- Climate change impacts require stronger tolerance of aquaculture seed to environment stress.
- Lack of availability or high cost of improved seed for small farmers.

The region needs to make a great effort to improve aquaculture seed production, which will help the aquaculture operators to effectively tackle a number of challenges. Apart from proper broodstock management that includes proper broodstock nutrition, ensuring that broodstock are in good health and maintenance of optimal environmental (culture) conditions, genetics plays an important role in ensuring the high quality of offspring. It is well-known that inbreeding depression is one of the main causes of the deterioration of the quality of seeds produced from a brood, with a negative consequence in farm productivity in the long term. Selective breeding programs that seek to improve the traits of the cultured species, together with improvements in captive breeding, husbandry, rearing conditions, larval rearing, nutrition, health management, among others, is thus critical to ensure that the seeds used for culture operations are of high quality and thus guarantee a sustainable high production.

In 2010 only about 8 percent of the total global aquaculture production came from seed/materials developed from selective breeding programs (Gjedrem and Rye, 2016). This contrasts with terrestrial livestock production that is almost entirely based on populations or breeds that have been genetically domesticated through millennia and are systematically and selectively bred for improved performance.

> Major improvements in European aquaculture, where there is much higher adoption of selective breeding than elsewhere in the world, have been achieved primarily through widespread use of stock developed through selective breeding. In 2012, about 80 percent of the total volume of fish production in Europe originated from selective breeding programs and the cumulative genetic gain in growth performance in terms of harvest weight ranged from more than 65 percent for turbot to more than 900 percent for trout (Janssen *et al*., 2017). Because it leads to major improvements in its production, selective breeding has had a major impact in European aquaculture and is expected to contribute to the future growth of the sector.

Developing a selective breeding program for the species of interest is not easy. One may wonder why of the 598 species of aquatic organisms being farmed (FAO, 2018), only a handful, not even 10 species, have successful selective breeding programs developed. This is because not all cultured species are amenable or appropriate for selective breeding. Some critical biological attributes of the species are necessary for a selective breeding program to be successful.

Closing the life cycle in captivity is a prerequisite for a selective breeding program. In addition, important biological traits like ease of domestication and captive breeding, robustness and hardiness, early onset of sexual maturity preferably within one year from hatching, ability for spontaneous spawning under captive conditions, among others, are important. For mass appeal, traits like fast growth rate, wide tolerance for environmental/climatic conditions, disease resistance, omnivorous feeding habits, ready acceptance of pellets in captivity and high market potential are of added value for the species. The top species in global aquaculture in terms of production volume possess most of the attributes mentioned, and thus have a successful selective breeding programs in place that ensures the production of high quality seeds used in farming in many countries in the world.

Take the case of common carp, one of the first species that have been domesticated. The selective breeding program allowed the development of various strains that improved their production performance and somehow enabled the species to adapt to different geographic areas and rearing systems, that led to its worldwide adaptation and to its being farmed in more than 1 00 countries (Teletchea and Fontaine, 2014). There are claims, though, that in Europe, the genetic improvement of common carp largely relied on crossbreeding of inbred strains and therefore selective breeding plays only a minor role (Janssen *et al*., 2015). Then there is Nile tilapia described as a nearly perfect species for aquaculture. A selective breeding program was initiated at the end of the 1980s (GIFT) and the cumulative gain for growth rate after five generations of selection was 86 percent, or an average of 17 percent per generation (Gjedrem, 2012). At least 20 family-based breeding programs are now in operation globally, more than any other aquatic species (Gjedrem, 2012). It is now farmed in approximately 140 countries (FAO, 2016) with GIFT and GIFT-derived strains being used in numerous farms throughout the world (Thodesen *et al*., 2012). For Atlantic salmon, close to 100 percent of the production in Norway and in the rest of the world are now based on improved stocks (Gjedrem, 2010). Farmed salmon is regarded as one of the most domesticated fish species farmed for food, and one Norwegian strain has been exposed to more than 12 generations of domestication (Gutierrez *et al*., 2016). Today, almost 100 of the Atlantic salmon comes from farming. Even though rainbow trout reproduces only once a year, the selective breeding in hatcheries and the control of the reproductive cycle using modifications of day length duration allowed producing eggs virtually year-round (Fornshell, 2002). Specific breeding programs also allowed the improvement of growth rate, disease resistance and fecundity. In addition, sterile triploid females can be produced from thermal or pressure shock on eggs, leading to the farming of monosex females which mature later than males and have much better flesh quality (Fornshell, 2002). Triploidy also ensures that escapees from rearing systems into the wild will not be able to reproduce in natural conditions. Recent data indicate that up to 14 generations of selection have been performed in family selection and up to 20 in mass selection (Janssen *et al*., 2015).

Drawing from the above experiences, it is imperative that countries within the region should take a closer look at the species that contribute substantially to the region's aquaculture production -- ones that show high potential for mass production based on the different characteristics stated. Collective efforts, from both the government and the private sector, from national to international level, should then be harnessed to initiate selective breeding programs for the priority species with the long-term goal of using the improved stocks for mass production across countries in the region. Catfish, may be a suitable species to start with. Several species of catfish are currently being farmed particularly in Viet Nam, and to a lesser extent, in Cambodia, Thailand, Lao PDR, Indonesia, Bangladesh and Malaysia. Genetic breeding programs, however, require sustained financial support and technical expertise. Governments and private institutions need to work closely in this regard to ensure long-term commitment especially for financial support. For important species that may not be a priority for investment by private sectors due, for instance, too long generation intervals and delays in return of investment, public support is then necessary. The establishment of a breeding center/nucleus, multiplier facilities and grow-out operators may be a good model to follow. Governments should put high priority on the establishment of seed production facilities for identified priority species as well as putting in place selective breeding programs for the same.

In addition to regional collaboration and public-private partnership to foster the genetic improvement of major culture species through selective breeding and other technologies, more effort is needed to improve the practices in aquaculture seed production. It is more pressing for the governments to strengthen the regulation and governance of aquaculture seed production through registration, licensing and enforcement of appropriate standards in aquaculture seed production. The governments need to encourage the investment in aquaculture seed production especially for upgrading of production facility and related infrastructure.

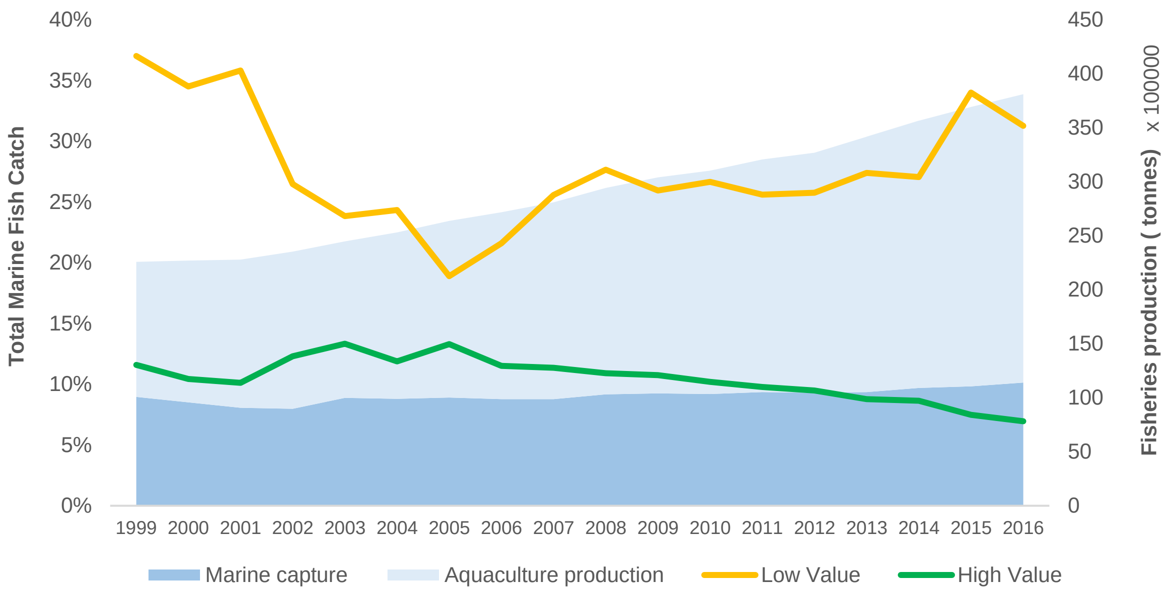
4 AQUACULTURE FEED AND FEED INGREDIENTS

4.1 USE OF LOW-VALUE FISH

Accurate information specific to the quantities of low-value fish (LVF) utilization in the Asia-Pacific region is limited. APFIC provided a conservative estimate that 25 percent of the fish landed in 2003 was processed into livestock and aquaculture feed for selected Asia-Pacific countries (APFIC 2005b). APFIC (2005) attempted to catalogue LVF use for 6 key Asia-Pacific fishing countries (Figure 1) and reported that the weighted average of LVF across the 6 countries accounted for 35 percent of the total marine catch in the investigated countries. An additional dynamic in regards to LVF utilization is the harvesting of juvenile species. APFIC (2003) reported that in, the Gulf of Thailand marine ecosystem 18 to 31 percent of total LVF landings consisted of juveniles from commercial species that are more valuable when harvested as adults (APFIC 2005).

Establishing an LVF specific information framework aimed to define and separate LVF usage and its role in national economies and food security. The drivers that influence LVF use are multi-sectorial and this requires data sets from various sectors. Fisheries management institutions are encouraged to identify data gathering systems to avoid broadly classifying LVF into one category.

Figure 1: LVF and higher value fish species captured by Chinese fisheries 1999 - 2016



Source: FAO FishstatJ. Low value species include: Chub mackerels and marine fish 'nei'; High value species include: Croakers and Hairtails

Defined and adopted categories that distinguish between LVF for human consumption (including processed products) and/or direct aquaculture feed, indirect aquaculture/livestock feed (meal and oil), others (non-food use e.g. fertilizers) and discards of specific fisheries would provided an evidence base for establishing policy and regulation for LVF exploitation.

It is likely that LVF use will grow, especially in emerging Asia-Pacific countries with aquaculture growth such as China, Thailand and Viet Nam. Appropriate estimations on the value of low value fish landings, rather than aquaculture pellets produced is needed to determine the true contribution of LVF to the region's fisheries.

The current practice of aquaculture has largely become synonymous with artificial feeds. Except for the seaweeds, molluscs and few filtering finfish like silver carp and bighead, most of the other commodities are fed when grown in captivity. Even the herbivores that can be farmed solely on the natural productivity of the culture environment are provided with supplemental feeds when cultured in high stocking densities. The provision of artificial feeds in aquaculture operations has indeed resulted in much higher yield and tremendous increase in aquaculture production. However, the use largely of fish meal and fish oils as the main source of protein and lipids in fish feeds has long been questioned and criticized as these are sourced mainly from low-value fish or fish-by-catch from capture fisheries that are also considered food especially the low-income people living in the rural coastal communities. This practice of "feeding fish with fish" has given farmed high value carnivorous fish species a somewhat negative image. While fish meal is important in aquaculture, the industry has to break free from its dependence if it wants to grow and continue to be a relevant food production sector in the future.

4.2 FEED ALTERNATIVES

To reduce the dependence from fish meal and fish oil as the major source of protein and lipids in aquaculture feeds, other potential sources of protein and fats were explored for quite some time now. After determining the nutritional value, digestibility and other considerations of the potential ingredients, candidate raw materials were tested as partial or full replacement of fish meal and fish oil as protein and lipid source, respectively, in fish feeds.

These raw materials include soybean and its products, maize and its products, leguminous seed meals from cowpea, mung bean, winged pea, pigeon pea, garden pea, leaf meals, copra meal and other meals such as cottonseed meals, sesame seed meal, ground nut cake, rapeseed meal, palm kernel meal, castor bean meal and molasses fermentation mixtures. Many are good source of protein, fats and carbohydrates but are also limiting in some essential amino acids and fatty acids. Besides, some of them also contain some anti-nutritional factors or inhibitors that require treatment for inactivation, otherwise they retard growth and impair nutrient utilization (Coloso, 2015).

Other alternative ingredients like poultry, livestock and fish processing wastes as well as microbial biomass as partial replacement of fish meal and fish oils are also tested and scientific data on their use in fish feeds are already available. Aquatic plants, like some species of algae the forage fish eat, contain high levels of omega-3's and other micronutrients and could be a viable replacement as fatty acid source for some species of farmed fish.

Scaling up of the production to replace the fish oil derived from wild fish, however, requires a huge volume of microalgae production. Determining the right ratios of fatty acids, such as omega-3's, is also another problem. Since ideally the natural balance of fatty acids found in fish oil needs to be followed, finding the right algal strain and provide it with the right nutrient combination to produce the correct fatty acid composition is a major task. Combining fatty acids from various algal strains is an alternative but coordinating the production of the various strains to get the right mix is also more difficult.

Some protein-rich yeast provided with specific nutrients are being tested as well. The use of yeast is sustainable because it can be produced independent of arable land, uses little fresh water and can use low-value biomass for which humans have little food use. Atlantic salmon that had a third of their diet composed of this yeast gained weight as fast as their conventionally fed counterparts (Nemo, 2019). Single-cell protein generated from the processing of nutrient-rich wastes from processing plants for use in animal feed including aquaculture feed is also in progress.

Proteins and oil from insects, like black soldier fly, has been considered as sustainable alternative to fishmeal. Malaysia is set to start operation of the largest production facility for insect meal in Southeast Asia (Fletcher, 2019). Many more other approaches to provide the protein and lipid requirement in aquaculture feeds away from fish meal and fish oil are being done to help promote the sustainability of the industry.

Feed manufacturers have used the available pieces of information to replace increasingly the amounts of fish meal or fish oils in aquafeeds. For many of the identified suitable alternative ingredients, however, there is incomplete information on their amino and fatty acid profiles making production of nutrient-balanced feed difficult.

The availability of the supply of the raw materials to be used in the mass production of feeds is also an issue. Soy and grain are already under pressure to supply food for other farmed animals such as cattle and to directly sustain humans. The leguminous materials are also heavily used by humans as food. It has been contended that only raw materials that are not used for human consumption should be used for inclusion as fish feed ingredients. While this may be reasonable to some extent, the inclusion of some of these raw materials in fish feed should be seen as an opportunity for the crop farmers to maximize production of their crops considering that a ready market for their product is available. This becomes advantageous for the crop growers especially if their production has not yet reached maximum because of constraints of the market. On the other hand, this also aggravates the situation of producing more crops with a shrinking availability of land and water resources.

Replacement of ingredients from marine resources should not only focus on the use of particular raw materials but rather on an alternative nutritional strategy. There is a need to shift to nutrient-based feed formulations, i.e. utilizing different combinations of complimentary raw materials that collectively meet established nutrient requirements of the farmed commodities (Turchini *et al*., 2019). For example, the use of microbial biomass complimented with animal and plant protein sources balanced the amino acid profile of the feed that allowed total replacement of dietary fish meal and fish oil without affecting production performance in shrimp is a very positive research result that needs to be verified for large-scale application. Similar strategies need to be applied and evaluated in the different farmed species.

The choice of species to culture is also very critical with the feed issue considering that about 60 percent of the production cost is due to feeds. The protein and lipid requirements are considerably lower in herbivorous and omnivorous species compared with the carnivorous species. Consequently, the amount of protein and fats in the feeds needed in the culture of the former are very much reduced compared to the latter species. In addition, herbivorous and omnivorous species adapt readily to feeds with little or no fish meal and fish oil inclusions, with the same approach proving more challenging in farming carnivorous fish and crustaceans. Mass production of priority herbivorous and omnivorous species are therefore more sustainable than the carnivorous species. The sector has to revisit and re-evaluate the herbivorous and omnivorous species that have good potential for mass production for the future in the region.

In order to effectively address the issue of feed and feed ingredients for sustainability, the aquaculture sector should take a more holistic approach. Public-Private Partnership needs to be strengthened in research and technologies development for more responsible and efficient use of all sorts of feed ingredients, to expedite the transformation of research outputs on fishmeal and fish oil alternatives to commercial production. Appropriate policy and strategy need to be developed to scale up the production capacity of newly developed feed ingredients to meet the need for commercial production. More support should be provided to feed mills particularly the small local ones to improve the feed manufacture practices for more efficient use of feed ingredients and better quality of feed. Equally important, farmers should be provided more support to improve the feed efficiency in production through good selection of species, feeding management practices and other related farming practices such as optimization of culture environment and improvement of survival of cultured animals throughout the culture period.

5 AQUATIC ANIMAL HEALTH AND BIOSECURITY

Outbreaks of diseases remain as a major threat to normal aquaculture operation and challenge to sustainable aquaculture development. Intensification, sometimes beyond the carrying capacity of the culture systems, driven by the high demand for the commodity and the revenues generated by the product contribute to constraints in health management in fish farms. We are aware of the occasional outbreaks in viral and bacterial diseases that have in recent years inflicted huge losses on, and set back the progress of, the shrimp industries of almost all shrimp growing countries.

5.1 THE CHALLENGES OF INTENSIFICATION

Much of the shrimp farming industry has moved from semi-intensive to intensive or super-intensive culture systems. The consequences soon hit the sector. Just a decade ago, the industry was severely hit by AHPND that caused mortalities during the first month of grow-out culture. The AHPND outbreak significantly affected the shrimp production in a number of Asian countries where the disease was successively reported. It revealed weaknesses in the mechanisms for control over the proliferation of diseases, in this case for shrimp across the region. It took 6 years from the beginning of the outbreaks (2009), to the first description of unique histopathology of the affected shrimp (2011), the identification of the causative agent (2013) and the development of rapid molecular detection methods (2014-2015), and the implementation of appropriate control measures to contain the disease. It highlighted the need for a globally coordinated emergency response which if already in place, may have significantly reduced the time interval to contain the spread of the disease (Prachumwat *et al*., 2018).

Innovations to address health management concerns have covered the wide spectrum of development and use of specific pathogen-free (SPF) stocks, pathogen exclusion and development of specific pathogen-resistant (SPR) stocks or stocks with increased tolerance to pathogens. Zero or low water exchange systems are recommended in areas with limited water resources and for minimum impact on the environment.

It is also a biosecurity measure where limiting water exchange will minimize risks of pathogens that come with the water.

5.2 IMPROVING ORGANIZATION AND COOPERATION FOR BIOSECURITY

Anticipating that similar incidents may happen in the aquaculture sector in the future, this led to efforts at strengthening the capacity of aquatic animal health experts at the national level on biosecurity issues and close coordination among national experts at the regional level and ultimately at the global level for rapid and coordinated response to disease emergencies.

The emergence and spread of Tilapia Lake Virus (TiLV) that caused mass mortalities of farmed Tilapia in many countries starting in 2014 in Israel has been correlated to environmental stress particularly increased water temperature (FAO, 2018). Tilapia, being a globally important aquaculture commodity, which is highly traded internationally in live and frozen forms, and which has been introduced in many countries for culture and domestication, the further spread of TiLV poses a major risk to the global tilapia industry.

Building from experiences in the past on cross-country spread of diseases, FAO, working with global experts, has provided guidelines to determine the extent of biosecurity risks associated with the spread of TiLV into TiLV-free areas or countries and devise biosecurity measures to manage the risks. Enhancing the technical capacities of established national and regional aquatic animal health management systems is essential in containing the spread of the disease.

In addition, a coordinated monitoring, surveillance and reporting system at different levels i.e. farm clusters, district or province, country and region will help ensure that the spread of a particular disease or pathogen will be contained even as transboundary movement of aquatic organisms for farming continues.

As a whole, the prevention of disease outbreak requires a full understanding of the various factors that trigger its occurrence and subsequent spread. A host of measures are needed to prevent disease from occurring which requires the full implementation of a national biosecurity plan that includes critical components like strengthening disease surveillance, identification and prevention at the farm level, enhancing national emergency preparedness, and governance. Interdisciplinary approaches are required and properly coordinated at all levels including the provision of adequate financial support for continuous innovations and technical capacity building.

5.3 ADDRESSING AMR IN THE APFIC REGION

Intensification of farming operations and is inevitable. There has also been increasing transboundary movement of live aquatic animal for trade and sourcing of seed have led to more disease outbreaks and consequently the inevitable use of antimicrobials (AMs) and other drugs. Misuse, abuse and indiscriminate use of AMs are a reality in present day aquaculture.

AMs have been long used to prevent and control diseases in aquaculture, which are believed to be caused by bacteria. Some AMs have been used for treatment before they are proven to be effective in certain organisms, which is against the principle that application of AMs should be specific for the control of a certain disease agent in specific organisms since the susceptibility to disease and symptoms vary across species (Henriksson *et al*., 2018). On the other hand, overuse and unnecessary use of AMs in aquaculture are common in many countries. As a consequence, an increasing number of AMs are less or no longer effective in the control of some diseases, especially the ones caused by bacteria.

Furthermore, the widespread use of AMs has already resulted in the increased incidence of antimicrobial resistance in some farming sectors. AMs and their breakdown products are most often released into the environment. In aquaculture, AMs are commonly applied with feed or directly to the water and thus may find their way into the environment through run-off water or sedimentation of faeces and uneaten feed particles. When consumed by other aquatic organisms, this increases the risks of AM resistance in humans through zoonotic diseases or through the transfer of AM resistance genes to human bacteria.

Aware of its critical importance to the sustainability of aquaculture in the region, FAO together with the national experts of countries in the region, assessed the use of AMs in aquaculture and its governance in the region through a Regional consultation and related country assessment studies in 2018. It also collated available knowledge on AM resistance and disseminated the same to countries in the region. Long-term strategies to address the issue and mitigate the risk were identified. All these contribute to the formulation of a regional surveillance guidelines for AM resistance in aquaculture. Initiatives like this put AM use and the possibility of developing AM resistance in the radar of all aquaculture practitioners.

5.4 THE NEED FOR RESEARCH AND DEVELOPMENT

Continued R&D on persistent, emerging or re-emerging diseases focused on understanding the mechanism of infection, development of diagnostic tools for identification of the pathogen, monitoring and surveillance, development of strategies for prevention and control of the spread of the disease, as well as timely and effective dissemination of innovations in health management in aquaculture will help build resilience in the aquaculture sector against disease outbreaks.

For example, the current approaches of biofloc technology, recirculating culture systems, and the use of other biological organisms that make use of the wastes generated within a culture system, among others, are approaches in the right direction. These however, require refinement to improve their efficacy in different systems and for their applicability to the different commodities that are presently farmed.

5.5 EFFECTS OF CLIMATE

Global warming has complicated the situation. With unusually high water-temperature, the organism's immune system is weakened. Some pathogens may proliferate faster and increase in virulence with increasing water temperature. A weakened immune system and the increased virulence of pathogens make cultured animals more vulnerable to pathogen Understanding how the immune systems of the different organisms respond to the pathogens is important in prudent use of AMs.

6 STRENGTHENING THE AQUACULTURE VALUE CHAIN

A 'value chain' refers to the set of interlinked businesses and actors that participate in the coordinated production and value-adding activities needed to make products that consumers are prepared to purchase. This background paper is an aid to formulating a regional, subregional or national project to develop and strengthen an inclusive aquaculture value chain. The first section highlights the sustainability framework applied to the food value chain. This is followed by the concept of value chain development and the strategies geared to attaining a pro-poor outcome. The last section gives examples from a case study of the role of government and key interventions that support the upgrading of an aquaculture enterprise to a higher value chain.

The food value chain framework developed by FAO (2014) highlights three main impacts from developing a sustainable value chain:

- Economic – The value chain generates profits (commercial viability) for all actors, secures food supply and creates jobs. The development of the chain does not impose a long-term burden to the government. And it generates tax revenues.
- Social – Society gains broad-based benefits, and the benefits generated from the value chain are distributed fairly. The result is social acceptance and increased consumer satisfaction such as improving food safety, nutrition, health and cultural benefits.
- Environmental – At a minimum, activities throughout the chain do not harm the natural environment.

6.1 VALUE CHAIN DEVELOPMENT

Value chain development (VCD) aims to improve business linkages across the entire chain in order to increase performance and competitiveness. In the Annex, the story, 'It's the stupid cows' (ILO, 2015) shows how the performance of one actor can be affected by the actions of others, which resulted in the poor performance of the entire chain.

The development of value chains often targets marginalized actors – this is known as 'inclusive' value chain. For small farmers, for example, benefits may include increased income, more secure linkages to markets, and access to new services to aid production. For wholesalers benefits may include higher quality products, and for processors improved quality and flow of raw material and reduced transaction costs.

There are four ways the value chain can be developed (ILO, 2015): (i) greater value chain integration – improving essential business linkages through vertical or horizontal integration, (ii) greater market access – accessing new markets often requires meeting new quality standards, or producing larger quantities, and may therefore generate innovation and be an incentive for greater value chain integration, (iii) better performing supporting functions – training, information system, market research services, certification system, roads and transport, and a reliable electricity supply are examples of basic supporting functions, and (iv) improved rules and application – setting rules of the game and facilitating effective compliance to the rules.

6.2 STRATEGIC APPROACH TO DEVELOPING VALUE CHAINS

The development of value chains consists of nine steps:

Step 1: Identifying target farmers or farmers' groups.
Step 2: Value chain analysis to identify business opportunities.
Step 3: Determination of business ideas, strategy, and goals.
Step 4: Identification of value chain upgrading strategies to increase value added.
Step 5: Determination of target market(s) and marketing strategies. It involves the determination and understanding of end markets and consumers.
Step 6: Business plan decision regarding what activities to do in the chain, the structure of business partners and actors, and the coordination system among them to achieve mutual goals.
Step 7: Formulating a business plan that comprises business ideas, analysis of situation, marketing plan, product and service production plan, risk management plan, and financial plan.
Step 8: Re-arrangement of relationships in the business operations with 'trust' as the common thread among business partners.
Step 9: Development of a monitoring and evaluation system that provide feedbacks and lessons for improving the chain and business operations.

6.3 MAKING VALUE CHAINS MORE INCLUSIVE

Following the above framework, key strategies are discussed here with examples to highlight a pro-poor outcome, targeting small farmers. This includes improving the value chain actors' coordination that allows engagement of small farmers to benefit more from their participation, and value chain upgrading strategies that create value addition and market opportunities for them. Building an enabling environment is equally important; this includes investment on supporting services (e.g. infrastructure, technology and innovation, financing, knowledge and information system, capacity building programmes, risk management, etc.) and establishment of institutional, legal and policy frameworks.

6.4 IMPROVING COORDINATION

Large corporations tend to operate at all levels of the chain making them very efficient and responsive to changes in consumer needs and preferences. In reality, chains compete with other chains, and large corporations are in direct competition with small-scale farmers. Being capital intensive, growth and expansion strategies can be impractical for individual small-scale producers, who then find themselves on the losing end of bargaining and market power.

Being organized can strengthen the bargaining and market power of small producers. Farmer groups and business partners coordinate to create their own chains to reduce transaction costs and access richer market information, which makes them more effective in meeting the needs of specific end-markets. Strengthening the linkages of the chain can also be done through vertical integration or through contractual arrangements.

The business models and examples in aquaculture, indicating the vertical and horizontal coordination and business partnership among actors are reviewed by Kaminski *et al.* (2020). Some examples are: (i) contract farming – e.g. mussel farming in South Africa, pangasius sector in Viet Nam where larger processors were suppliers of inputs (seed and antibiotics) and buyers of pangasius based on international food standards, (ii) cooperatives, associations, groups – e.g. shrimp farmers' cooperatives in Thailand, a sea cucumber farmer association in Madagascar, retirees in Nigeria who formed a group working together in catfish farming and invited private investment and public extension support, (iii) public-private partnership – e.g. 'aqua-parks' where governments designate a site specifically for aquaculture development and offer incentives (e.g. tax and permit exemptions) to the private sector to establish fish farming enterprises.

6.5 VALUE CHAIN UPGRADING STRATEGIES

The value added can be created through upgrading activities, of which there are four: (i) product upgrading, (ii) process upgrading, (iii) functional upgrading, and (iv) chain upgrading. The specific upgrading goals and examples are summarized below (Table 4).

Table 4: Value chain upgrading and examples of the activities

Type of Upgrading	Goal	Example
Process	Increasing outputs and/or reducing unit cost of production	Change of farm practices – farmers adopt new feeding techniques and better farm practices that improve feed conversion and yield.
Product	Improve product quality and increase value for the consumer	Development of a new product – a group of shrimp farmers produce 'bio shrimp' that meet the standards required by specific buyers.
Function	Change the mix of functions (operation, logistics, marketing, management functions) performed by actors.	Improvement of business operations – the farmer group, seeing it was no longer profitable to just produce and sell fresh fish, process their harvest (and buy more fresh fish for processing, from other farms) and work the logistics and marketing channels themselves.
Value chain	Build new business linkages with other value chains to shift the whole chain to a new and higher value chain.	A farmer group, instead of selling their fish to a local collector, work together with their trusted partners in product development, processing and marketing and receiving agreed price.

7 CLIMATE CHANGE THREATS TO AQUACULTURE IN THE REGION

Climate change related impacts have become immediate threats to aquaculture sector. Average temperatures are rising and falling rather irregularly across the globe. According to IPCC, by the end of the century drought will become more common and severe across the planet's mid-latitudes and the subtropics due to changing rainfall pattern. In 2019, Australia was hit by the severest drought in the country's history and has experienced 9 of the 10 warmest years on record since 2005 (Quackenbush, 2019). On the other hand, the temperate countries and the polar regions are also experiencing the severest snowfall ever.

The current changes in the global weather pattern and other natural disasters associated with climate change have already affected aquaculture operations in many parts of the world and especially in the region. Of particular importance are the irregularity in temperature change, rainfall patterns that cause severe flood and drought and associated inland salinization and shortage of freshwater, saline water intrusion due to rising sea level, increasing frequency and escalating intensity of natural disasters such as typhoons and storms.

They may bring physiological and chemical changes that will affect growth, development, reproduction, survival and disease episodes, among others, of the culture organisms, and may inflict on facilities and people's well-being as well.

The causes of these events, how they affect the biology of the farmed organisms and the various aspects of the farming operations, and more importantly, its overall impact on people (livelihood and survival) and the environment have to be fully understood and appreciated by all concerned parties (government policy maker, research and extension professionals, aquaculture farmers, associated private sectors and the communities) in order to come up with appropriate mitigation and adaptation measures to increase the resilience and ensure sustainable growth of the aquaculture sector.

From current available data, it is predicted that aquaculture in many countries in Asia and the Pacific is vulnerable to climate-related extreme events. Eight of the top 10 most vulnerable countries for freshwater aquaculture are Viet Nam, Lao PDR, Bangladesh, Myanmar, China (including Taiwan Province of China), Cambodia, Thailand, India and Indonesia, in that order. For brackish water aquaculture, Viet Nam, Taiwan Province of China, Thailand, Philippines, and Indonesia are in the top 10 vulnerable countries. China, Viet Nam, the Philippines and South Korea are also in the top 10 vulnerable countries for marine aquaculture production (Handyside *et al*., 2016; Barange et al., 2018).

7.1 IMPACTS OF TEMPERATURES ON AQUATIC ANIMAL PHYSIOLOGY

Various physiological processes and associated chemical changes are affected by temperature changes, which have significant implications on the growth, development and survival of cultured animals. For example, the rising temperature or the extreme high and low water temperatures may cause reproductive failure of cultured species since reproduction proceeds only following specific temperature optima for many species. Gamete production and early development are also highly sensitive to temperature fluctuations. Exposure to warm water temperature during prolonged hot sunny days, likewise, weakens the natural defences of the stocks thereby compromising their immune system. Incidentally, this also favours the multiplication and spread of some microorganisms and increases their virulence, creating a situation where disease outbreak is more likely to occur. The water quality of the culture environment will similarly be affected by extended duration of abnormally warm and coldwater temperatures and consequently impacts on the growth of natural food affecting growth and survival of stocks.

Global warming has also resulted in the increasing intensity of extreme weather events like storms and typhoons that bring strong winds and heavy rains causing floods that in many cases have destroyed culture facilities in inland and nearshore areas because of the fast flowing water. Saltwater intrusion into freshwater farms near the coastal areas as a result of sea level rise renders freshwater farms unsuitable for freshwater farming. It can be seen, however, as an opportunity to culture other species that can tolerate the increase in salinity levels resulting in diversification of culture species, a positive note. Many of the events mentioned above are already happening and experienced by fish farmers, and the prediction is for these events to intensify if nothing is done to arrest the rising temperature of the planet.

7.2 CHANGES IN SEASONAL TEMPERATURES AND RAINFALL

The observed changes in the climatic events are closely linked to the changes in the weather system, which is largely affected by global warming and the global wind circulation patterns. It has been observed that the once highly regular and predictable weather patterns have become highly irregular and somehow do not follow a pattern. This irregularity in the weather patterns and the accompanying climatic events disrupt production cycle schedules which are highly dependent on the prevailing climatic conditions. This has become problematic for the farmers who are largely dependent on the local climate for the timing of their production cycle. Because the occurrence of a specific type of climatic event is largely influenced by the prevailing weather system, it is possible that a climatic event can be predicted given the prevailing weather condition, and since the occurrence of a weather system can be forecasted in advance, the kind of climatic event that is associated with the particular weather pattern somehow can also be foreseen. It is thus critical for fish farmers to have ready access to “advance” weather forecast or information in their area for them to be able to prepare an appropriate adaptive response and minimize their losses. It is encouraging to note that some countries in the region like in Southeast Asia (example, the Philippines) have initiated the provision of advanced localized weekly weather forecast/bulletins to the farmers using various media channels including: local radio stations, weather bulletins through the local government units, text messaging and mobile application, among others (FAO/TCP/3502).

7.3 THE IMPORTANCE OF ADAPTATION OF AQUACULTURE SYSTEMS

Given the above, it is thus imperative that the sector has to find other mitigating and adaptive measures for aquaculture operations to sustain in a warmer world. Some guidance on appropriate adaptive tools are available and needs to be implemented. The activities include those at the level of the institutions (institutional and legal frameworks, policies, planning and management) and the farmers for livelihood adaptation. Essential component activities for risk reduction and management for resilience that includes provision for early warning systems for weather disturbances, storms, disease or temperature extremes and preparedness for response are integral part (Poulain *et al*., 2018). At the level of the institutions, capacity building for government officials at all levels and aquaculture managers to undertake climate change vulnerability and risk assessments and contingency planning are important tasks in addition to providing investment in research and better coordination between concerned agencies and research institutions to aid in decision making (Uppanunchai *et al*., 2018).

Diversification of culture species to suit the changing environmental conditions is an example of an activity that a farmer can implement for livelihood adaptation. Factors related to climate change are externalities that a fish farmer has no control over and hence they must be provided with all the necessary support for their farming operations to continue.

It is important to understand that the impact of climate change-related calamities and natural disasters on different aquaculture systems and commodities are very different.

Therefore, it is essential to investigate the actual impacts of extreme weather and natural disasters on specific aquaculture systems and commodities to develop appropriate adaptive measures for farm level operation and area management. These measures include, but not limited to modification of farm facility (e.g. increased pond depth), altered production cycle and management practices (e.g. shortened production cycle, adaptive water management scheme and increased stocking size), new technology for more effective water quality manipulation and improvement of public infrastructure (e.g. water supply, power supply and flood control).

Stocking bigger size fish at the start of the grow-out culture period can shorten the culture duration for the stocks to reach marketable size, potentially avoiding high risk seasons where extreme weather events may destroy or disrupt aquaculture production (strong winds and/or flooding; high temperatures and low rainfall).

Governments are encouraged to support the development and adoption of adaptive measures to cope with the impacts of climate change-related extreme weather events and natural disasters on specific farming systems and commodities and encourage investments that can facilitate the effective implementation of the adaptation measures.

While supporting the aquaculture sector to adapt to climate change impacts, it should be recognized that aquaculture, particularly intensive aquaculture, can also contribute to green house gas emission. Such contribution can increase with the development of the sector. More effort should be made to study the carbon footprint of different commodities and different farming systems in the region. The government should support the technological innovation and improvement of farming practices that can improve energy efficiency for reduced emission and promote new aquaculture systems and practices that can contribute to carbon sequestration. Significant progress has been made in some countries in the region. The sharing and upscaling of the successes should be promoted through appropriate mechanism, such as south-south cooperation.

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