dietary inclusion levels of many plant-based fishmeal substitutes. In addition, appropriate processing techniques to increase the nutritional composition of alternative ingredients that can be locally sourced needs further studies. Standards on the quality and safety of alternative feed ingredients specifically for use in aquaculture feeds have yet to be developed. Stakeholders interested in alternative protein sources have limited access to the results of feed development studies or the low adoption of these feed formulations by the commercial feed companies.

Way forward

Continued development of alternative feeds for economically important fish species in the region is necessary. Other raw materials that hold enormous potential in aquaculture feed formulation should be explored and evaluated under realistic farm conditions. These include biofloc meal, insect meal, aquatic weeds, and other agriculture and fisheries wastes and byproducts which could keep production costs down. Suitable equipment is also needed to process a huge amounts of these unconventional raw materials as feed ingredients. In this aspect, the collaboration between local government agencies, the academe, and research institutions is encouraged to develop low-cost equipment to process these materials into utilizable feed ingredients.

In 2018, SEAFDEC/AQD initiated the development of a database on alternative feed ingredients (http://afid.seafdec.org.ph). This initiative is a crucial step to collate and exchange information among the AMSs on the emerging alternative feed ingredients with promising use in aquaculture feeds. At present, the database covers information from at least 70 published papers. This will be constantly updated for there are many new and novel protein sources that are successfully applied to replace fishmeal in aquaculture feeds. In fact, a lot of alternative plant-based protein sources are continuously produced with the help of biotechnology. Research efforts should also address the application of emerging protein and lipid sources in aquaculture feeds and their effects not only on the biological performance but also on the fish health and quality of farmed species. Also, appropriate processing treatments to enrich the nutritional value of locally available indigenous protein sources should be applied and their suitability, viability, and profitability tested in diets of farmed species to promote cost-effective feeds for fish culture. Therefore, cooperation and collaboration among the AMSs, specifically the research and development institutions, private sector, and the academe both at the national and local levels, in several areas of research in fish nutrition and feed development should be strengthened, especially now that biotechnology is employed in producing cost-effective feeds. It is also of paramount importance that the promotion of alternative feed ingredients and sound feeding management practices be integrated or addressed in synergy in future feeds and feeding studies, the results of which should be disseminated to small-scale fish farmers engaged in fish culture. Other policies recommended for the AMSs on overcoming the dependence on fishmeal by development and use of alternative dietary ingredients in aquaculture feed are shown in **Box 34**.

Box 34. Recommended policies on the use of alternative dietary ingredients in aquaculture feeds

- Develop national standards on alternative feed ingredients, including the protocols for detecting contaminants in alternative feed ingredients and aquaculture feeds
- Increase regional and local awareness of the importance of reducing aquaculture's reliance on fishmeal and "trash fish" as major protein sources for aquaculture species
- Create a network involving food (fish and fruit) processors and aquaculture feed millers at the national and local levels to determine the volume of wastes and byproducts generated from the primary food processing industries and their potential use in aquaculture feed production
- Strengthen collaboration among the government sector (particularly the policymakers), research and development institutions, and the private sector (feed industry and farmers) on initiatives related to identification, development, promotion, and mass production of alternative protein sources
- Implement programs on the proper processing techniques of alternative feed ingredients to maximize their use in aquaculture feed formulations that small-scale fish farmers can adopt
- Compile and disseminate information on available alternative plant products through training programs as well as traditional and online information-sharing platforms
- Conduct field trials involving farmers, extension workers, and feed millers to demonstrate the effectiveness of using alternative ingredients in formulated feeds

7.1.4 Production and Dissemination of Good Quality Seedstocks

Aquaculture continues to lead aquatic food production globally (FAOa, 2019) with over 90 percent (102.9 million mt) of global aquaculture production is supplied by Asia in 2017. Southeast Asia plays a significant role in food security, with freshwater fish accounting for 30 percent of the aquaculture production. The region continues to move towards intensified farming of high-value aquaculture species (*e.g.* shrimp, mangrove crab, seabass, grouper, pompano, among others), which was previously dominated by low-trophic herbivorous fish (*e.g.*, milkfish, tilapia, siganid, carp).

With the diminishing production of capture fisheries over the years, the focus has shifted to the aquaculture industry in order to respond to the increasing demand for fish, thus, requiring increased area and intensified production. However, propelling this strategy has resulted in increased production cost from feed inputs, deterioration of the environment (land and water), an outbreak of viral and bacterial diseases, and reduced quality of seedstocks. Extensive research and development on replacing fish meal and oil to attain sustainability, disease diagnostics and therapeutics, development of intensive yet sustainable aquaculture systems, and adoption of a plausible genetic program should be accomplished and straightforwardly applied to the aquaculture industry.

Seed Production

- ***Marine Fish***

Seed production technologies have been established for a range of economically valuable species of marine finfish in the region through research and development. Among those species with life cycles that have been successfully closed in captivity and can be mass-produced in hatcheries include milkfish (*Chanos chanos*), groupers (*Epinephelus* spp.), Asian sea bass (*Lates calcarifer*), snapper (*Lutjanus* spp.), mullet (*Mugil* spp.), rabbitfish (*Siganus* spp.), and carangids such as pompano and trevally. While milkfish farming today is primarily based on hatchery-bred fry, farming of other marine species in the region relies partially or entirely on wild-captured seeds. However, the production of a sufficient volume of marine seeds is constrained by a number of issues surrounding captive breeding and larval rearing. Captive breeding of marine fish requires high investment and operational costs, which is beyond the means of most small-scale farmers.

In Indonesia, the government has established a centralized captive breeding facility for milkfish to supply eggs for subsequent larval rearing in small backyard hatcheries. The system proved to be successful in ensuring a sufficient supply of milkfish fry, which also allowed the country to mass produce groupers and other marine fish. The high investment cost of breeding most marine fish is partly due to their late sexual maturity, which requires a long period of broodstock conditioning. For instance, milkfish, groupers, and the Asian sea bass attain sexual maturity at the age of 3–5 years. Some studies were undertaken at SEAFDEC/AQD to advance the onset of puberty in marine fish to breed with younger and even smaller broodstock. Reproductive hormones, such as gonadotropin hormone-releasing hormone (GnRH) and follicle-stimulating hormone (FSH), administered through injection or feeding effectively advance the gonadal development in juvenile grouper (Palma *et al*., 2019a, 2019b; Nocillado *et al*., unpublished).

Moreover, the low larval survival of marine fish remains a bottleneck in its mass seed production. Most marine fish larvae, such as groupers, have small mouths, thus the choice of initial live feed is limited. The SS-type rotifer (*Brachionus rotundiformis*) is widely provided as an initial live feed for marine fish larvae although the survival rate has been relatively low and inconsistent. Several species of minute rotifer belonging to the genera *Proales*, *Colurella*, and *Lecane* have been isolated and evaluated for their potential as an initial live feed. *Proales similis* improve the survival of grouper larvae when provided in combination with *B. rotundiformis* in the first 10 days of rearing. Development of mass production techniques for *P. similis* and its application to other species of marine fish larvae is ongoing at SEAFDEC/AQD. For copepods, despite its excellent nutritional value and established suitability as live feed for marine fish larvae, use in aquaculture remains uncommon because of limitations in the production system. To improve nutritional value, especially the fatty acid profile of live prey, short-term enrichment methods have also been developed and applied for marine fish. These enrichment preparations have also been utilized for thyroid hormone manipulation to hasten metamorphosis in marine fish larvae, a critical period in which larvae are highly sensitive to environmental disturbance. At SEAFDEC/AQD, iodide supplementation has shown to accelerate metamorphosis in rabbitfish larvae (Cabanilla-Legaspi *et al*., 2021a).

Viral disease outbreaks remain a major problem in marine fish farming, particularly viral nervous necrosis (VNN) which significantly impacts larval survival. Methods to vaccinate marine fish larvae against nervous necrosis virus (NNV) have been developed through immersion or feeding of live feed bioencapsulated with the vaccine. At SEAFDEC/AQD, a vaccination regimen for marine fish breeders was established to prevent vertical transmission of NNV thereby allowing the production of NNV-free seeds from infected breeders (Pakingking *et al*., 2018).

Molecular markers have been developed for several marine fish in the region, including milkfish, sea bass, and groupers which can be applied in breeding programs. Yet, in contrast to the success in freshwater finfish, particularly tilapia, breeding programs in marine fish is difficult due to the challenges in captive breeding as mentioned above and thus not commonly applied in the industry. Most marine fish hatcheries in the region continue to utilize wild-caught breeders.

In the Philippines, one of the most economically viable marine species kawakawa (*Euthynnus affinis*) is being observed as a possible commodity for aquaculture. The full-cycle farming technology from Ehime Prefecture in Japan would be adopted. The Philippines has the optimum conditions for rearing kawakawa as it requires a warmer temperature (around 20–28 °C) to achieve rapid growth. Currently, SEAFDEC/AQD is conducting studies to determine the reproductive biology, feeding habits, and migration patterns of kawakawa. Subsequently, the techniques for broodstock management would be established (Cabanilla-Legaspi *et al*., 2021b).

- ***Crustaceans***

Mangrove crab

Mangrove crab belongs to the genus *Scylla*, which comprises four species, namely: *S. serrata*, *S. tranquebarica*, *S. olivacea*, and *S. paramamosain*. The first three are commonly found in the Philippines, while *S. paramamosain* is common in Viet Nam, Indonesia, and Thailand. The rising global demand for mangrove crabs and ecological threat to its natural population paved the way towards the development of a culture technology in Southeast Asia.

In Malaysia, *S. olivacea* is the most abundant mangrove crab species, while the presence of *S. paramamosain* is relatively low, while *S. serrata* is not recorded (Naim *et al*., 2019). Although *S. paramamosain* is scarce, it is favored for culture as it can reach the market size after only three months of culture. Hence, the breeding and larviculture technology of *S. paramamosian* was developed in Terengganu, Malaysia. Results showed that 80 to 90 percent of the broodstock spawned while the survival rate from larva to crablet was 5 to 10 percent. It should also be highlighted that biosecurity measures should be properly observed to prevent mortality caused by fungal, bacterial, and protozoal infections (Khoa & Harrison, 2019). In order to develop inter-species breeding among mangrove crabs, the study of Fazhan *et al*. (2017) of the Institute of Tropical Aquaculture, Universiti Malaysia Terengganu, showed that mating among all three *Scylla* species (*S. olivacea*, *S. tranquebarica*, and *S. paramamosain*) is feasible in captivity. *S. tranquebarica* and *S. olivacea* showed the highest versatility in selecting other species as mating partners. However, *S. paramamosain* preferred their own species to mate and choose other species only when other choices are unavailable. This information is important in developing a protocol for the breeding and seed production of mangrove crab hybrids. Consequently, it also serves as baseline data for future studies on the spawning and hatching of hybrid larvae.

In the Philippines, *S. serrata* is preferred for culture because it is fast growing. At SEAFDEC/AQD, existing hatchery protocols for *S. serrata* are continuously refined to improve the production of the seedstock. As a result, crablet production doubled from 1 percent in 2017 to 2 percent in 2019. In addition, the average survival from zoea 1 to crab instar continued to improve such that a 10 percent survival rate has been achieved. A total of 7.3 million newly-hatched larvae had been produced in the hatchery, which generated 656,200 pieces of crablets and 581,040 pieces of which were sold to local stakeholders. The increase in survival was attributed to reduced frequency of antibiotic application, increased feeding frequency starting the megalopa stage, and frequent water exchange (SEAFDEC/AQD, 2019). Additionally, the SEAFDEC/AQD formulated *Tetraselmis* paste showed promising results in producing rotifers compared to live and commercially available paste thus, a good alternative to live algae in the hatchery rearing of *S. serrata* seedstock (SEAFDEC/AQD, 2019). For quality assessment, exposure of newly-hatched *S. serrata* larvae to 40 mg/L formalin for 3 hours, also known as a formalin stress test, appeared to be a reliable and practical method for selecting good quality larvae for culture (Quinitio *et al*., 2017). It has also been observed that *S. serrata* juveniles developed morphological deformities upon exposure to antibiotics during the larval stage. As such, antibiotic use in larviculture should be eliminated, and search for potential alternatives could be pursued (Pates *et al*., 2016).

In Thailand, *S. olivacea* is considered high-value crustacean species due to its tasty meat and ovary. Consequently, its dwindling natural population has been observed due to overexploitation. To ensure the production of gametes and larvae in captivity, Khornchatri *et al*. (2019) studied the endocrine controls involved in reproduction which is the first step in successfully breeding *S. olivacea*.

Although the successes in mangrove crab hatchery operations had been reported in some countries, the production of its larvae remained low as most hatcheries face inconsistent survival rates from zoea to crablet stages. This problem is often attributed to the difference in the quality of newly-hatched larvae due to the multiplicity of broodstock sources, mass mortality caused by "molt death syndrome" during the transition from zoea 5 to megalopa stage, lack of suitable larval diets, fungal and bacterial infections due to non-compliance with biosecurity measures, and lack of species-specific culture protocol.

Penaeid shrimp

The global production of farmed shrimp is consistently growing at a rate of 6 percent annually, with a global trade estimated at USD 28 billion per year (FAO, 2020a). Among the crustacean species, the white leg shrimp (*Penaeus vannamei*) occupied the world's top aquaculture production by volume in 2020. Meanwhile, shrimp aquaculture in the region is dominated by *P. vannamei* and *P. monodon*.

In 2017, SEAFDEC/AQD initiated the revival of the giant tiger shrimp (*P. monodon*) industry under the banner program called "*Oplan Balik Sugo*" (Operation Black Tiger Shrimp Revival). The program aims to bring back the once-booming tiger shrimp industry in the Philippines through the production of high-quality post larvae (PL) in the hatchery. This initiative can be achieved through an effective breeding program using specific pathogen-free (SPF) broodstock and disease-resistant PL. Hence, the biosecure hatchery complex was built at SEAFDEC/AQD to support the breeding program of *P. monodon*. In 2019, hatchery-produced PL of *P. monodon* was stocked in SEAFDEC/AQD's Dumangas Brackishwater Station (DBS) ponds for grow-out culture, yielding harvests of about 2.8 mt with 93 percent survival after 113 days in the 5,000 m^2 pond and 4.4 mt with 89.7 percent survival after 120 days in an 8,000 m^2 pond in October and November, respectively.

During the Regional Meeting on Agricultural Biotechnologies in Sustainable Food Systems and Nutrition in Asia-Pacific of the Food and Agriculture Organization of the United Nations (FAO) in 2017, the Chulalongkorn University of Thailand presented its work on RNA-sequencing analysis to identify differentially expressed genes in response to infectious diseases and candidate markers associated with disease resistance in *P. vannamei*. The aim of the efforts was to assist selective breeding of disease resistance shrimp lines and develop a platform to evaluate the health status of shrimp based on gene expression profiling. Furthermore, data on shrimp hatchery surveys in Thailand showed that controlling temperature with larger tanks and probiotic supplementation improved the survival rate of shrimp postlarvae (Nooseng, 2019). The potential of inactivated vaccines (Amar *et al*., 2020) and RNAi (Amar *et al*., unpublished) in improving the growth and survival of *P. monodon* has also been shown in experiments conducted at SEAFDEC/AQD.

Flathead lobster

Lobsters are known as high-value seafood and its demands inspired the development of aquaculture techniques for the species, particularly the flathead lobster (*Thenus orientalis*). There are very few attempts to conduct full-cycle aquaculture for lobsters in Southeast Asia, and due to the interest of entrepreneurs, sourcing seeds from the wild is being widely practiced in Indonesia, Philippines, and Viet Nam (Radhakrishnan, 2015). SEAFDEC/AQD is currently conducting R&D activities to develop breeding and farming techniques for this lobster species as the availability of healthy and quality seeds is still a major constraint. This project conducted in Iloilo, Philippines by SEAFDEC/AQD aims to promote the local lobster production industry that is not fully dependent on capture fisheries (Ursua *et al*., 2021).

Freshwater species

Freshwater aquaculture in Southeast Asia has long been dominated by tilapias (*Oreochromis* spp.), carps (Cyprinidae), and catfishes (*Clarias* spp.). The successful culture of these fish species is mainly associated with the early establishment of the aquaculture system. Early genetic improvement initiatives using either or both conventional and advanced genetic techniques have progressed the production of high-quality seedstocks from these species (Eknath *et al*., 1993). Hence, genetically improved broodstocks are well developed and available in different parts of the region.

The success of the catfish industry in Indonesia can be attributed to the effective national breeding program, which resulted in several superior strains of catfish. The initiative was driven by the decreasing reproductive performance of cultured catfish in the country, which was mainly linked to poor broodstock management and improper farming methods. At present, the outputs of this genetic improvement program are widely used in the country (Gustiano *et al*., 2021).

Similarly, the development of tilapia strains of desirable traits (*e.g.*, fast growth and saline tolerance) resulted in various strains of this species in the Philippines. The impact of these tilapia technologies on the availability of good quality seedstocks and advancement of freshwater aquaculture, overall, is not just within the bounds of the region but stretches wide to other parts of Asia and America (Worldfish, 2015). However, challenges such as the decreasing tilapia seed production brought about by the increasing water temperature and the reported mismatch between the species of maternal origin and present-day offspring of the genetically improved strains threaten the potential of these technologies.

To increase the spawning rate and seed production of tilapia in a pond-based hatchery system during summer months, the aquashade technology (*i.e.* partial, complete shading, or roofing of ponds using nets) for tilapia broodstock is applied to reduce the water temperature by as much as 3 °C. As per the issue of the genetic purity and integrity of improved tilapia strains, several technical and non-technical interventions can be applied, such as but are not limited to: a re-evaluation of the improved strains and development of effective broodstock management. Re-evaluation of the effectiveness and genetic gains from these strains should be emphasized (Ordonez *et al*., 2017) and regularized as part of the entire genetic improvement program. Likewise, a more effective center to farm-level broodstock management protocol should be developed as it is critical in the continuity of genetic gains, which ensure the quality of seeds from these improved strains (Hulata *et al*., 1986; Macaranas *et al*., 1995).

Furthermore, giant freshwater prawn (*Macrobrachium rosenbergii*) is expected to play a significant role in regional aquaculture production due to the recent development in neo-female broodstock technology wherein functional females can produce all-male progenies. This can be achieved using either microsurgical ablation of the androgenic gland or silencing of the sexual-differentiation gene. Currently, Thailand is taking the lead in improving this species by applying modern genetic techniques (*i.e.*, gene silencing technology). In contrast, SEAFDEC/AQD is exploring the potential of the earlier technology, ablation-derived neo-female broodstock, to improve the quality of seedstocks in the Philippines.

In general, technologies developed for the farming of freshwater species have played significant roles in sustaining the availability of good quality seedstock in the region. Apart from the need to further explore the nutritional aspects of freshwater species, mitigating the effect of stressful conditions, and developing or adopting efficient breeding programs, regularly evaluating the effectiveness of genetically improved strains, and implementing stricter and more effective schemes in broodstock management are relevant interventions to ensure the availability and sustainability of quality seedstocks.

- ***Mollusks***

Mollusks contribute about 21.3 percent (17.5 million mt valued at USD 34.6 billion) of the world aquaculture production (FAO, 2020b), while Asia accounts for about 92 percent of mollusks production in the world (FAO, 2020a). Major countries in Southeast Asia actively farming mollusks are Cambodia, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam. The major mollusk species groups of commercial significance in the region are abalone (*Haliotis* spp.), green mussel (*Perna viridis*), oysters (*Crassostrea iredalei* and *Crassostrea* spp.), and blood cockle (*Anadara granosa*). While the farming of these species persisted for decades, the method of obtaining seeds is largely dependent on the wild. Meanwhile, efforts have been made on the hatchery and seed production in some of these species aimed at providing a sustainable supply of quality seeds to farmers.

Abalone

Abalone is a high-value seafood commodity in the region and is one of the most highly-priced delicacies with a significant value despite its relatively small production quantity. The bulk of production is contributed by Malaysia, Philippines, and Thailand (FAO, 2020b; Cook, 2014). In the Philippines, the species *Haliotis ovina*, *H. glabra*, *H. varia*, and *H. asinina* are commonly found, the latter being the most abundant. SEAFDEC/AQD has been into large-scale seed production of the donkey's ear abalone (*H. asinina*), and the research focused on increasing juvenile yield through feeding the appropriate diatom strain, supplementation with microparticulate diet, and application of anesthetics. Similarly, the effect of seaweed quality and enrichment (Santizo-Taan *et al*., 2020) on broodstock, larval, and juvenile performance has also been evaluated. The five percent improvement in seed production is attributed to the increase in diatom feeding. Out of about 3.80 million trochophore larvae produced, 47 percent (about 1.80 million larvae) developed into the veliger stage. A total of 61,137 early juveniles with 3–8 mm shell length had also been produced in the hatchery (SEAFDEC/AQD, 2019). Despite the established culture techniques for abalone, its aquaculture remains stagnant. One of the reasons could be the lack of information on good sources of quality abalone broodstock and seedstock. Hence, Romana-Eguia *et al*. (2019) conducted a study aimed at generating a preliminary database on possible sources of genetically diverse *H. asinina* stock. In the study, samples from one hatchery-bred and nine wild-sourced founder stocks and their F_1 offspring were analyzed for genetic variability using microsatellite markers. The information generated from this study will be used to identify local stocks most suitable for breeding and farming. Furthermore, Indonesia is exploring the potential of probiotics supplementation to enhance the growth and survival rates of juvenile abalone (Amin *et al*., 2020).

Green mussel

Mussels had been one of the major mollusk groups extensively cultured in Southeast Asia with Indonesia, Philippines, and Thailand contributing significantly to the global aquaculture production (FAO, 2020a). Although the thriving culture of this species relies on the collection of seeds from the wild, there are initiatives to establish the seed production technology for this species in response to the observed decline in production trend brought about by the diminishing natural spatfall. In the Philippines, initial studies had been conducted on the establishment of a mussel hatchery, where conditions are optimized to attain: high fertilization success and survival to the D-hinged stage (Piñosa *et al*., 2020); high growth and survival from D-hinged to pediveligers (Apines-Amar *et al*., 2020); and high survival and settlement rates and bigger spats (Mero *et al*., 2019). The result of preferential feeding trials showed that mussels fed on *Isochrysis galbana*, *Chaetoceros calcitrans*, and *Tetraselmis tetrahele* (Maquirang *et al*., 2020) with a combination of *I. galbana* and *C. calcitrans*, supported better growth and higher survival (Apines-Amar *et al*., 2020). In Myanmar, an experimental larval rearing of *P. viridis* was also initiated. The study demonstrated that penicillin and streptomycin resulted in a higher growth and survival rate of *P. viridis* (Nwe, 2020).

Oysters

Farming of tropical oysters *C. iredalei* and other *Crassostrea* spp. have been practiced in the region for decades. Almost all oyster aquaculture in Southeast Asia relies heavily on wild spats, unlike the oyster aquaculture in temperate and subtropical countries that increasingly access hatchery-produced spat. In recent years, however, the Southeast Asian countries have progressed towards artificial propagation of oyster seed in hatcheries as a consequence of the diminishing, unsustainable, and unreliable spatfall from the natural environment. Experimental and commercial oyster hatchery operations were reported in Malaysia (Tan *et al*., 2014), Philippines (Madrones-Ladja *et al*., in press), Thailand (Day *et al*., 2000), and Viet Nam (O'Connor *et al*., 2012). The potential of hatcheries to provide supplementary sources of oyster spat to sustain small-scale farmers and businesses is still on its burgeoning stage in the region. More so in Viet Nam, where the oyster industry has developed and thrived as a result of the development of oyster seed supply. Genetic techniques to improve seed quality, such as triploid induction, are also being explored (O'Connor *et al*., 2012). Furthermore, recent developments to move forward the hatchery seed production of oysters is the continued investigation on the genetic improvement program for this mollusk species group, particularly in Viet Nam (Vu *et al*., 2020). On the other hand, Malaysia evaluated the aquaculture potential of inter- and intra-specific crosses between *C. belcheri* and *C. iredalei* (Wan Nawang *et al*., 2019).

Way Forward

The rapid growth of aquaculture production in the region requires a sufficient supply of seedstocks, especially marine seeds, given the expansion or shift towards mariculture. Sustainable seed production can be achieved through genetics-based breeding programs to ensure the selection and maintenance of genetically variable breeders through successive generations capable of producing seedstocks that are healthy, fast-growing, and resilient to diseases and environmental stresses. Breeding programs are strongly practiced among freshwater species, particularly tilapia, which allowed the development of various strains with superior growth performance. For marine crustaceans, particularly penaeid shrimps, significant threats from viral diseases have forced similar breeding programs to ensure the availability of disease-free spawners and seeds. Such breeding programs are uncommon in the marine fish industry given major issues that persist in captive breeding. Research and development activities are underway to circumvent the reproductive difficulties surrounding marine fishes although technologies take considerable time to be established. The consolidated progress of genetics, fish health management, intensified culture system, and cost-efficient feed program can lead the way in creating a more sustainable aquaculture production in the succeeding decades. Non-technical intervention from the government is needed to address the gap. The centralized breeding facility for marine fish to supply backyard hatcheries proved efficient in enabling mass seed production. Enabling policies and incentives should be promoted to encourage more operators to venture into the production of seedstocks.

7.1.5 Production of Safe and Quality Aquaculture Products

As the human population continues to grow, coming with it is the greater demand for food. Aquaculture is the fastest-growing food source, and the industry tries to catch up with demands through rapid intensification. However, this intensification has resulted in the occurrence of diseases and degradation of the environment. Farmers have resorted to using antibiotics as therapeutants to prevent and treat diseases. Chemicals and products that have claimed to improve water and soil quality or strengthen the immune system of shrimp and fish had been introduced into the market. Also, fish farmers have been using different kinds of feed (live and manufactured), which could be contaminated with harmful chemicals and zoonotic organisms. Moreover, the indiscriminate use of antibiotics could result in antimicrobial-resistant strains of bacteria. These antimicrobial-resistant genes can be transferred horizontally from aquatic to terrestrial to human and vice versa, affecting the organisms and the environment. Some countries are stricter to the point that detection of drug residues in imported aquaculture products means rejection. Consequently, the production of safe and quality aquaculture products is a challenge to fish farmers, and the current trend is towards responsible aquaculture through ecosystem approaches for the production of safe and quality aquaculture products.

Safe and quality aquaculture products

Recognizing the threat that antimicrobial resistance (AMR) brings, the Food and Agriculture Organization of the United Nations (FAO) implemented a project on the prudent and responsible use of antimicrobials in fisheries and aquaculture in 2017. The project was aimed at developing and enhancing the knowledge, skills, and capacity of the participating Competent Authorities (CAs) on fisheries and aquaculture; and assisting the CAs to develop and implement policies and national action plans (NAPs) on the prudent and responsible use of antimicrobials.

Recognizing the importance of detection protocols for different food hazards, the SEAFDEC/MFRD and the SEAFDEC/AQD with funding from the Government of Japan, developed standardized methods of their detection. Laboratory manuals on the detection of antibiotic and pesticide residues were published including oxolinic acid and oxytetracycline/tetracycline/chlortetracycline by high power liquid chromatography (HPLC)-fluorescence method in 2004; 29 pesticides residue using gas chromatography in 2004; and chloramphenicol and nitrofurans using liquid chromatography-tandem mass spectrometry (LC-MS/MS) method in 2005. SEAFDEC/MFRD also produced three Technical Compilations, namely: 1) Heavy Metals, Pesticide Residues, Histamine and Drug Residues in Fish and Fish Products in Southeast Asia 2004-2008; 2) Biotoxins Monitoring in ASEAN Region 2009-2012; and 3) Traceability Systems for Aquaculture Product in the ASEAN Region 2010-2015. Moreover, two regional guidelines were developed by SEAFDEC/MFRD, namely: 1) Traceability System for Aquaculture Products in the Asian Region and 2) Cold Chain Management of Fish and Fishery Products in the ASEAN Region. Aside from manuals on antibiotic and pesticide residue detection, SEAFDEC/AQD also published a manual on antimicrobial sensitivity tests including bacterial isolation and identification techniques in 2004. SEAFDEC/AQD acquired an atomic absorption spectrophotometer for the detection of heavy metals and metallic elements. Detection of different foodborne pathogens using polymerase chain reaction (PCR)-based methods were also reported such as *Escherichia coli* (2008), *Salmonella* spp. (2008), *Shigella* spp. (2010), *Staphylococcus aureus* (2010), and *V. Cholerae*