Importing countries have set standards with regards to the safety of exported aquaculture products, checking for antibiotic residues and the presence of other contaminants or food hazards. They are also particular with the method and the environment of the products that were produced, and whether the farmers practice responsible aquaculture to ensure environmental sustainability. To address these issues and ensure that farms adhere to these standards, exported aquaculture products need to obtain certification from recognized certification bodies. Several aquaculture certification services assist farmers in Southeast Asia to demonstrate responsibility and adherence to best practices. Some of these include the Aquaculture Stewardship Council (ASC) which is supported by the World Wildlife Fund (WWF) issues certification for aquaculture products that target the American and European markets; Best Aquaculture Practices (BAP) which is developed by the Global Aquaculture Alliance (GAA) and is used by the American markets; and GlobalGAP that is used for products targeting the European markets. Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam are some of the clients of such aquaculture certification bodies.

Issues, Challenges, and Constraints

Food safety of aquaculture products starts at the farm level. However, aquaculturists, especially small-scale farmers, have low awareness and understanding of food hazards and their effect on humans and the environment. In spite of the extensive effort of both the government and local and regional institutions to educate the aquaculture sector on food safety, food hazards, good aquaculture practices, HACCP, certification, antimicrobial resistance, among others, the majority of the stakeholders remain adamant, non-compliant to GAqP, still uses antibiotics, and rejects government advises. This leads to the production of aquaculture products that are unsafe for human consumption and the possible degradation of the environment. Adoption of GAqP by the aquaculture sector would require a great effort on the part of the governments.

Way Forward

Responsible aquaculture through ecosystem approaches for producing safe and quality aquaculture products is one direction to produce safe and quality aquaculture products. Practicing the principles of HACCP should be promoted and recommended to the aquaculture sector. Information, education, and communication strategies and techniques to create food safety awareness among the stakeholders should be improved so that even those who could not go to school would understand the importance of delivering safe aquaculture products. Government should assist, especially the small-scale farmers in the implementation of GAqP, not only in terms of technology but also financially.

7.1.6 Impacts of Intensification of Aquaculture on the Environment

For several decades, aquaculture has emerged as a significant contributor and the fastest-growing food sector in the world (FAO, 2020) bringing economic benefits to rural and coastal communities while playing an increasingly vital role in global food security (Beveridge *et al*., 2013; Bene *et al*., 2016). The benefits of aquaculture include simple access to high-quality food, a source of income, and revenue for developing countries (Martinez-Porchas & Martinez-Cordova, 2012; Salin & Ataguba, 2018). The aquaculture sector has continued to dominate in developing countries, particularly in Asia (de Silva & Davy, 2010); and contributed to an average of 90 percent of the total volume of aquaculture production globally (Hall *et al*., 2011), wherein 16 percent came from Southeast Asia in 2019 (**Figure 101**). In Southeast Asia, aquaculture rapidly expanded in response to market demand, both domestic and international (Hishamunda *et al*., 2009). The highest producing country from Southeast Asia is Indonesia followed by Viet Nam, accounting for an average of 62.10 percent and 17.41 percent, respectively, of the total volume of the region's production in 2019 (**Figure 102**).

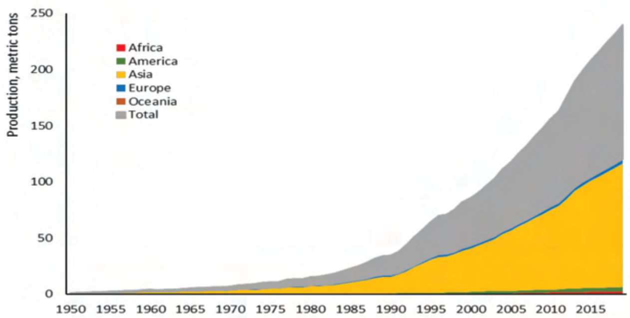

Figure 101. Total volume of aquaculture production from 1950 to 2019

*(**Source:** FAO Database)*

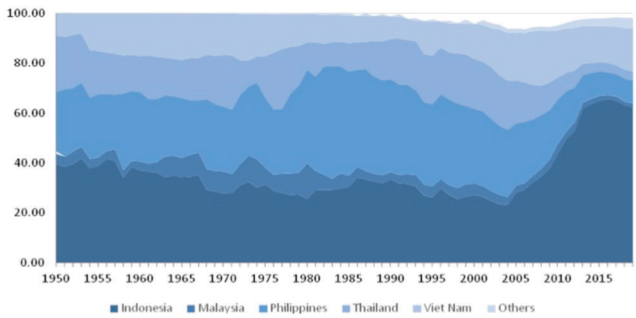

Figure 102. Percent contribution of Indonesia, Philippines, Malaysia, Thailand, Viet Nam, and other Southeast Asian countries (Brunei Darussalam, Cambodia, Lao PDR, Myanmar, Singapore, and Timor-Leste) to the total volume of aquaculture production in Southeast Asia from 1950 to 2019

*(**Source:** FAO Database)*

The relevance of aquaculture in the region goes beyond its significant contribution to global aquaculture production since the people of the Southeast Asian countries consume fish as the primary source of animal protein and an essential part of their diet (Hishamunda *et al*., 2009). For instance, in 2016, Indonesia recorded 43.88 kg/capita/year (KKP & JICA, 2017), Malaysia with 59 kg/capita/year (FAO,2021a), and Thailand with 27.2 kg/capita/year (FAO, 2021b), while the Philippines reported 36.8 kg/capita/year of fish consumption in 2015 (BFAR, 2019). Moreover, the rise of aquaculture is timely and relevant to the increasing demand for fish and fishery products and the dwindling supply of wild fishery stock due to overexploitation (Little *et al*., 2016). As a result, the aquaculture sector is expected to grow continuously in the future (Bostick, 2008).

Adverse impacts of aquaculture intensification

Aquaculture expansion is inevitable and likely to increase rapidly for the next 40 years due to the growing demand for fish as the human population is expected to continuously rise (Hall *et al*., 2011; Godfray *et al*., 2010). Increased aquaculture production comes with increasing environmental impacts (Hall *et al*., 2011). Even though ecosystems have a remarkable ability for recovery, poor aquaculture management has resulted in irreparable damage (Martinez-Porchas & Martinez-Cordova, 2012). The environmental impacts of aquaculture vary with species, system, management, production methods, intensity, location, and environmental carrying capacity to absorb impacts (Little *et al*., 2016).

- *Destruction of habitats*

Mangrove systems in Southeast Asia are the world's most biodiverse and have contributed a wide array of commodities and services critical to the coastal community lifestyles, such as protection from typhoons and storm surges, erosion control, sediment trapping, nutrient recycling, and wildlife habitat, and nurseries (Primavera, 2006; Macintosh, 2011; Garcia *et al*., 2014). However, aquaculture development, such as the construction of shrimp ponds, has negatively impacted coastal ecosystems due to a significant decrease in the acreage of mangroves (De Silva, 2012; Garcia *et al*., 2014). The conversion of mangrove forests means destroying the natural habitat that supports microscopic to huge terrestrial and aquatic wildlife as well as damaging the breeding and nursery grounds of many commercial aquatic faunas (Bagarinao & Primavera, 2005).

Between 1980 and 2005, Asia lost over 54 percent of the total world mangrove areas, with aquaculture accounting for 12 percent of that loss (Giri *et al*., 2008). In the Southeast Asian region, Indonesia with approximately 28 percent of the world's mangrove forest lost about 3.11 percent between 2000 and 2012 (Hamilton & Casey, 2014). About 17 percent of the mangrove area in Malaysia was lost from 1965 to 1985 (Barbier & Cox, 2004). Philippines, holding at least 50 percent of mangrove species (around 65 species) of the world (Garcia *et al*., 2014), lost an estimated 279,000 h or 50 percent of mangrove area from 1951 to 1988 mainly due to pond construction (Primavera, 2000). In Thailand, the construction of shrimp farms diminished the mangrove cover from 312,700 ha to 168,683 ha between 1975 to 1993.

- *Loss of biodiversity*

The aquaculture sector has been over-dependent on the wild population for fish meal and fish oil production (de Silva, 2012). Fishmeal and fish oil are important feed ingredients in aquaculture, and its global use has significantly increased despite several developments done in the feed industry to lower feed conversion ratios (Huntington & Hasan, 2009). Large quantities of fish collected for the production of fish meal and fish oil have contributed to excessive fishing pressure on some fish populations, with potentially detrimental implications (Leadbitter, 2019). With this, there is scientific agreement that fish populations are rapidly depleting worldwide (Jenkins *et al*., 2009), and some argue to instead use it directly for human consumption (de Silva, 2012).

Diana (2009) listed the effects of aquaculture on biodiversity (**Box 35**). In addition, the introduction of alien fish species is considered as one of the biggest threats to finfish biodiversity, with direct and indirect impacts that can have immediate or long-term effects (De Silva *et al*., 2009). Predation and diseases are the potential direct effects of alien fish introduction, resulting in decreases in native species, endangering species, and eventually leading native species to extinction. In addition, indirect consequences classified into two categories could include ecological impacts (*e.g.* habitat damage, competition with native species) and genetic change (*e.g.* hybridization, introgression), all of which could lead to displacement or extinction of native species (De Silva *et al*., 2009).

Box 35. Effects of aquaculture on biodiversity

- Escapement of aquatic crops and their potential hazard as invasive species
- The relationships among effluents, eutrophication of water bodies, and changes in the fauna of receiving waters
- Conversion of sensitive land areas such as mangroves and wetlands, as well as water use
- Other resource use, such as fish meal and its concomitant overexploitation of fish stocks
- Disease or parasite transfer from captive to wild stocks
- Genetic alteration of existing stocks from escaped hatchery products
- Predator mortality caused by, for example, killing birds near aquaculture facilities
- Antibiotic and hormone use, which may influence aquatic species near aquaculture facilities

Aquatic pollution

- *Excess feeds*

Fish nutrition and feeding are critical to aquaculture sustainability, wherein, as fish farming becomes intensive, it also becomes less dependent on natural food and more reliant on prepared feeds. However, aquafeeds are a significant source of pollutants in the aquaculture production system (Millamena *et al*., 2002). The composition of feeds and feed conversion affect both the physical and chemical nature of waste materials and the amounts produced (Alava, 2002). Aquaculture wastes from feeds can be categorized as solid wastes and dissolved wastes. Solid wastes are primarily derived from excess feeds and fecal matter that remain suspended in the water culture system or settle and be deposited as organic matter at the seabed and pond bottom soil, resulting in sediment chemistry and biology changes (Dauda *et al*., 2019). Excess dissolved nutrients in water like phosphorus can lead to eutrophication of water bodies (Patrick, 2017). Both these wastes are present in the water of the culture system and, if they exist at elevated levels, may negatively affect the water quality and harm the fish and other inhabitants. The routine method used in dealing with this problem is the continuous replacement of the unsuitable water through water exchange using clean water (Chatla *et al*., 2020). Discharge of this untreated poor-quality water to the environment could contaminate the nearby culture systems and the natural aquatic environment, resulting in acute toxic effects and long-run environmental risks (Dauda *et al*., 2019).

- *Chemicals*

For the past years, chemicals were used as therapeutants, disinfectants, algicides and pesticides, plankton growth inducers (fertilizers and minerals), feed additives, and water and soil treatment compounds (Rico *et al*., 2012; Primavera 2006). The unnecessary release of these chemicals to the natural aquatic environment could cause significant impact and environmental toxicity at elevated levels.

- *Antibiotics*

Antibiotics were widely used and successful in treating aquatic animal diseases. However, indiscriminate use of antibiotics, specifically in intensive farming, results in residues of antibiotics in cultured products and bacterial resistance. Bacterial resistance has been observed in widely used natural antibiotics, namely: erythromycin, oxytetracycline, tetracycline, and chloramphenicol. Modes of application, such as oral administration using feeds containing antibiotics, bath treatment, and pond sprinkle, affect the aquatic environment. In Malaysia, low to moderate tetracyclines and sulfonamides, and quinolones with a level higher than the two were already widely distributed in Malaysian farms (Chen *et al*., 2020). In the Philippines, aquaculture intensification has led to the use of various chemical products such as oxytetracycline, oxolinic acid, chloramphenicol, and furazolidone, which have been incorporated in artificial feeds of shrimps as treatments against luminous vibriosis (Cruz-Lacierda *et al*., 2000). However, it has been suggested that the use of antimicrobials must be avoided since this could lead to the development of drug-resistant strains of bacteria that may affect future therapy of shrimp diseases (Tendencia & de la Pena, 2002).

Alleviating the negative impacts of aquaculture

Aquaculture development will not be sustainable unless there is a significant improvement in the local, national, and regional planning and management considering the environmental, social, economic, health, and animal welfare concerns (Salin & Ataguba, 2018). Besides, aquaculture should also operate in line with other primary food-producing sectors such as agriculture and animal husbandry within ecological limits to reduce environmental degradation (Edwards, 2015). Although aquaculture can alleviate unemployment and poverty, the environmental repercussions must not be sacrificed on the platform of poverty reduction (Salin & Ataguba, 2018). Therefore, a balance must be attained between increasing productivity while reducing environmental consequences. A holistic approach involving stakeholders should be adopted for aquaculture to reach its goal of food security and poverty alleviation without causing harmful effects on the environment (Primavera, 2006). With proper monitoring and management, the impacts of aquaculture on the ecosystem and biodiversity could be kept to a minimum (Salin & Ataguba, 2018). Over the past decade, national development laws, policies, strategies, and plans, including best management practices and manuals on farming techniques, are being made in addressing the negative impacts of aquaculture (Hishamunda *et al*., 2012).

- *Habitat rehabilitation*

Several efforts on restoration and rehabilitation of mangrove areas have been successfully initiated in various parts of Southeast Asia including Indonesia (Kusmana, 2017), Malaysia (Hashim *et al*., 2010), Philippines (Primavera & Esteban, 2008), Thailand (Kongkaew *et al*., 2019), and Viet Nam (Hai *et al*., 2020) that reversed the widespread environmental problems associated with mangrove destruction and degradation (Macintosh *et al*., 2002). In Indonesia, different planting designs (*e.g.*, square, zigzag, and cluster) and techniques (*e.g.* "banjar harian," bamboo pole, *guludan*, water break, enormous polybag, ditch muddy, huge mole, and cluster) had been used to rehabilitate damaged mangrove ecosystems utilizing *Rhizophora* spp. (Kusmana, 2017). A coastal structure has been used in Malaysia in conjunction with a mangrove restoration project in coastal forests that are prone to erosion, resulting in 30 %

mangrove sapling survival after eight months of monitoring (Hashim *et al*., 2010). In the Philippines, several successful mangrove rehabilitation activities had been carried out by the national government. Its implementation was done at the grassroots level in excellent coordination with local government units, non-governmental organizations, and local communities through people's organizations with regular monitoring and field visits (Primavera and Esteban, 2008). With the help of NGOs, government cooperation, and the stabilization and strengthening of sustainable management, Thailand's community-based mangrove management has also been particularly successful (Kongkeaw *et al*., 2019). Rehabilitation success in Viet Nam was attributed to several reasons, including careful species selection, explicit monitoring and reporting standards, and the implementation of a co-management model that gives incentives for local populations to profit from the management of restored mangroves (Hai *et al*., 2020). Furthermore, mangrove-friendly aquaculture technologies had been adopted in mangrove conservation and restoration sites by small-scale, family-based operators by rearing aquatic organisms in an enclosed area without allowing mangrove trees to be cut. Examples of these aquaculture technologies include silvofisheries in Indonesia, aquasilviculture in the Philippines, and mangrove-shrimp ponds in Viet Nam (Primavera, 2006).

- *Stock enhancement*

Several stock enhancement activities have already been done in Southeast Asia, which include the successful stocking of common carp and several gouramis in Indonesia (Kartamihardja, 2016), Nile tilapia and Indian major carp in Lao PDR (Garaway *et al*., 2006), tiger shrimp, giant clam, abalone, and mangrove crab in the Philippines (Altamirano *et al*., 2016; Lebata-Ramos *et al*., 2016; Salayo *et al*., 2020), and various freshwater species in Viet Nam (Dzung, 2016).

Stock enhancement requires clear and well-defined objectives and well-formulated stocking strategies that consider the risk, benefits, environment, and fish stocked. Harvest yields and the social, economic, and cultural benefits are all essential factors to consider when evaluating stocking success. Furthermore, fisheries management measures, such as fisheries policies, rules, and guidelines for dealing with property and access rights, must be implemented to assist stock enhancement (Ingram & de Silva, 2015). Lebata-Ramos *et al*. (2016) suggested that any stock enhancement action should be preceded by a baseline evaluation of the population of the target species for release (**Box 36**).

Box 36. Baseline assessment of the population of target species for release before stock enhancement activity

- Assessment of the habitat for the presence of food and shelter for the stocks to be released
- Consider possible predators that may prey on the released stocks
- Animals for release should be tagged to differentiate them from their wild conspecifics
- In areas where poaching is prevalent, secured areas such as marine protected areas, sanctuaries, and the like are the recommended sites for release to provide stocks with some form of protection
- Proper information dissemination should be employed before releasing for all stakeholders to be aware of the proposed activity, which may, in one way or the other, affect their livelihood

- *Integrated multi-trophic aquaculture*

Over the years, environment-friendly and integrated aquaculture had been considered as one of the mitigation approaches to address aquaculture waste, especially excess uneaten feeds and nutrients in the culture system. Currently, the integrated multi-trophic aquaculture (IMTA) is an economically and environmentally sustainable aquaculture practice that involves a combination of fed-species and extractive species to be effective and efficient (Edwards, 2015; Jumah, 2020; Park *et al*., 2018).

Several studies have already been conducted on the IMTA system which is aimed at reducing waste in the culture system and obtaining additional income from the extractive species. One of these is the combination of milkfish (*Chanos chanos*), sandfish (*Holothuria scabra*), and seaweeds (*Kappaphycus* sp.) in a pen culture, which was carried out in Guimaras, Philippines. Since sea cucumber was found to have an excellent performance in reducing the fecal matter of the cultured fed species, a combination of finfish, sea cucumber, and macroalgae is highly recommended (Jumah, 2020). In addition, IMTA in the open waters of Cebu, Philippines made use of the donkey's ear abalone (*Haliotis asinina*) as fed species and seaweeds (*Gracilaria heteroclada* and *Eucheuma denticulatum*) as inorganic extractive species resulting in the successful growth of the two-month-old hatchery-bred donkey's ear abalone. The abalone reached 53.8 × 28.2 mm (L × W) and body weight of 37.8 g after 12 months. The red seaweeds, *G. heteroclada*, and *E. denticulatum* functioned as a natural filter of ammonia and nitrate but not nitrite and phosphate (Largo *et al*., 2016).

- *Feeding management*

As suggested by Dauda *et al*. (2019), the immediate solution in managing the environmental impacts of aquaculture is proper feeding management that can reduce wastes resulting from the fish feed. Boyd (2003) also suggested some practices for proper feeding management that include the use of high quality, water-soluble feeds that contain only the required amount of nitrogen and phosphorus and application of feeds conservatively to avoid overfeeding and ensure that much of the feed is consumed as possible. Aquafeeds should be environment-friendly by considering new knowledge on nutrient requirement and digestibility and improving the techniques of producing more water-stable feeds and broader use of alternative protein sources (Millamena *et al*., 2002).

SEAFDEC/AQD has been strengthening its research and development activities to identify and employ cost-effective feed ingredients as alternatives for fish meal, the major dietary protein source for aquafeed production. Alternative protein sources are considered to reduce environmental impact and lower costs in aquaculture, especially if these ingredients are locally available. Several nutritional studies involving fish protein substitutes (plant, terrestrial animals, and fish by-products) in fish diets have been conducted, with results indicating that some feed ingredients could be used commercially without affecting fish growth or revenue from the farmed fish. Also, the use of distiller's dried grains with soluble (DDGS), hydrolyzed milkfish offal, mungbean produced positive results in laboratory experiments (Mamauag, 2016). Furthermore, research on the utilization of low-cost feed is being undertaken to reduce reliance on the fish meal for aquafeeds (SEAFDEC/AQD, 2020).

- *Zoning and site selection*

A coherent legal and regulatory framework for aquaculture zoning and site selection in bodies of water as well as the granting of tenure rights and aquaculture permits should be established (Aguilar-Manjarrez *et al*., 2017). As an initial step towards local-scale aquaculture licensing, a carrying capacity assessment is required to define and quantify potential aquaculture zones (Ross *et al*., 2013). With this, legislation can help promote, regulate, and develop aquaculture in a controlled manner.

In addition, various combinations of technological advancements, improvements in the existing technologies and management techniques, and better site selection to satisfy the ecosystem's carrying capacity may be the solution to environmentally sustainable aquaculture. Carrying capacity, or "the potential maximum production a species or population can maintain in relation to available food resources" (Davies & McLeod, 2003), is a vital idea for ecosystem-based management (Ross *et al*., 2013).

Progress in R&D is already being achieved in reducing the adverse environmental impacts of intensive aquaculture effluents. However, codes of conduct, best management practices (BMPs), good aquaculture practices (GAqP), and the ecosystem approach to aquaculture (EAA) should be implemented extensively to better integrate aquaculture into inland watersheds and coastal zones with a more productive utilization of land and water (Primavera, 2006; Philippine National Standard, 2014; Edwards, 2015).

Way Forward

The rapid rise of aquaculture is considered a significant contribution to world fish supply and a solution to the declining productivity of marine fish stocks due to overfishing and helps to ensure food security. However, the intensification of aquaculture has produced several environmental concerns, including loss of biodiversity, destruction of habitats, and aquatic pollution, among others. Improving and re-designing aquaculture is necessary to minimize its negative impacts and make it more environment-friendly and sustainable.

SEAFDEC/AQD is gearing towards improving fish production that will contribute to the livelihood of the stakeholders through developed aquaculture systems that are sustainable, economically viable, environment-friendly, and socially equitable. Responsible aquaculture entails the development of environment-friendly technologies and monitoring its impacts on biodiversity and water quality. As a result, various research and verification projects are continuously being done to generate high-quality seed stock, specifically shrimp postlarvae, using enhanced biosecurity measures and environment-friendly schemes. In partnership with the National Fisheries Research and Development Institute (NFRDI) of the Philippine the Bureau of Fisheries and Aquatic Resources (BFAR), cost-effective feed formulation is also being done in various aquaculture locations in the Philippines. Currently, SEAFDEC/AQD is continuously refining protocols in nutrition, seed production, grow-out, and health management (SEAFDEC/AQD, 2020).

In addition, other organizations such as the WorldFish Centre also target to strengthen livelihoods and enhance food and nutrition security by improving fisheries and aquaculture through developed technological innovations, supported institutions and policies, and delivering transformational impacts. The challenge of building sustainable aquaculture and resilient small-scale fisheries and enhanced contribution of fish to nutrition can only be addressed by partnering with the communities, research innovators, entrepreneurs, and investors who play essential roles in co-creating demand-driven research (WorldFish, 2020). On the other hand, the Network of Aquaculture Centres in Asia-Pacific (NACA) continues to publish a wide range of publications, including technical papers and manuals, policy briefs and guidelines, certification standards, codes of practice, and other voluntary aquaculture instruments to guide better management practices to improve crop outcomes and on-farm resource utilization efficiency leading to enhanced profitability of farmers and environmental performance.

Reducing the negative environmental implications of intensive aquaculture effluents is already progressing in R&D. The results of scientific studies should be adequately and broadly shared with fish farmers and local communities.

Furthermore, research organizations must work in close collaboration with policymakers and government agencies to better understand and apply environment-friendly technologies and attain sustainable and responsible aquaculture.

7.1.7 Genetics in Aquaculture

In 2018, global aquaculture production (82.1 million mt) was almost at par with capture fisheries production (96.4 million mt) with the increased farmed fish production dominated by contributions from Southeast Asian countries (FAO, 2020). Aquaculture production statistics in 2018 showed that Indonesia, Philippines, Thailand, and Viet Nam are among the top aquaculture-producing countries in the region. This notwithstanding, the annual growth rate of aquaculture production, in general, has been decreasing for the past 10 years, which could be attributed to global challenges in fish farming and inbreeding such as the lack of quality seedstock, adverse impacts of climate change, environmental degradation, fish diseases, high cost of inputs (*e.g.*, feeds), and others. Some of these problems could be due partly to aquaculture intensification, which could be avoided or minimized. Aquaculture in the Southeast Asian region has not been spared from such issues; hence, research and innovations, be these environmental and genetic interventions that could help resolve these challenges, are important.

Genetic tools for improved fish production

Environmental or non-genetic methods, *e.g.*, culture systems improvement, husbandry techniques, and others, that can improve subtropical and tropical aquaculture yield, have been well studied in Southeast Asia. In contrast, research and programs on genetic and genomic interventions in aquaculture have been relatively slow, especially since these approaches, particularly genomics, require scientific and highly technical laboratory and bioinformatics skills. This situation occurs because information on linkage maps, reference genomes, and single nucleotide polymorphism (SNP) arrays in tropical aquaculture species is still lacking. In addition, such programs (*e.g.*, genome-wide association studies or GWAS) have high investment costs since genomic selection requires genotyping large numbers of samples (Khatkar, 2017).

Research advancements in aquaculture genetics, which applies theories of heredity and variation of inherited characters or traits in farmed fish, and aquaculture genomics, which is a branch of molecular biology that deals with the structure, function, and mapping of complete sets of genes (also known as genomes) in aquatic organisms, have become of interest in recent years. Genetics and genomics are both biological disciplines that allow an understanding of how production and performance traits are passed on through generations in a particular aquatic species and how their genes influence the expression of phenotypic traits and physiological functions. As a means or tool in stock improvement, genetics has been used more often in plant breeding (*e.g.* variety development) since plants can be easily bred and manipulated genetically. On the other hand, aquatic animals have more complex genetic, reproductive, and physiological mechanisms. Nevertheless, several genetic improvement programs on commonly farmed fish and crustaceans have been implemented in Southeast Asia in three decades, starting with applying traditional selective breeding schemes mostly on low-value species that have short generation intervals such as tilapias. In the last five years, advanced schemes supported by genetic markers or genomic information have been conducted. Starting with genetic profiling of aquaculture stocks using DNA markers (*e.g.*, mitochondrial DNA markers, simple sequence repeat markers or microsatellite markers, single nucleotide polymorphism markers, and others), the results can later be used as a reference to fast-track genetic improvement via marker-aided broodstock management and selective breeding. **Table 75** summarizes the various species and the conventional genetic programs (some complimented with DNA marker tools for tagging and genetic traceability) used by public research and development agencies and some privately-operated fish production industries in quality strain development.

Genomics studies, on the other hand, have likewise been pursued and later on applied to determine the genes linked to important production traits, such as growth, reproductive efficiency, disease resistance, stress tolerance (especially heat stress due to climate change and sex determination), among others. Genomic data such as RNA sequencing (RNA-seq) to profile transcriptomes provide a valuable resource to evaluate gene function and genetic variants within genes. It is particularly useful in identifying genes involved in immune response and an organism’s reaction to environmental factors like water temperature (as reviewed in Yañez *et al*., 2020). Most of these genetics and genomics research, aside from earlier studies on tilapia genetic improvement, which mainly utilized international funds, is supported by grants from both international and local sources. Some research is also done as collaborative initiatives among Southeast Asian countries with the primary intent of sustainably managing aquatic genetic resources in conservation and aquaculture. Examples are the genetic management and conservation of the tropical Anguillid eels, Carangid species, commercially farmed seaweeds, mangrove crabs, and others. **Table 76** lists the different genetic stock diversity studies and aquaculture genomics work on stocks bred and developed in Southeast Asia. Although costly, the ultimate goal of having a genetic marker or genome-wide molecular marker research is to generate reference data for marker-assisted selection, genome-wide association studies, genomic selection, and, if permitted, gene editing and other more advanced genetic improvement technologies.