7. Aquaculture Development

7.1 Status, Issues, and Concerns

7.1.1 Socioeconomic Importance of Aquaculture for Food Security and Poverty Alleviation

Southeast Asia is home to 661.5 million people or about 8.5 % of the world's total population in 2020, with an average GDP per capita of USD 5,017 (World Bank, 2021). Although not fully recognized as a major contributor to GDP, the productivity of aquaculture and its ancillary industries add to the growth of the GDP of the Southeast Asian countries. Noteworthy to mention is the role of aquaculture as leverage in managing and improving the balance of trade through seafood trade for food and industrial needs of importing countries. In countries like Indonesia, Myanmar, the Philippines, Thailand, and Viet Nam, the aquaculture sub-sector contributes to the means for reducing trade deficit at lower opportunity costs. High levels of local fish production also create food sufficiency for domestic consumption and offer a good reduction in fish importations.

The availability of locally produced food fish to feed the growing populations of Southeast Asian countries would mean lower costs due to reduced transport costs. More so, when aquaculture products in various forms are exported, especially the high values such as shrimps and those processed in higcostsh value forms, contribute significantly to the export incomes of the Southeast Asian economies, notably in Thailand, Indonesia, Philippines, and Myanmar. However, the contribution to foreign currency earnings statistics related to export income from aquaculture products is not generally available and this affects the estimation of the contribution to foreign currency earnings through exports of aquaculture products. Nonetheless, in view of the contribution of aquaculture to Southeast Asian countries' GDP through earnings from the exportation of aquaculture products, the importance of aquaculture to the national economies in terms of poverty alleviation and nutritional benefits needs a thorough evaluation.

The world's population by 2050 is projected to grow to about 10 billion, and consequently, food demand would also increase. The aquaculture industry has grown globally, and its generally high levels of productivity continue to successfully fill in the shortage of fish supply from capture fisheries. FAO (2016) reported that fisheries and aquaculture provide income and support livelihoods for many people around the world, and it has been estimated that many developing countries in Asia would contribute over 80 % of total aquaculture production to the world's food system. Most Southeast Asian countries are the major net exporters of food fish for consumption around the globe. Many of these exports are mainly finfishes and shrimps, as well as other aquatic resources for non-food and industrial uses such as seaweeds. The aquaculture sub-sector provides luxury to gourmet seafood diners and health-conscious consumers of metropolitan centers of the world. Production and exports of seafood come from a variety of aquaculture production systems, including those practiced by industrial and small-scale producers. The industrial production scale dominates the brackishwater shrimp and freshwater tilapia aquaculture. Medium and small-scale producers are often the source of high-value farmed finfishes such as groupers in the live food fish trade. In contrast to industrial aquaculture in developed countries which has gained significant private investments, aquaculture systems in Southeast Asia are predominantly small-scale and family-owned, managed, and operated as small-scale endeavors (European Environment Agency, 2016). The contribution of small-scale aquaculture (SSA) to economies is evident and significant in most developing countries, while a range of benefits could also be obtained by households not directly involved in fish culture but through indirect linkages. Households can benefit from an increased supply of fish and fish-based products in local markets, as well as from reduced prices of fish. Furthermore, increased opportunities for employment are not only generated along the fish farming value chain, but also through the direct employment on farms, and associated services such as the production of aquafeeds, seeds, and fertilizer (Karim *et al*., 2020).

Role of aquaculture in national economies of Southeast Asian countries

In spite of the role of many SSA producers in seafood production for local consumption and export trade, poverty and food insecurity in fishing and aquaculture communities persist right in these food production areas in Southeast Asia. One deep-seated reason is that poverty is rooted in the insecurity of jobs and income sources in the aquaculture sub-sector. Hunger and food insecurity remain a challenge and are most devastating and formidable for the world's poor and disadvantaged (Blanchard *et al*., 2017; Tacon & Metian, 2018). How do we feed the world nutritiously and equitably while sustaining the natural capacity of resources to provide food and other equally essential services?

While the development of aquaculture is mainly driven by an increase in demand, production, and associated income, the growth of this sub-sector is constrained and disproportionately influenced by several socioeconomic factors, including access to financial capital and land-use policies. For example, water bodies in some Southeast Asian countries such as Myanmar, remain unexplored for SSA even if aquaculture in these water bodies would likely show potential benefits (Karim *et al*., 2020). Nevertheless, a significant potential contribution of SSA to local and regional markets in providing increased income and health nutrition could be expected (Belton *et al*., 2015).

A study of aquaculture industries in Central Visayas in the Philippines revealed the socio-cultural and economic aspects of aquaculture right in coastal fishing communities (Rica, 2015). Most (79 %) of the aquaculture production systems are conducted in freshwater ponds producing Nile tilapia, *Oreochromis niloticus*, and in brackishwater ponds that grow milkfish, *Chanos chanos*. These ponds are being operated by private individuals who often informally hire individuals or families living near the aquaculture sites as caretakers and helpers on a non-permanent and on-call basis. Ironically, aquaculture operations are labor-intensive as caring for live aquatic animals requires the full-time engagement of caretakers. Food security is compromised as observed by the periodicity of consumption in these communities. The regularity of consumption, not necessarily of fish but of most food items in general, is normally low but with periodic high only during harvest time (50 %) which usually happens every 3 - 4 months, as oftentimes wages and commissions are delayed until harvest. Nonetheless, the staple rice is generally secured as it is being provided by the aquaculture enterprise owners as part of the compensation for the caretakers of the fishponds. In comparison, capture fishers do not have this assured supply of staple rice. Overall, aquaculture enterprises developed in capture fishing communities have provided some level of food security to fish farm workers. More so, the increasing demand for ancillary services required in aquaculture farms and fish marketing enterprises has created more jobs, although similarly insecure, for households in the vicinities of aquaculture farms. Aquaculture, therefore, although to a limited extent, helps to provide access to staple food for its workers and spares its workers from poverty. However, the security of jobs and food sources needs improvement.

Potential aquaculture stakeholders need access to affordable low-risk aquaculture technologies, markets, control, and access over common property resources and rights to participate in aquaculture development planning. Aquaculture has brought employment that contributes to poverty reduction in developing countries such as the Philippines, Cambodia, and Viet Nam (Irz *et al*., 2007; Nguyen *et al*., 2016; Sheriff *et al*., 2008). In some rural areas in Cambodia for example, poverty is linked to food insecurity. The fisheries sector of Cambodia has undergone a major reform that prioritizes poverty alleviation and food security. According to the study of van Brakel & Ross (2011), the majority (65 %) of the rural households are either landless or land poor, owning one hectare or less of land, and usually net buyers of food. Food consumption amounts to 70 % of the total household expenses. Capture fisheries contribute mainly to food security, nutrition, and income generation. Through pond-based and rice-fish aquaculture, the development of its aquaculture subsector has received increasing attention because of its potentially important role in providing food security and rural income generation. Aquaculture in cages and pens are the major fish farming systems in inland areas in the country. However, this culture system is highly dependent on feeds using fish from the wild. Concerns have therefore been raised over the impacts of the mounting demand for fish food on the availability of fish protein sources to consumers, as well as its detrimental effect on the environment. Thus, concerns about wild seed supply, availability of fish feed, and the integrity of water quality should be addressed.

In Viet Nam, Nguyen *et al*. (2019) found that the growth of aquaculture productivity enables poverty reduction that seems to have a more significant effect on the not-so-poor than the ultra-poor sectors of the economy. Further, it also revealed that the higher the value of fish species, the more likely is the impact of aquaculture productivity marked on poverty reduction. Shrimps and lobsters are high-value species exported such that several aquafarmers are engaged in various farming activities of such commodities. Thus, aquaculture production improves farmers' scarce resources while at the same time, stimulating the overall economic growth. Similarly, van Houng and Cuong (2012) highlighted that the increasing availability of seeds, appropriate control of inputs, and access to loans for capital investments enhance aquaculture's contribution to the poor farmers' income and food security. Subsequently, it can be an effective solution to alleviating hunger and poverty since freshwater aquaculture plays a crucial role in stabilizing concerns on fish food supply in fish capture scarcity.

Indonesia is one of the major global aquaculture producers for both domestic and international markets. Aquaculture and capture fisheries are essential contributors to the Indonesian economy providing food security, income generation in rural areas, and significant export earnings. Aquaculture is a growing sub-sector with potentials for expansion and is deemed as an essential contributing factor to the four national pillars of development in terms of economic growth, creation of job opportunities, reduction of poverty, and environmental recovery and mitigation (Rimmer *et al*., 2013). While Indonesia emphasizes the economic importance of aquaculture production in generating income from rural communities and exporting commodities to bring in foreign earnings to the country, it also thrusts on the expansion of markets and improved trading advancement that links economic transformation and the marketing of diversified products. It is the gateway to international markets that can strengthen and capacitate human skills in trading and exporting aquaculture products.

Thailand is likewise one of the world's sources of seafood from capture fisheries and aquaculture. Shrimps (*Penaeus vannamei* and *P. monodon*) and freshwater prawns (*Macrobrachium rosenbergii*) are major exports produced in large-scale and medium-scale farms that provide benefits to corporate investors and a multitude of workers and traders. The study by Sheriff *et al*. (2008) meanwhile showed that grouper culture provides an

opportunity for poor households to engage in fish culture and generates substantial financial benefits. However, the role and contribution of aquaculture in economic growth are being challenged by the need for financial capital and access to credits, as capital investments are required in the development of aquaculture, and these concerns have also been felt by SSA operators. With limited capital to finance aquaculture operations, especially industrial-scale enterprises, exposure to risk and uncertainties are a major concern among stakeholders.

In the Philippines, Irz *et al*. (2007) found strong evidence that aquaculture contributed to the alleviation of poverty in rural areas. In-depth analysis of the sharing of benefits among low-income fish farm workers and the better-off investors in fish farming operations showed that the former received a relatively large share of the revenue from aquaculture than the better-off people whose financial investments in aquaculture production systems are highly exposed to risks. Aquaculture enterprises, big or small, have primarily employed unskilled workers, often with insecure terms of engagement. However, the study was conducted several years ago, and it is unknown whether the benefits for the poor are sustained.

Singapore reported the prevalence of family-based ownership of most aquaculture farms (Shen *et al*., 2021). A relatively small farm that can produce 600 mt of fish per year is unwilling to invest in new technologies, fearing that recouping their investments might not be possible once the technology fails. Thus, private investments and agri-tech venture capital, especially in aquaculture operations, are poorly developed as they are unfamiliar with the industry. There are constraints in migrating or transferring from the low-technology to high-technology production systems, although the future of the aquaculture industry of Singapore is leaning towards the need to invest in high technology, bio-secure, space-efficient, and dynamic aquaculture operations. Singapore is a small county, but it is positioned to serve as a research and education hub for R&D on tropical aquaculture that should focus on reproduction, genetic improvement, and hatchery technologies generating a genetically improved seed for local and overseas production.

The aquaculture feasibility study of Brunei Darussalam conducted by the ASEAN-Japan Centre in 2021 categorized that the aquaculture industry has a high potential for contributing to the country's economy and has therefore been engaged as a leading alternative industry for the country's economy. With the objective of increasing fisheries output, the Government of Brunei Darussalam is promoting export-driven aquaculture activities towards foreign investors. Although the country has limited natural water resources available within and surrounding its territory, it propels further expansion and investment for aquaculture through a vital industry that overall contributes to the fisheries sector.

Brunei Darussalam is engaged in various aquaculture farming systems. Pond culture is the most basic form of aquafarming used by farmers. Since this type of system does not require complex technology, capital costs are generally lowered. Such system is commonly used for the production of freshwater fish and prawns. On the other hand, marine fish farming in floating cages is common in coastal and inshore areas but is usually operated by commercial and foreign investors due to its high requirements for capital and operation costs. Recirculating aquaculture system (RAS) farming is commonly adopted in both the marine and freshwater fish in either concrete or fiberglass tanks. While RAS is environment-friendly, it needs more capital input due to the costs of its filtering systems. Highlighting the country's aquaculture industry potential for further expansion and contribution to economic development, foreign investments usually venture into large-scale and commercial companies because of a faster and higher rate of return on investment. While investment in small-scale enterprises still exists in the industry, it is minimal. Nonetheless, benefits are still evident from these small players because they stimulate the local economy, foster long-term economic sustainability for these businesses, and contribute to the industry's value chain system, opening more opportunities as the industry further develops.

In Lao PDR, aquaculture also plays a crucial role in sustaining food consumption. It is an alternative source of fish as well as other aquatic organisms especially when fish are inaccessible (Dalasaen & Amnath, 2016). Fish is preferred and considered the primary source of animal protein for most people in Lao PDR. A study reported that fish farmers in Lao PDR become involved in pond fish culture due to its relatively low entry cost, particularly, in constructing ponds. Likewise, fingerlings of tilapia and carp are again accessible from nearby countries (Garaway, 2005). Nevertheless, there have been no recent studies citing that aquaculture has significantly reduced the nation's poverty.

The country report of Malaysia revealed that aquaculture is a strong driver of the nation's economic growth. It is projected that the aquaculture sub-sector would address the continuous demand for fish consumption and reduction of fish supply due to overfishing with the growing population of the country. Further, Yusoff (2015) reported that the Malaysian government initiates a program to develop locations for the culture of various high-value aquatic species. The program is meant to strategize the Malaysian Government's goals towards food security, job opportunities generation, and increased income earnings.

Enhanced role of aquaculture during the COVID-19 pandemic

Discussions about the role of aquaculture in poverty alleviation and food security will not be complete and updated without looking into the impacts of the COVID-19 pandemic, which has caused significant shocks affecting the coastal social-ecological systems in different parts of the world (Manlosa *et al*. 2021). Its widespread impacts have unraveled vulnerabilities in many aspects of society, including food systems. Specifically, fishing and aquaculture operations and the trade of high-value tropical seafood harvested are constrained by limited shipment and more stringent international transport measures. Thus, the likelihood of reduced export earnings and compromised trade balance has been a major concern (Bennett *et al*., 2020; Zhang *et al*., 2021)

Nonetheless, the fisherfolks and small-scale aquaculture operators who are important players in the food fish production systems had already been living in a difficult situation even before the pandemic. The untoward impacts of the health pandemic, such as increased health risks especially for the already marginalized fishing households in remote and poverty-stricken fishing communities due to further lack of food, malnutrition, and constrained access to health facilities, had enhanced the impacts. Lost jobs for women in the processing sector, market disruptions, lower demand, and access to high-end markets, especially for highly perishable fish and products, are among the severe situations that affected the global food system (Bennett *et al*. 2020).

Nevertheless, some studies had established some trends that showed the resilience and innovativeness of the stakeholders in the aquaculture and fisheries sector to be able to perform its role in securing fish supply in the midst of the impacts of the COVID-19 pandemic (Bene, 2020). There is a probable lower disease infection rate as operators and workers in fish farms are fairly stationary than in capture fisheries which are characterized by the migratory nature of fishing activities (Bennett *et al*., 2020). In many communities of fish farmers, there is a resurgence of food fish, and aquatic resource sharing during the crisis. This has occurred in areas around the tilapia growing systems in lakes in rural Laguna in the Philippines (Magcale-Macandong *et al*., 2021). In smaller distant fishing communities, the revival of local food networks through direct selling of fish within the immediate community, either at low prices, barter, or give-away, is more profound to address hunger and avoid sickness aside from those symptoms associated with the pandemic (Bollido, 2020). In more urban and metropolitan areas, there is a shift in demand for seafood raw materials or pre-cooked seafood from restaurants to residences inclined to home cooking. During the crisis, some opportunities, therefore, arise, *i.e.* 1) enhanced collective action among fish farmers, fishers, and traders and local government; 2) application of the already existing ecosystems approach to fisheries management during the pandemic period; 3) for the enterprising fishers, networking, online selling, and deliveries offer improved income and employment opportunities; and 4) emergence of small-scale local processing and value-adding of fishery products. Small-scale aquaculture livelihoods are among the opportunities being promoted to complement a short value chain and localized distribution system. Last but not least, opportunities for sea ranching and stock enhancement in intertidal flats to increase economically important fish stocks and harvest. Such strategies are feasible as community quarantine measures include stay-at-home advisories that harmonize with close monitoring and protection of released stocks and monitoring of spill-overs and catch in nearshore waters. Therefore, during this COVID-19 pandemic, the role of aquaculture is manifested and magnified in its continuous performance in the local food systems. Although there were disruptions in the geographic functionality of the food fish distribution, both involving wild and aquacultured fish that are distributed through a complex and far-reaching trading system (Manlosa *et al*., 2021), the presence of aquaculture systems spread around various locations compensated for making fish available in many fish consumption areas in most Southeast Asian countries.

Two-pronged role of aquaculture for securing food and livelihoods

1. Aquaculture for direct food fish production

The increasing demand for food fish to feed the growing global population in the midst of the declining productivity of some capture fisheries gave impetus for the development and investments in aquaculture technologies. As Southeast Asia recovers from the COVID-19 pandemic, governments and industries must transform their food production systems to make them more modern, climate-proof, and inclusive (ADB, 2021). Looking back, the production of fish juveniles in hatcheries is a major breakthrough that enabled grow-out culture systems to contribute to food fish production to augment the catch from capture fisheries intended for direct human consumption. The breeding and rearing of freshwater, brackishwater, and marine species continue to address the growing demand for fish or animal protein in general. Hence, more than half of the fish eaten around the globe had been produced from aquaculture. When producing food fish through aquaculture, control of the supply of fish in the market gives the fish farmer the ability to create surplus stock or reduce their production to reap optimal profits.

Indonesia produces about 15.6 mt of aquacultured commodities annually, with about 28 % of its aquatic animal culture integrated with rice farming, in the so-called fish-rice farming system. Viet Nam yields 3.6 million mt of aquaculture products annually, mainly comprising catfish

and giant tiger prawn. The Philippines ranked next with 2.3 million mt of produce from aquaculture dominated by milkfish and shrimps. These aquaculture production levels have been highly dependent on seed production and fish farming technologies. Likewise, the success of fish production is also dependent on the advances in feed development, improved fish nutrition, and fish health management, comprising the overall progress in fish culture techniques. These fish production levels in marine aquaculture systems are mainly conducted in large water bodies along the marine coastlines especially in archipelagic countries like Indonesia and the Philippines. Likewise, Viet Nam has a long coastline which is equally beneficial for offshore fish culture operations.

Meanwhile, Cambodia, Thailand, and Viet Nam benefit from the use of the huge Tonle Sap Lake and the Mekong River system for freshwater fish production. These water bodies likewise support aquaculture operations in ponds, tanks, reservoirs, and other forms of water impounding systems. The aquaculture production of Thailand has significantly increased during the last few decades and significantly contributed to the country's socioeconomic development. Estimates of total aquaculture production in Thailand have gradually grown from around 0.6 to 0.9 million mt over the last twenty years. Farmed shrimp is the main animal aquatic product that accounts for about 40 % of the country's total aquaculture production and is closely followed by fish (38 %) and mollusks (22 %). To be assured of a sustainable fish food supply through aquaculture, investors should be innovative and find practical solutions that rely on diverse technology inputs and smart market-based management approaches.

2. *Aquaculture for fisheries conservation, rehabilitation, and improved productivity*

Arising from aquaculture's fundamental role to produce fish for direct consumption, often through intensification of culture systems, there are implications that aquaculture contributes to the endangerment of aquatic biodiversity and the pollution of the environment. On the contrary, there still exists the less well-recognized role of aquaculture in the conservation and recovery of threatened and endangered species. This other role of aquaculture aside from the direct production of food fish for direct human consumption is in the aspects of the restoration of threatened and endangered species populations, and wild stock population enhancement. The aquaculture sub-sector is in an advantageous position to minimize the extinction of the wild relatives of farmed species. In support of this role of aquaculture in the conservation and rehabilitation of threatened aquatic stocks, genetic markers, and genetic stock identification have been used to help differentiate species and stocks of wild and farmed species. Some aquatic species that are threatened in the wild are also farmed to ensure that farmed species are the ones being traded for food and other uses, instead of those from the wild.

Policy and governance support towards sustainable aquaculture

The aquaculture sub-sector around the globe is one of the several food production systems where policy and governance support towards sustainable management and operations is well instituted. The sub-sector is guided by the FAO Code of Conduct for Responsible Fisheries (CCRF) where Article IX is focused on Aquaculture. Thus, both voluntary and legally binding international mechanisms, guidelines, and codes of practice have been developed to ensure adherence to the principles of sustainable aquaculture. Given such a regulatory and governance framework, the role of aquaculture in food production, economic development, and food security is a work in progress. Industrial-scale aquaculture continues to gain the interest of investors and in some cases an item of interest among foreign corporate investors. On the other hand, small-scale aquaculture is being used as a strategy to improve food fish supply in rural communities to address hunger and lack of income opportunities. Small-scale aquaculture is a crucial intervention for food security and nutrition in developing countries because this enables the low capital and labor-rich households to counter poverty and hunger through engagement in the self-sustaining food production system. The contribution of SSA to food security and nutrition should be taken into account in the formulation and implementation of policies, both local and international, while the integration of SSA producers will enable their participation in productive and profitable market enterprises.

Policies and legal framework towards the overall development of the aquaculture sub-sector with a focus on its role in poverty alleviation and food security are imperative to enable the sub-sector to meet the challenges of the new normal. The Asian Development Bank (ADB) recently added that governments in Southeast Asia should enact policies that integrate technology, infrastructure investments, innovation, and regulatory reforms to ensure food security (*e.g.* affordable crop insurance) and continued economic development. Increasing access to credit and microfinance programs with low-interest rates, flexible loan repayments, and options for restructuring loans for aquaculture operators. Digitization of fisheries businesses, both downstream and upstream has been recommended in Indonesia and some other Southeast Asian countries (Indonesian Traditional Fisherfolk Union DPP KNTI, Jakarta, April 17, 2020). Digitization will eventually expand the market access of fishery products to national or international markets, even in the midst of health pandemics.

In view of the significant contribution of mariculture operations in large-scale fish production, Ruff *et al*. (2020) studied the extent of certain socioeconomic, governance, and biophysical factors that can explain country-level

patterns of mariculture production. Results showed that socioeconomic conditions are a significant contributor to whether a country would engage in mariculture and the magnitude of its operations. The socioeconomic parameters, including governance factors, explained up to 33 % more of the variation in mariculture production compared to models including only biophysical parameters. Therefore, improving seafood farming infrastructure, creating local demand for seafood, and facilitating knowledge transfer from land-based and freshwater aquaculture could help countries develop stronger mariculture industries.

In Thailand, policy instruments are recommended to address the problems reportedly encountered by its aquaculture sub-sector that faces a range of production, market, and financial risks extending beyond the private space of farms to include public spaces and shared resources. The Government of Thailand has attempted to manage these shared risks using the lens of territorialization and institutionalized risk management through spatially explicit forms of collaboration among and between farmers and non-state actors in the shrimp and tilapia production sectors in the country (Sampantamit *et al*., 2010). Its findings demonstrate how these policy instruments address risks through dissimilar but overlapping territories that are selectively biased toward facilitating the individual management of production risks while enabling both the individual and collective management of market and financial risks.

7.1.2 Fish Health Management

Aquaculture is the fastest-growing food-producing sector in the world. In 2018, inland aquaculture accounted for 62.5 percent of the world's farmed food fish production. A 527 percent rise in global aquaculture production was observed from 1990 to 2018. However, this production growth is being threatened by fish diseases resulting in losses of more than USD 6 billion per year (FAO, 2020). In this regard, fish health management is one way of abating the problem, which begins with disease prevention and control rather than treatment. One component of fish health management is the emergency preparedness and response system (EPRS) for managing aquatic disease outbreaks. EPRS comprises contingency planning arrangements that can minimize the impacts of severe aquatic animal disease outbreaks through containment or eradication in case of disease occurrence. In 2016, the EPRS was harmonized among the AMSs with the initiative of SEAFDEC/AQD in collaboration with the Network of Aquaculture Centres in Asia-Pacific (NACA), Food and Agriculture Organization of the United Nations (FAO), ASEAN Network of Aquatic Animal Health Centres (ANAAHC), and Department of Fisheries, Thailand (DOF Thailand).

Disease surveillance and monitoring program

In different countries, disease surveillance or monitoring is one of the activities being conducted to determine the presence of diseases in their territory or to demonstrate disease-free status. Except for Cambodia and Lao PDR, most AMSs have a monitoring or surveillance program. Diseases included in the monitoring and surveillance program are usually those listed in the OIE database and other significant and emerging aquatic animal diseases. However, some AMSs have different priorities with respect to disease surveillance and monitoring. Like for example in Malaysia, surveillance is conducted on diseases that cause high economic losses for the country. In Brunei Darussalam, an active surveillance program is carried out in the shrimp industry and a passive surveillance program for the rest of the country's fish industry.

Quarterly, the AMSs submit the aquatic animal disease reports to the OIE and NACA through the OIE Regional Office in Tokyo, Japan and NACA headquarters in Bangkok, Thailand. In addition, the AMSs provide disease information on the OIE-listed aquatic animal diseases to the OIE World Animal Health Information System (WAHIS) every six months. Information in the WAHIS can be accessed and verified by the public.

Information on emerging diseases provided by the OIE, FAO, and NACA are communicated by competent authorities to the stakeholders to raise their awareness. Furthermore, precautionary measures are recommended such as movement restrictions, health certification, and quarantine to control the introduction or spread of the emerging transboundary diseases.

Fish health diagnostic laboratories

An important aspect of aquatic animal disease prevention and control is the existence of a laboratory with skilled personnel who conduct diagnostic services at different levels (**Box 32**). The fish health diagnostic laboratories of the respective AMSs (**Box 33**) are managed by personnel who continuously undergo training to update and enhance their skills in carrying out disease diagnoses.

Box 32. Disease diagnosis levels (Bondad *et al.*, 2001)	
Level I	Diagnosis is done through gross clinical observation: observation of the cultured animals and the environment
Level II	The laboratory is capable of traditional diagnostic techniques like bacteriology, mycology, parasitology, and histopathology
Level III	The laboratory is capable of advanced diagnostic techniques like virology, electron microscopy, molecular biology, and immunology