FISH for the PEOPLE

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Sustainable Development of **Small-scale Fisheries and Aquaculture** for Economic Sufficiency in Southeast Asia

Southeast Asian Fisheries Development Center

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Editorial

The fisheries sector, which includes aquaculture, has always been one of the most dependable economic sectors in the world. Specifically for the Southeast Asian region, the fisheries sector, although small-scale in nature, has consistently ensured the region of socio-economic stability and food security, by providing livelihoods to peoples living in coastal areas where a large number of fishing households inhabit not only in particular areas near the coastlines but also along the shores of inland waters such as rivers, lakes, dams, reservoirs, and the like. These fishing households use small-scale fishing boats and a large variety of fishing gears to harvest the multispecies fishery resources. Moreover, family members are mobilized, either part time or full time, to form part of the fishery workforce, making it difficult to estimate and record the exact number of small-scale fishers in the Southeast Asian region. Generally, however, the financial capabilities of the fishing households are very fragile and shaky due to the seemingly prevailing poverty in the coastal areas, as well as weak enforcement of laws and regulations, hindering all efforts to promote appropriate fisheries management systems for the sustainability of the fishery resources. Being the region's technical arm in sustainable fisheries development, the Southeast Asian Fisheries Development Center (SEAFDEC) has been exerting efforts to address the concerns that affect the sustainable management of the fishery resources through the introduction of appropriate management tools not only for the marine coastal fishery resources but also for inland resources as well.

The issuance of the Voluntary Guidelines for Securing Sustainable Small-scale Fisheries in the Context of Food Security and Poverty Eradication by the Food and Agriculture

Organization (FAO) of the United Nations, its first edition in 2015 and the second in 2018, is just fitting for the role of the small-scale fisheries sector has been finally recognized, not only in terms of its capability in improving the economies of the countries but also its strength in ensuring that the fishery resources are sustainably managed. It should be recalled that in mid-2000s, the Southeast Asian countries and SEAFDEC had expressed the desire of having a global program on the management of small-scale fisheries developed, to provide the momentum for the promotion of sustainable small-scale fisheries in the Southeast Asian region. Although voluntary in nature, the Guidelines could therefore pave the way for the better management of the region's small-scale fisheries and aquaculture.

Furthermore, the initiative of the United Nations General Assembly declaring the year 2022 as the International Year of Artisanal Fisheries and Aquaculture (IYAFA), and as a platform for supporting the roles of small-scale fishers, fish farmers, and fish workers in food security, poverty eradication, and sustainable utilization of the natural resources, is also a welcome development. Such declaration has given SEAFDEC the opportunity to showcase its efforts in harnessing the potentials of the fishery resources of Southeast Asia and promote the most appropriate fisheries management measures for the sustainability of such resources for the benefit of all. Initial groups of articles focusing on the management of the small-scale fishery resources including that of the most-economically important aquatic commodities are included in this issue of *Fish for the People*, and more in the forthcoming issues.

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FISH for the PEOPLE is a special publication produced by the Southeast Asian Fisheries Development Center (SEAFDEC) to promote sustainable fisheries for food security in the Southeast Asian region.

Call for Articles

FISH for the PEOPLE is a policy-oriented special publication of SEAFDEC. Now on its 19th year, the Publication is intended to promote the activities of SEAFDEC and other relevant fisheries concerns in the Member Countries. We are inviting contributors from the SEAFDEC Departments, Member Countries, and partner organizations to submit articles that could be included in the forthcoming issues of the special publication. The articles could cover fisheries management, marine fisheries, aquaculture, fisheries postharvest technology, fish trade, gender equity in fisheries, among others. Written in popular language and in layperson's terms for easy reading by our stakeholders, the articles are not intended to provide detailed technical and typical scientific information as it is not a forum for research findings. Please submit your articles to the Editorial Team of Fish for the People through the SEAFDEC Secretariat at *fish@seafdec.org*. The article should be written in Microsoft Word with a maximum of 10 (ten) pages using Times New Roman font 11 including tables, graphs, maps, and photographs.

Black Tiger Shrimp Culture Rejuvenation: the OPLAN *Balik Sugpo* of SEAFDEC/AQD

Roger Edward Mamauag, *Dan Baliao*, and *Joesyl Marie dela Cruz*

Back in its glory days, black tiger shrimp was an economic jewel of the Philippines and other countries in Asia that garnered millions of dollars' worth of earnings from production and export. Until production methods became destructive to the environment — causing havoc to mangroves, producing harmful substances in ponds, and sending excessive organic load to downstream riverine and marine ecosystems. However, the international demands and value of the species did not waver. With this, the Government of the Philippines through the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) mandated SEAFDEC Aquaculture Department (AQD) to revive the production of black tiger shrimp by using more sustainable and environment-friendly practices in its existing aquaculture systems. Thus, SEAFDEC/AQD has come up with sustainable and profitable intensive shrimp culture techniques to bring back the precious black tiger shrimp into the international market.

Figure 2. Production volume (t) and value (USD million) of black tiger shrimp in the Philippines from 1996 to 2020
Source: Philippine Statistics Authority (2021)

In the Southeast Asian region, the shrimp aquaculture industry is an essential source of income and provides jobs and secures food supplies (Vergel, 2017). The black tiger shrimp (*Penaeus monodon*) (**Figure 1**) is the preferred Penaeid species because of its large body size, high survival rate, and high value; and it has been successfully bred under captivity. In the Philippines as well as in Indonesia, Thailand, and Viet Nam, the black tiger shrimp industry is a multi-million-dollar industry. In 1990, the industry earned the Philippines a total of USD 21.8 million and constituted 3 % of its total exports, which tallied to USD 8.1 billion (Lamera, 1993).

Consequently, while trying to keep up with the demand, more farmers resorted to intensified and unregulated shrimp farming practices which led to environmental degradation and disease outbreaks. Causing concern to its export destinations, importing shrimps from the Philippines and other Asian countries was banned in the early 2000s (Lamera, 1993; Baliao, 2002; Ekmaharaj, 2018; Bureau of Fisheries and Aquatic Resources, 2018). The decreasing trend of production volume from culture of black tiger shrimp in the Philippines since 1996 (Philippine Statistics Authority, 2021) is shown in **Figure 2**.

Figure 1. Black tiger shrimp (*Penaeus monodon*)

OPLAN *Balik Sugpo*

In the Philippines, the national government gave SEAFDEC/AQD the mandate to rehabilitate the shrimp industry using eco-friendly culture schemes. This is to address the protest actions of shrimp importing countries planning to impose a trade embargo against farmed shrimps produced in a manner that harms the environment (*i.e.* discharge of organic and inorganic substances potentially harmful to marine organisms (Baliao, 2004)). This initiative is also aimed at potentially increasing shrimp production and at the same time creating a sustainable environment.

The mandate is being carried out as part of AQD's Joint Mission for Accelerated Nationwide Technology Transfer Program for Aquaculture (JMANTTP-II) which aims to develop technologies in broodstock development, seed production, and grow-out for economically important finfishes, crustaceans, mollusks, and seaweeds in various stages of development. A joint undertaking by SEAFDEC/AQD and DA-BFAR, the program "OPLAN *Balik Sugpo*" (Revival of the Shrimp Industry) which was adopted during the Forty-first Meeting of the SEAFDEC Program Committee in 2018, intends to develop and verify sustainable shrimp culture technology packages that are friendly to mangroves and the environment.

AQD Chief *Mr. Dan Baliao* launched the program "OPLAN *Balik Sugpo*" that aims to revive black tiger shrimp production in the Philippines

Eco-friendly strategies and biosecurity protocols

The "OPLAN *Balik Sugpo*" program generally aims to revive the tiger shrimp industry in the Philippines through the production of high-quality postlarvae (PL) from the hatchery and promote environment-friendly strategies for grow-out culture in ponds. Hatcheries with enhanced biosecurity systems are already in place at the Tigbauan Main Station of SEAFDEC/AQD where high-quality and disease-free *P. monodon* PL have been produced and used for grow-out culture.

For grow-out culture in ponds, the technology demonstration has been carried out in two phases. The first phase at the Dumangas Brackishwater Station of SEAFDEC/AQD starts with the low/partial discharge and closed-recirculating systems of shrimp farming using environment-friendly schemes at the intensive, semi-intensive, and modified extensive levels of production (Baliao, 2000; Baliao & Tookwinas, 2002). For the second phase, the successful technology is being replicated in private shrimp farms whose owners have been requesting technical assistance from SEAFDEC/AQD on shrimp farming.

The low-discharge and closed-recirculation systems (**Figure 3**) are found to prevent diseases and remove or reduce organic wastes, harmful bacteria, and other pollutants from fouled water. These systems are therefore environment-friendly because they integrate reservoirs, sedimentation ponds, crop rotation, probiotics, life support systems, biomanipulators, biofilters, and sludge collectors. For effective low-discharge and closed-recirculation systems, the several factors that should be considered are shown in **Box 1**.

Furthermore, a successful biosecurity protocol should focus on three main aspects: pond bottom preparation and water management prior to stocking; seed selection and stocking; and post-stocking management (Turkmen & Toksen, 2010). For shrimp farming, the biosecurity protocols are shown in **Box 2**.

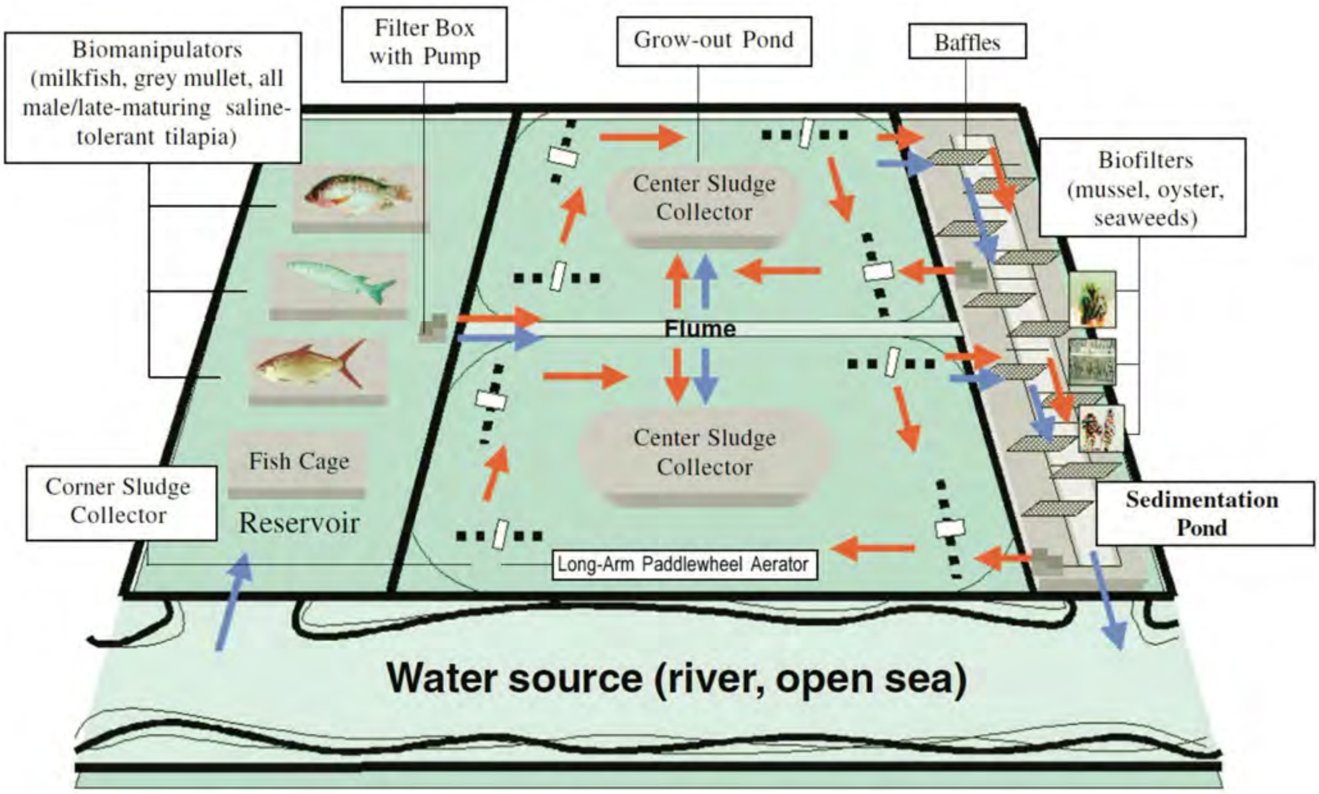

Figure 3. Suggested pond layout of low-discharge and closed-recirculation shrimp farms (blue arrows indicate a low-discharge system, and red arrows indicate closed-recirculation system)

Box 1. Essential factors for effective low-discharge and closed-recirculation systems

Crop rotation: Producing the same crop in the same field over the year may reduce soil fertility and collect harmful nutrients in the pond bottom (Yi & Fitzsimmons, 2004). As a sanitary practice, crop rotation involves shifting shrimp ponds to finfish culture in about one to two cropping. This process will help reduce cultivated land, flooding, and the spread of disease (Yuvaraj *et al*., 2015; Paclibare *et al*., 1998).

Construction of head and tail reservoirs: The system should include a head reservoir as source of quality water with good plankton profile. Sediments and other suspended organic solids are settled for about a week in the head reservoir before its water is used. The head reservoir should comprise at least 50 % of the total grow-out pond area. A tail reservoir serves as a treatment pond with biofilters e.g. seaweeds, oysters, and finfishes, and a sedimentation pond with a baffle system. The tail reservoir is meant to lengthen the flow of water and allow sediments to settle before the water is drained out or recirculated back to the grow-out pond (Paclibare *et al*., 2002).

Installation of filter box: A mechanical filtration or filter box is installed in ponds to ensure that hosts and carriers of pathogens such as crustaceans are reduced, if not eliminated. The filter box is fitted with a two-horsepower submersible pump operated for six to 12 hours per day about three times a week, depending on the quality of the water.

Salinity reduction: The desired salinity of the grow-out pond should be about 18 to 20 ppt, and which should be maintained through the continuous introduction of freshwater in culture ponds. Lower salinity can decrease the potency of luminous bacteria and can also make shrimps grow faster. Thus, a freshwater source (groundwater) should be established (Abraham & Sasmal 2009; Prapaiwong & Boyd, 2012).

Installation of long-arm paddlewheels: Intensive shrimp culture ponds should be aerated appropriately, and paddlewheels should be positioned strategically to create a circular motion in the water for the wastes to be concentrated in the center of the pond and create a wider and cleaner feeding area for the shrimp stock.

Establishment of sludge collectors: There are two types of sludge collectors: center sludge collector which should comprise 3–5 % of the total grow-out pond area, and corner sludge collector of about 2 % of the total pond area. With this set-up, sludge, sediments, dirt, and uneaten feeds in all areas of the pond are collected to ensure adequate water circulation. Efficient water circulation prevents stratification and lessens the accumulation of nitrogenous compounds in spots where sludge accumulates. Organic matter made up of feces, uneaten feeds, and biological waste is produced during shrimp pond operation. With the presence of pond waste, growth of phytoplankton and the general productivity of the pond will be significantly affected, thus, affecting also shrimp survival and production (Bera *et al*., 2018). Increase in sludge production in pond can lead to increase in oxygen demand and create anaerobic conditions resulting in production of hydrogen sulfide which affects shrimp appetite and leads to poor feed conversion ratio. In addition, suspended particles cause turbidity of the water which reduces light penetration leading to decreased photosynthetic activity and dissolved oxygen levels (Turkmen & Toksen, 2010).


Corner *(left)* and center *(right)* sludge collectors

Stocking of biomanipulators: Inside the corner sludge collector, adult or juvenile tilapia and milkfish could be stocked to serve as biomanipulators at standing biomass of 1.5 to 2.5 t/ha and 0.5 to 1 t/ha, respectively. As biomanipulators, they produce green water and suppress the growth of harmful bacteria. Tilapia integration in shrimp culture practice has been attributed to lowering luminous *Vibrio* load throughout the period of the shrimp culture, as well as improving the soil and water quality, enhancing nutrient cycle, and providing continuous supply of fertilizer that can maintain optimal and constant phytoplankton biomass (Paclibare *et al*., 2002; Huervana *et al*., 2006). Fish mucus contains an antibacterial property that helps in preventing microbial colonization by inhibiting bacterial growth. Mucus layer of fish skin and gills contains epidermal cells which produce numerous immunological molecules like lysozyme, lectins, complements, and immunoglobulin (Thanh *et al*., 2017; Lio-Po *et al*., 2005; Tendencia *et al*., 2004). Also, bivalves are efficient filter feeders of organic materials that increase efficacy in maintaining good water quality and healthy culture system and can also reduce suspended organic and inorganic matters and bacteria in the pond culture system (Jones *et al*., 2002; Shpigel & Neori, 2007).

Box 1. Essential factors for effective low-discharge and closed-recirculation systems *(Cont'd)*

Provision of high-quality feeds: Successful intensive shrimp farming requires efficient feeding management. Feeds should be palatable and stable with high protein contents and good attractant. A complete feed is formulated to provide all nutrient and protein requirements of the animal. Ideally, crude protein should be 35–45 %, and crude lipid should be 10–12 % (Alava & Lim, 1983; Millamena & Pascual, 1990). Feeds should translate to a feed conversion rate ranging from 1.1 to 1.4, thus, reducing waste accumulation in the ponds as well as the cost of production. To ensure the freshness of the ingredients, feeds should be stored in short duration.

Maintaining substrates: In intensive shrimp culture system, substrates are utilized to reduce the negative effects of increased stocking density. Substrates provide an additional surface area for the shrimp to avoid space competition and cannibalism. The periphyton that grows in the substrates can serve as a natural food source as well as maintain good water quality. Substrates could be made up of polyethylene and fine mesh net and installed up to the first 45-50 days of shrimp culture (Schveitzer *et al*., 2013).

Introduction of bioaugmentation or microbial inoculants: Over time, viruses and diseases develop drug resistance due to the extensive use of antibiotics in shrimp ponds. This has led to a shift in alternative use of environment-friendly schemes such as the utilization of probiotics in aquaculture. To reduce toxic gases in the sediment and water as well as enhance the growth of beneficial bacteria, probiotics for bioaugmentation are applied in both grow-out and reservoir ponds. These factors could accelerate degradation of decomposing organic matter in pond bottom, and prevent the proliferation of pathogenic bacteria, particularly luminous bacteria (Ninawe & Selvin, 2009). Probiotics increase the innate defense mechanisms of an animal before exposure to a pathogen or improve survival during exposure to a pathogen. In shrimp culture systems, probiotics aid shrimp to overcome stressful conditions. Supplementation into feed is more effective in conveying probiotics into animals compared to direct application into rearing systems (Jamal *et al*., 2019).

Box 2. Biosecurity protocols for shrimp farming

Pre-stocking protocols: Shrimps are bottom dwellers; hence, it is necessary to remove the layer of black soil, sludge, or debris accumulated on the pond bottom from previous cropping. This is necessary, particularly in ponds with high stocking densities of up to 8 PL/m^2. Proper removal of bottom sludge can be achieved through drying, scrapping, and tilling of the pond bottom, application of lime and fertilizer in pond preparation, and disinfecting of the pond water. These practices could reduce the risk of disease outbreaks in low stocking density farms. Using a twin bag filter of 250 µm mesh size is the best way to filter the water. Water should also be conditioned from 10 to 15 days before stocking. Installing physical biosecurity measures, including car and foot baths, bird scare, and crab fencing, could reduce the risks of animals catching diseases from neighboring ponds and other farms.

Seed selection and stocking: Shrimps are most vulnerable during the PL stage that even with the best pond preparation the PLs could die during stocking if they are not healthy. Uniform in size and color, and actively swimming against the water current are some of the characteristics of a healthy PL. Poor quality shrimp seeds are usually less active. Weak or sick PLs were eliminated through disease surveillance with the help of polymerase chain reaction (PCR) screening. Transport time can also affect the PLs as longer transport time (> 6 h) of seeds from hatchery or nursery to pond can increase the chances of disease outbreak. Stocking into green water and avoiding transparent water should also be observed. However, the most helpful tip at this stage is to get high quality and disease-free fry from hatcheries with enhanced biosecurity measures.

Post-stocking management: Monitoring and record-keeping are essential and can be used as basis for water management and other treatments to maintain optimum pond conditions for shrimp growth. Performing visual inspection of the animals, observing clinical signs, should be conducted daily. While weekly sampling of shrimp and water should be observed. The shrimp's gut can give tell-tale signs of the animal's health. Checking the presence of food in the shrimp's intestinal tract can help monitor its food intake, while look for changes in gut's color can predict onset diseases.

Economic analysis

The protocol described above differs from the farming system used in the 1990s, back when the shrimp industry collapsed. This environment-friendly scheme for shrimp farming is a business with the primary objective of obtaining maximum profit from both the short- and long-run. Results of the cost and return analysis (**Table 1**) indicate not only added investment cost but also higher shrimp survival and profits.

Promising demonstration runs

Following the aforementioned environment-friendly schemes for shrimp culture, SEAFDEC/AQD and DA-BFAR successfully produced a series of impressive harvests. In July 2019, disease-free fry was stocked in the Dumangas Brackishwater Station of SEAFDEC/AQD to begin the experimental run. After 113 days of culture, 93.3 % of the 100,000 PLs survived and attained an average body weight of 30.0 g. By October 2019, over 2.8 t of tiger shrimp were harvested from 0.5-hectare pond. In November 2019, another 4.4 t of tiger shrimp with an average body weight of 30 g were harvested from a 0.8-hectare pond after 120 days of culture yielding a survival rate of 89.7 %.

Table 1. Cost and return of tiger shrimp culture in ponds using environment-friendly strategies

Particulars	
Area (m^2)	5,000
Feed conversion ratio (FCR)	1.25
Total stock (number of individuals)	100,000
Stocking density (ind/m^2)	20
Number of days of culture (DOC) at harvest	113
Average body weight (ABW) (g)	30
Biomass (kg)	2,800
Survival rate (%)	93
Average price per kg (USD)	9.94
Gross sales (USD)	27,844.07
Expenses	Value (USD)
Fry	238.66
Feeds	4,365.04
Salaries/wages/over-time-pay	932.94
Pond preparation	457.44
Lime	875.10
Biomanipulators	59.67
Probiotics	1,988.86
Power/lights/water	1,988.86
Fuel/lubricants	198.89
Sludge collector/cages	596.66
Feeding bridge/tray	497.22
Laboratory analysis	1,591.09
Depreciation	1,140.41
Repair and maintenance ponds/dikes/ equipment	994.43
Communications	198.89
Transport and travel	397.77
Total expenses	**15,495.47**
Net profit	**12,348.61**
Equipment	**5,698.49**
Investment requirement	**21,079.99**
Return on investment	**59%**
Payback period	**2 croppings (~1 year)**

Way Forward

The technology verification runs are still ongoing as part of the first phase of the grow-out technology demonstration project. Once verified and proven effective, the technology will be adopted by DA-BFAR and demonstrated in their technology outreach stations, and will be packaged and transferred to fish farmers. In the future, thorough research would be conducted to explore whether the eco-friendly culture schemes are effective in different seasons.

Black tiger shrimp produced from the environment-friendly culture system at AQD's Dumangas Brackishwater Station

When proven effective and efficient, this eco-friendly shrimp culture scheme will be part of the sustainable aquaculture technology packages that will be disseminated in the nationwide techno-caravan, field demonstrations, and hands-on training activities under JMANTTP-II. Furthermore, actual demonstration and training for fish farmers from the ASEAN Member States would be organized by SEAFDEC/AQD as well as extension manuals and publications produced to encourage the adoption of the environment-friendly culture techniques developed through the "OPLAN *Balik Sugpo*." This information dissemination and extension work bridges the gap between research and stakeholders, as it gives the fish farmers access to the economically viable, environment-friendly, and socially equitable shrimp culture techniques developed by SEAFDEC/AQD.

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Management of Catadromous Eel Resources in Southeast Asia Toward Sustainability: a Synthesis

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Although the fisheries of catadromous eels are known to be practiced in many countries in Southeast Asia, *e.g.* Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam, the statistical information on eel production from these so-called eel-producing countries had been very limited exacerbated by the inadequate classification of the eel species caught and cultured in these countries. In an effort to address such concern, the Inland Fishery Resources Development and Management Department (IFRDMD) of the Southeast Asian Fisheries Development Center (SEAFDEC) based in Palembang, Indonesia conducted baseline surveys to gather information on the systems of data collection on production from eel fisheries and aquaculture practiced by the said countries. The surveys formed part of the five-year project "Enhancement of Sustainability of Catadromous Eel Resources in Southeast Asia," which was implemented by IFRDMD from 2015 to 2019 with funding support from the Japanese Trust Fund (JTF) as well as that of a parallel activity funded by the Japan-ASEAN Integrated Fund (JAIF). Results from the surveys were then used to establish the data collection scheme for eel production of Southeast Asia, with the main objective of assessing the management of the eel resources toward sustainability. The target eel species are the Anguillid eels, such as *Anguilla bicolor* (*A. bicolor bicolor* and *A. bicolor pacifica*), considering that these species comprise most of the region's production of Anguillid eels that are bound for the export market in the East Asian region. These species of catadromous eels have been considered as replacement for the declining European and Japanese eel supply in the world's eel market, as the taste of *Anguilla bicolor* is almost the same as that of the European and Japanese eels.

Reports on the JTF Project and JAIF activity on the sustainable utilization and management of Anguillid eel resources have indicated that in Southeast Asia, various species of catadromous eels, especially the *Anguilla* spp. are found in Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam (**Figure 1**). In order to obtain the necessary information on eel fisheries from these countries, baseline surveys were carried out, and catch data were collected from enumerators or consolidators (eel collectors) for glass eels, elvers, and yellow eels to investigate the abundance and trends of tropical eel resources (SEAFDEC, 2019; SEAFDEC, 2020). Representatives from local government units as well as aquafarmers in the sites where eel fishing and culture activities are being practiced were also interviewed.

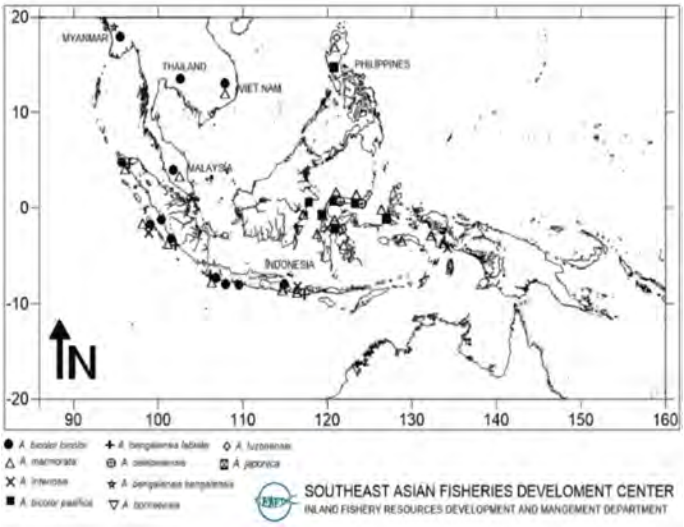

Figure 1. Geographical distribution of Anguillid eels in Southeast Asia

The baseline surveys were carried out to determine the present status of eel fisheries in the ASEAN Member States (AMSs) since many countries do not compile national statistical data on the tropical Anguillid eels. As a result, baseline data from Cambodia, Indonesia, Myanmar, Philippines, and Viet Nam were compiled that included the information on the status and trends of Anguillid eel harvest (SEAFDEC, 2019). From the data obtained, it could be gleaned that the eel samples from Indonesia, Myanmar, and the Philippines comprise six species/subspecies, namely: *Anguilla bicolor bicolor, A. bicolor pacifica, A. marmorata, A. bengalensis, A. interioris*, and *A. luzonensis*.

The rapid decline of temperate eels in the world market during the recent years had resulted in the drastic rise of the value of tropical eels, leading to the dramatic rise of the capture of glass eels (juveniles of eel) in the tropical zone, and prompting some countries to adopt measures to avoid the over-exploitation of glass eels (SEAFDEC, 2020). For example, the Government of Indonesia had issued a regulation prohibiting the export of less than 150 g eel seeds from any areas in the Indonesian territory. Similar policies prohibiting the export of eel seeds have also been enforced by other Southeast Asian countries. Moreover, conservation and management policy issues on tropical eel resources for their sustainability had become a priority not only in Indonesia but also in other Southeast Asian countries.

Status and trend of Anguillid eel fisheries and trade in Southeast Asia

For the sustainability of the region's Anguillid eel resources, it has therefore become necessary for the Southeast Asian countries to establish policies that would strike a balance between the utilization and management of these tropical eel resources. Nonetheless, considering that knowledge on tropical eel species in the region is still limited, the IFRDMD Project was therefore implemented in the AMSs to determine the current status of eel fisheries, establish the collection methods for statistical data on eel fisheries and aquaculture production, and promote management plans for conservation and sustainable use of the tropical eel resources (SEAFDEC, 2020). The surveys on the trends of catadromous eel fisheries carried out in 2015 – 2019, resulted in the compilation of valuable information that depict the status and trends of eel fisheries in the Southeast Asian region (**Table 1**).

The compiled status and trends of eel fisheries and eel resources in the Southeast Asian region (**Figure 2**) indicates that Indonesia and the Philippines played significant roles in eel fisheries landings (SEAFDEC, 2019). From 1980 to 2017, the estimated reported landings of Indonesia had increased but fluctuated since 1990, while that of the Philippines had steadily increased since 2000 but then gradually decreased after 2013.

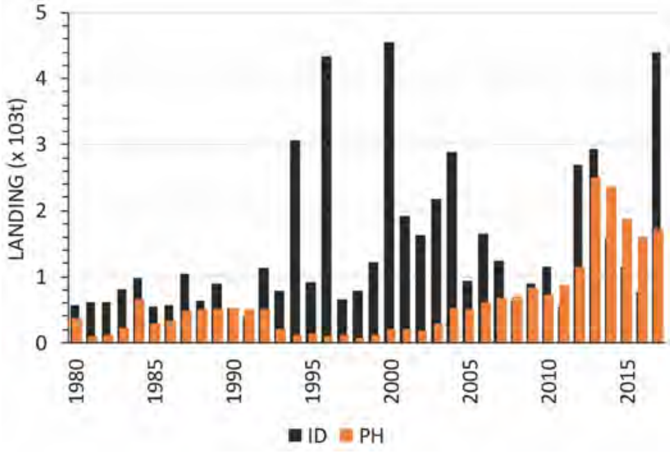

Figure 2. Annual landing data of Anguillid eels (nei) in Indonesia and Philippines (1980–2017)
Source: SEAFDEC (2019)

Moreover, the surveys were also able to determine the commercial distribution and trade of catadromous eels in the Southeast Asian region (**Table 2**).

Table 1. Status and trends of eel fisheries in the Southeast Asian region

Countries surveyed	Outputs/Remarks
Cambodia, Indonesia, Myanmar, Philippines, Thailand, Viet Nam	**Compilation of data on:** • the trends and intensity of eel capture including glass eel catch • the target species and stages of Anguillid eels used as seeds for eel culture • the technical information on the target species and stage of Anguillid eels used as seeds for eel culture • the fisheries of Anguillid eel stages (glass eels and/or yellow eels) that are used as seeds for eel culture
	Analysis of current status and trends in the AMSs: ***Cambodia*** • no tropical Anguillid eel fisheries but one eel culture exists ***Indonesia*** • 11 eel aquafarms registered in 2017 • more than 2,500 fishers operate fisheries of glass eels and elvers/yellow eels • the main target species for eel fisheries and culture is *A. bicolor bicolor* and its glass eel, elvers and yellow eels are used as seeds for eel culture ***Myanmar*** • no specific fisheries catch tropical Anguillid eels • one aquafarm operates eel grow-out • target species for eel fisheries and aquaculture is *Anguilla marmorata* and its yellow eels are used as seeds for aquaculture ***Philippines*** • 28 aquafarms registered • more than 4,000 fishers operate fisheries of glass eels and elvers/yellow eels ***Thailand*** • eel capture fisheries not practiced • one eel aquafarm is known to exist ***Viet Nam*** • more than 1,320 eel aquafarms exist, 90 % at family scale • about 300 fishers are involved in eel capture fisheries
	General Remarks • Based on national landing data reported in the FAO global fishery and aquaculture production statistics (2019), Indonesia and the Philippines have been playing significant roles in sustaining river eel fisheries in this region, where the estimated reported landing from 1980 to 2017 of Indonesia increased and fluctuated since 1990, while that of the Philippines had steadily increased since 2000 then gradually decreased after 2013

Source: Adapted from SEAFDEC (2019); SEAFDEC (2020)

Table 2. Commercial distribution and trade of Anguillid eels from the Southeast Asian region

Countries surveyed	Outputs/Remarks
Cambodia, Indonesia, Myanmar, Philippines, Thailand, Viet Nam, and to some extent the other AMSs	**Compilation of data on:** • the commercial distribution and trade of catadromous eels • the commodity chains and demand-supply relationships of eel seeds for aquaculture • the status of eel trades and markets in the AMSs • the amount and route of existing eel trade
	Analysis of current trade status in the AMSs: ***Myanmar*** • only one eel farm rearing Anguillid eels (mainly *A. marmorata*) and rice-paddy eel • almost all eel products are exported to China, especially before the Chinese New Year ***Indonesia*** • since the rearing from glass eels to elvers needs high-level skills and conditions, only limited number of eel aquafarms (11) could operate eel farming from glass eels • most eel aquafarms are in Java Island at various scales of operation • large-scale eel aquafarms are funded by foreign companies to rear eels • baked eel "unagi-kabayaki" exported to East Asian countries • small and middle-scale eel aquafarms trade their products in domestic markets in Indonesia
	General Remarks • Export data on catadromous eels are available globally, and the general export data of river eels (nei) and elver (live) indicated that Indonesia, Myanmar and the Philippines play significant roles in eel trading in the Southeast Asian region, although the export of Indonesia decreased in 2013, and also that of Myanmar and the Philippines in 2014, but after 2010, Myanmar and the Philippines provided the major contribution to the eel trade

Source: SEAFDEC (2019); Suryati, et al. *(2019)*

The existing information regarding the amount and route of eel trade in Indonesia, Malaysia, Myanmar, Philippines, Thailand, Viet Nam, and other AMSs compiled by IFRDMD, indicated that in the general export data of river eels (nei) and elvers (live), Indonesia, Myanmar, and the Philippines are the major players in the trading of eels (**Figure 3**). While the export quantity of Indonesia decreased in 2013, those of Myanmar and the Philippines had decreased in 2014 (SEAFDEC, 2019). Nonetheless, after 2010, the major contributors from the Southeast Asian region to the eel trading arena were Myanmar and the Philippines.

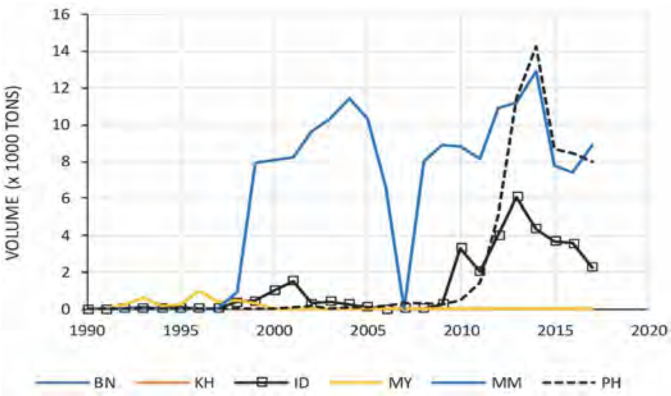

Figure 3. Annual export of eel and elvers (live) from the AMSs (1990 – 2017)
Source: SEAFDEC (2019)

Species identification of catadromous eels in Southeast Asia

In order to enhance the capacity of the countries in the identification of Anguillid eel species in Southeast Asian and in determining the composition of eel catch and aquaculture production, the use of DNA technique had been promoted in the AMSs. However, the studies to address these issues are currently ongoing with the objective of thoroughly finding the ways and means of identifying the eel species found in the region (SEAFDEC, 2020). Meanwhile, IFRDMD provides the technical assistance for the preparation of samples and materials for the said analysis. Nevertheless, through ocular surveys of Anguillid eels in the AMSs, the results showed that the dominant species are *A. bicolor* and *A. marmorata*. Moreover, from the samples of Anguillid eels in Southeast Asia, it could be gleaned that the eel species/subspecies found in Indonesia are *Anguilla bicolor bicolor*, *A. bicolor pacifica*, *A. marmorata*, *A. bengalensis*, and *A. interioris* which were identified based the results of studies conducted in Indonesia's Palabuhan Ratu, Aceh, Tasikmalaya, Bengkulu, and Poso. The eel species found in the Philippines are: *A. bicolor pacifica*, *A. marmorata*, and *A. luzonensis*; and one species was identified in Myanmar: *A. bicolor bicolor*.

In the evaluation of the species diversity of tropical Anguillid eels in Indonesia, Philippines, and Viet Nam using the genetic data from 5' region of mtDNA D-loop region, five species and subspecies of glass eels were present in the samples from Indonesia, four in the Philippine samples, and four in the samples from Viet Nam. These provide the information needed for future studies of the tropical Anguillid eels that would contribute to the development of strategies for the management of the eel resources in the Southeast Asian region.

Statistical data collection methodologies

The concerned Southeast Asian countries indicated that data and information on Anguillid eel fisheries exist in their respective official statistical records, *e.g.* Indonesia, however, these are mostly fragmented making them not accurate and useful for stock assessment of the country's eel resources. In an effort to improve the catch statistics on anguillid eels, especially in response to the requirements of CITES for not listing Anguillid eels in the CITES Appendices, IFRDMD initiated an independent data collection system for Anguillid eels with the help of the eel collectors in Palabuhan Ratu and Bengkulu in Indonesia who have been asked to report the daily catch and effort of their Anguillid eel fisheries. Meanwhile, the current practice of collecting catch statistics on Anguillid eels at each stage of their development, in the SEAFDEC Member Countries had been analyzed for improvement taking into consideration the experience of Indonesia, especially regarding the collection of information on the indices of effort for monitoring the trend and fluctuations of the catch of eel seeds in the region (Muthmainnah *et al*., 2016).

In an attempt to come up with continuous data, the catch and fishing effort (CPUE) data from Indonesia and the Philippines were used to determine the trend of tropical eel stocks by observing the change in the CPUE. However, considering that long-term fishing effort data of the catch is necessary for analyzing the trends and status of the fishery resource, and since such data are not readily available, the five-year data collected through the Project's surveys was analyzed, but the results did not clearly indicate any trend that could suggest a decline in abundance based on the CPUE. Nonetheless, the basic information compiled on the characteristics of the fisheries for tropical Anguillid eels in the AMSs could still be useful for future stock assessment and management of the eel resources.

The increased attention given to tropical Anguillid eels is meant to compensate the decline of the populations of temperate Anguillid eels, especially in the East Asian eel market (Arai, 2015). Such a situation had prompted many aquaculturists to establish eel farms, *e.g.* in Java Island, Indonesia for the aquaculture of tropical Anguillid eels being eyed for export to the East Asian countries. To date, eel aquafarming still relies heavily on wild-caught seeds in their various stages, such as glass eels (**Figure 4**), elvers and yellow eels, and these eel seeds could be captured in various places in many Southeast Asian countries, *e.g.* Indonesia, Myanmar, Philippines, Viet Nam. But the amount of tropical Anguillid eel seeds caught and used as seeds for eel aquafarming is yet to be established.

Figure 4. Fisher collects the glass eel using a scoop net *(above)*, the captured glass eel *(below)*

Further analysis of the data compiled from Indonesia, indicated two different patterns of the commodity chains of eel seeds from both Sukabumi Regency and Bengkulu Province of Indonesia to the eel farms in Java Island (Muthmainnah *et al*., 2020). In order to sustainably utilize the Anguillid eel resources and the state of exploitation of eel seeds in

Figure 5. Anguillid eel resources in Southeast Asia as exemplified by the Anguillid eel resources in Sulawesi, Indonesia and eel fishing ground in the Province

Southeast Asia, it has become necessary for the countries to take immediate actions for developing their respective national catch statistics on Anguillid eel fisheries as these would facilitate the establishment of appropriate management strategies for the Anguillid eel resources of Southeast Asia (**Figure 5**).

Conservation, management and sustainable utilization of catadromous eel resources

The IFRDMD Project had also initiated the compilation of preliminary information regarding the relationship between upward migration of eels and the construction of structures in the rivers of some countries, based on a pilot study carried out in one hydropower dam in Indonesia, the PLTA Poso II located in Poso River and operated by P.T. Poso Energy. The study involves the construction of a fish ladder as a precautionary approach which the company had adopted to maintain the sustainability of eel resources especially in Poso Lake (Ditya *et al*., 2021). As part of the company's Corporate Social Responsibility (CSR) program on eel conservation, Anguillid eels had been stocked in the lower part to the upper side of the dam to study the survivability of eels crossing the dam. The company had also restocked 200 kg of elvers in Peura Village near Poso Lake, while silver eels were restocked at the river mouth of Poso.

The progress of the pilot study had been continuously monitored to enable the IFRDMD to establish the relationship between upward migration of eels and construction of infrastructures in rivers, and the construction of fish ladders to mitigate the issues on disruptions of the migration route of eels in rivers for the completion of their life cycle (**Figure 6**), as what is being done by the Poso Energy Company. The life cycle of the Anguillid eels could be severely affected by

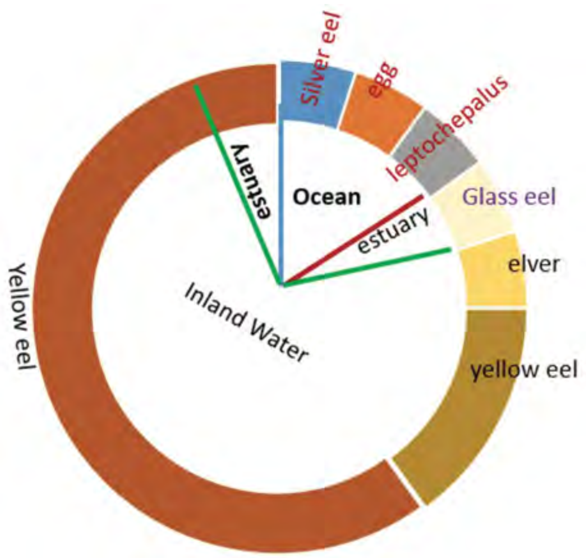

Figure 6. Habitats of the life stages of Anguillid eels

the construction of infrastructures in rivers and other water bodies, as a big part of their life stages is spent in inland waters. Although only an estimation, it has been presumed that more than 50 % of the life cycle of Anguillid eels is spent in inland waters, and it is also in these areas that interactions with human activities and interventions usually take place.

In the life cycle of the Anguillid eels, the glass eels enter the river mouths and estuaries where they grow to become elvers and yellow eels in these inland water environments, until they become silver eels and migrate to the oceans. It is in the inland water environments that the eel seeds are vulnerable to damages due to human activities as well as natural disasters. Generally, in the Southeast Asian region, interest has been rising on the collection of glass eels and elvers as these have been extensively used for the aquaculture of Anguillid eels to produce adult eels that could compensate for the dwindling eel supply in the market. The estimated production from capture fisheries of Anguillid glass eels and yellow eels in Southeast Asia is shown in **Figure 7**. The present target eel species is *Anguilla bicolor* (*A. bicolor bicolor* and *A. bicolor pacifica*) produced by Indonesia and the Philippines. East Asian countries, *e.g.* China, Japan, Taiwan, and South Korea have been the biggest importers of cultured Anguillid eel and used to replace and compensate for the declining supply of the European and Japanese eels (Arai, 2015). Besides, the taste of *Anguilla bicolor* is almost similar with that of the European and Japanese eels.

Figure 7. Production from capture fisheries of glass eels and yellow eels of Anguillid eels in Southeast Asia

In Southeast Asia, eel collectors gather glass eels from fishers, rearing the glass eels for a few days in temporary rearing tanks, then transporting the eel seeds to eel aquafarms. Finally, eel aquafarmers rear the glass eels to marketable size, and as soon as the eels reach the size for consumption, these are harvested and processed into food products such as the grilled *unagi* or *kabayaki*. While glass eels and elvers are shipped to eel farmers, the yellow eels are shipped to local and overseas markets. The distribution channel for eels is concentrated on the consolidators because of the need to transport or trade eels in their live state. The production and utilization of the tropical Anguillid eels in aquaculture by selected Southeast Asian countries has also been established (**Table 3**).

Issues and Concerns

A major concern encountered in the region's Anguillid eel fisheries is the general status of the eel fishers: mostly small-scale and continue to survive below the poverty line. This condition deprives them from having considerable access in utilizing the fishery resources, and because of lack of capital for acquiring the necessary fishing gear, they usually do not

Table 3. Production and utilization of tropical Anguillid eels used for eel aquaculture by some AMSs

Countries surveyed	Catch tropical Anguillid eels and utilization of eel seeds in aquaculture
Cambodia	Although there is no capture fisheries that exploit the country's tropical Anguillid eel resources, its culture activities make use of elvers imported from the Philippines. In 2017, Cambodia imported about 1.0 t of elvers from the Philippines comprising 70 % and 30 % *A. marmorata* and *A. bicolor pacifica*, respectively. However, some fishers reported to have caught Anguillid eels from the country's rivers using crab traps set at night and hauled the next morning, but the main target of this fishery operation is not only the eel species but other fishes too. Some fishers also use hooks to fish in the shallow waters of rivers, fishing the whole day or using longline during the low tide.
Indonesia	Among th Southeast Asian countries, Indonesia remains very active in the capture fisheries and aquaculture of the tropical Anguillid eels There are four main fishing areas for eel fisheries in Indonesia: Palabuhan Ratu Sub-district, Manado District, Poso District, and Cilacap District, where glass eels, elvers, and yellow eels of *A. bicolor* or *A. marmorata* are dominantly caught. There is variation in the fishing gear used and time of capture of glass eels and elvers. In Palabuhan Ratu Sub-district, glass eels are mainly caught between September and December using scoop net. While in Cilacap District, elvers and yellow eels are mainly caught by scoop net or PVC trap from October to November. Glass eels, elvers, and yellow eels in Poso District are mainly caught by fyke net or barrier trap from July to August. In Manado District, glass eels are caught by scoop net but the peak fishing season is still unknown. In Palabuhan Ratu, glass eel fishing activities usually start at night from around 6:00 p.m. until 5:00 a.m. in the morning. Glass eels are abundant from October to March with a peak occurring in January. Eels for consumption are usually caught in April-September by *anco* or lift net. The eel fishery system in Palabuhan Ratu in Sukabumi has been in existence for decades but still requires proper management for the sustainability of the eel resources. Meeting the market demand for glass eels for the development of eel aquaculture has recently resulted in the shift of procuring eel seeds from capture fisheries to cultured eels. Nevertheless, success in eel aquaculture still remains largely dependent on the availability of seeds that rely heavily on nature. The country's production from farming of *A. marmorata* and *A. bicolor* in 2017 was 478.50 t which increased to 515.18 t in 2019 (KKP, 2020). Almost all production from these areas are exported to China, Korea, Japan, Taiwan, and other countries.
Myanmar	There are no specific fisheries for Anguillid eels in Myanmar. Yellow eels of 90 % *A. bicolor* and 10 % *A. bengalensis* are accidentally caught by stow net, crab trap, or longline hook in the rainy season. *A. bicolor* is the main species farmed in Myanmar by only one aquafarmer, with production that reached 15.0 t in 2017, and exported to China by truck through the border.
Philippines	Fishers of the Philippines catch the eel species, *Anguilla marmorata* from glass eels, elvers, and yellow eel stages in the waters of Luzon and Mindanao Islands. Glass eels are caught between April and August mainly by using fyke net, stow net, scoop net, or push net. The annual catch of glass eels has been fluctuating yearly since 2007. In 2017, the catch was about 2.0 t from Luzon and 10.0 t from Mindanao. The fishing gears used to catch the elvers/yellow eels are seine nets, bamboo traps, hook line, and spear gun, usually between December and February, and the annual catch from both islands in 2017 was about 0.3 t. The production volume of the 28 eel aquafarmers in the Philippines, based on local official data in 2017, showed that *A. marmorata* and *A. bicolor* from Mindanao was about 100.0 t and about 20.0 t from Luzon. The country's production of *A. bicolor* is exported to Japan, Korea, and Taiwan, while that of *A. marmorata* is bound for China and Taiwan.
Thailand	Only elvers/yellow eels of *A. marmorata* and *A. bicolor bicolor* are caught in Thailand usually in May to October as accidental catch when fishers operate fish traps. Elvers/yellow eels are captured in three areas: Ranong Province, Satun Province, and Phangnga Province. To meet the development needs of eel aquaculture in several provinces, glass eels are imported from China while elvers/yellow eels come from Indonesia. The country's eel production from aquaculture is exported to China.
Viet Nam	The composition of the country's glass eel production is 95 % *A. armorata* and 5 % *A. bicolor pacifica*. Glass eels are mainly caught in Phu Yen Province although there are also few catches in Bin Dinh Province, Auar Ngai Province, Khan Hoa Province, and Nah Tuan Province. The main fishing gears used to catch glass eels are towing net and scoop net. The peaks of the fishing season in Phu Yen Province occur from November to May. The total annual catch of glass eels ranges between 0.60 and 0.75 t (or 4,000,000-5,000,000 individuals). Several fish farmers are rearing eels in Phu Yen Province and Khan Hoa Province (Thuc & Van, 2021). The country's largest eel farm is located in Khan Hoa Province which produces 200,000-300,000 individuals of elvers/yellow eels. Compared with those of the other Southeast Asian countries, people in Viet Nam consume large amounts of Anguillid eels.

Source: SEAFDEC (2019); SEAFDEC (2020) have sufficient ability to catch this pricey fish. As a result, fishers depend heavily on middlemen who lend them the needed capital, and so fishers are also bound to sell their catch directly to middlemen who have provided them the capital or fishing gear prior to undertaking fishing operations.

Eel farming could have also provided a solution not only to the unstable supply of eel products in the market but also in terms of creating prospects to increase the income and sustainable livelihoods of fishers (Siriraksophon *et al*., 2014). However, this is still not attained as eel aquaculture in the region is still at its infancy. Although there are companies that operate eel aquafarms in eel producing countries, their products are directly exported to eel-consuming countries. For example, the value of the Anguillid eel exported to Japan during the past four years could easily averaged USD 2.3 million per year.

Another very crucial concern is in the sustainable management of the Anguillid eel resources in the Southeast Asian region, considering the limited ability of many eel-producing countries to estimate the status of their tropical eel stocks by pursuing stock assessment (Arai, 2015). As this endeavor would require that the data-poor eel fisheries production is improved using simple methods of data collection, efforts should be made to improve such data collection systems and come up with the real status and trend of eel production from capture fisheries and aquaculture. Moreover, for the sustainable management of the tropical Anguillid eels, it is also necessary that the capability of the eel-producing countries is enhanced to enable them to identify the eel species caught and cultured.

Although IFRDMD has already compiled the information on five Anguillid eel species in Indonesia (Palabuhan Ratu, Aceh, Tasik Malaya, Bengkulu and Poso), *i.e. Anguilla bicolor bicolor, A. bicolor pacifica, A. marmorata, A. bengalensis*, and *A. interioris*; three species in the Philippines, *i.e. A. bicolor pacifica, A. marmorata*, and *A. luzonensis*; and one species in Myanmar, which is *A. bicolor bicolor*, such information could be used for visually identifying the species of the eel samples. However, there is still a need to analyze more samples from other sites and countries, and be able to identify the other species of tropical eels found in the Southeast Asian region.

The development of simple aquaculture method could be one of the possible solutions that could reduce the market price of eels. In Indonesia for example, the price of glass eel could be around IDR 1.0–3.0 million/kg glass eels or USD 70–250/kg. This price could still increase depending on the availability of marketable stocks, especially that the production of glass eels depends on the catch from the wild and correlates with the season and location. Added to this is the high mortality during eel seed transfer, especially if the distance between the fishing and collection areas of the glass eels id far from the aquafarms, thus necessitating the development of improved eel transport techniques.

While research on the breeding of the tropical Anguillid eels is still being developed, another concern in eel aquaculture is the availability of cheaper feeds for hatchery operations. The current price of feeds is still quite expensive at about USD 2.5–4.0/kg, as the feeds should have high protein contents (40–50 %) and some ingredients for the feed formulation are still imported. Strategies should therefore be developed to reduce the price of feeds through the adoption of improved feed development technologies (Muthmainnah *et al*., 2020).

Furthermore, challenges in Anguillid eel conservation had also been raised on many occasions and fora, as many factors have led to the deteriorating state of the habitats of eels. For example, the continued construction and installation of development structures, overfishing, diseases, climate change, and water pollution among others. The construction of dams or weirs in many rivers of the AMSs to supply the water needed for crop irrigation and for running hydroelectric power plants, has created obstructions of the flow of water that hinders the migration pathways of many aquatic species as they complete their life cycles. In the case of eels, such developments block the movement of eels going upstream or undergoing reverse migration to complete their life cycle.

Infrastructures constructed along rivers could also delay fish migration contributing to the decline and even possible extinction of fish species that depend on longitudinal movements along the stream during certain phases of their life cycles. Nowadays, the construction of fish pass or fish passage has been promoted to address possible river blocking that significantly addresses the possible deterioration of fish habitats that could eventually improve the survival rates of aquatic species. As many countries in Southeast Asia had been planning to construct or have already constructed dams and weirs, it is necessary that such construction comes with the installation of fish passes or fish passages or fish ways. For the already constructed dams and weirs, efforts should be made to build fish ways for the sustainability of the freshwater aquatic resources.

Most of the eels produced in the Southeast Asian region are bound for the export market, but locally, eels are not known as a nutritious food fish. Notwithstanding the market price of eels that seems to be prohibitive and unaffordable by the local people, eel products could be promoted domestically so that the local people could learn to patronize the products. In Indonesia for example, eel products are being introduced to local communities through processing to produce food that is suited to the people's palate. Packaging of Anguillid eel products have also been altered by avoiding designs that make eels appear like a snake. Such efforts could also be undertaken in the other Southeast Asian countries so that eels could be consumed locally, thus, increasing the demand. The promotion of information, education and communication (IEC) should be enhanced through sharing of publications, leaflets and other audio-visual materials on Anguillid eels. The organization of meetings, training sessions, and field visits could also enhance the knowledge and capacity of the AMSs in the conservation, management and sustainable utilization of the catadromous eel resources.

Way Forward

There are still many challenges that need to be addressed for the sustainability of the Anguillid eel resources in the Southeast Asian region. Aside from the issues and concerns mentioned above, other constraints that hinder the sustainable management and utilization of Anguillid eels could include enhanced habitat protection, improved governance, development of measures that mitigate natural factors, *e.g.* climate change, diseases, as well as anthropogenic concerns, *e.g.* overexploitation, pollution. Efforts are therefore being made by SEAFDEC to extend the activities of the project that were terminated in 2020, through the implementation of new projects starting in 2021 that aim for the sustainable utilization and management of the Anguillid eel resources.

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Enhancing Fisheries Community Resilience for Sustainable Livelihood and Coastal Resources Management

Mazalina Ali and *Achmad Zamroni*

Enhancing coastal community resilience for the promotion of sustainable livelihoods and coastal resources management involves various cross cutting issues, and requires strong commitment from and coordination of the national government, organizations and local institutions. The Islamic Development Bank (IDB) provided funds to SEAFDEC for the implementation of the Project "Enhancing Coastal Community Resilience for Sustainable Livelihood and Coastal Resources Management" through a Technical Assistance Grant Agreement with SEAFDEC/MFRDMD as the Lead Department. With the main objective of improving the socio-economic status of coastal communities including the community fisheries organizations through capacity building programs, the Project had as target beneficiaries the coastal Muslim communities in the IDB countries in Southeast Asia, namely: Brunei Darussalam, Indonesia, and Malaysia. This article is based on the output of the Project with special focus on one coastal community in Indonesia, which is the Takalar District of South Sulawesi.

Coastal areas and communities around the world are not only increasingly at risk from both natural and human-induced hazards (Almutairi *et al*., 2020), such as tsunamis, impacts of climate change, floods, and so on, but are also recognized as most vulnerable places (Cucuzza *et al*., 2020). In assessing and planning for both social and ecological well-being of the vulnerable communities, community resilience is essentially a first step toward reducing disaster risk in communities and enhancing their resilience to natural and human-induced disasters (Burton, 2015) that would ensure their longevity (Berke & Conroy, 2000). Community resilience is the capacity of a community to adapt to and influence the course of environmental, social, and economic change (U.S. Indian Ocean Tsunami Warning System Program, 2007) without fundamentally altering their essential identity, structure, and functions (Berkes & Folke, 1998; Leslie & Kinzig, 2009).

The IDB-funded Project "Enhancing Coastal Community Resilience for Sustainable Livelihood and Coastal Resources Management," implemented through a Technical Assistance Grant Agreement between SEAFDEC and IDB, aims to improve the socio-economic status of the coastal communities including the community fisheries organizations through capacity building programs on fisheries. Implemented in 2016 - 2018, the Project had as its target beneficiaries the coastal Muslim communities in the IDB countries of Southeast Asia, namely: Brunei Darussalam, Indonesia, and Malaysia (Mazalina et.al., 2018). Particularly for Indonesia, the pilot site was in Takalar District in South Sulawesi (**Figure 1**), as it reflects a microcosm of the country's typical coastal fishing communities.

Takalar District, South Sulawesi, Indonesia

In Indonesian fishing communities, the fluctuation of fishery resources stocks, shifting fishing seasons, and climate change have challenged the coastal communities to respond continuously to such predicaments. Generating coastal livelihoods and improving coastal management are among the approaches that could achieve resilience in fishing communities, especially in the case of Indonesia. The pilot site for this IDB Project implemented in Indonesia was at Takalar District in the South Sulawesi Province, located in the eastern part of the country. Takalar District is located between the Strait of Makassar and Laikang Bay, and includes Laikang Village where most of the respondents of the survey were drawn, considering that most of the seaweed farmers are also from this village.

Figure 1. Takalar District, South Sulawesi, Indonesia

South Sulawesi Province has abundant natural resources particularly in Takalar District and the Province itself is the largest producer of seaweeds (wet/dry) in Indonesia. Nevertheless, the increasing intensity of exploitation threatens all efforts toward the conservation of natural resources in that area. The growing dependence of fishing community in Takalar District to seaweed farming as main source of income, had allowed seaweed farming to develop more quickly, potentially resulting to greater prosperity in the coastal areas. However, the density of seaweed plots and unclear separation of farm ownership led to conflicts among interested parties. The issues about foreshore claims should be addressed by the village and government authorities in order to avert any socio-economic crisis to happen in the future. Furthermore, ecological studies should be conducted on the carrying capacity of the coastal environment in Laikang Bay and how seaweed farming has impacted on the environment, in an effort to strike a balance of the social acceptability and positive ecological effects of this particular activity.

Needs Assessment Survey

The community questionnaire survey on demographic and capacity building needs of the coastal communities in Takalar District was carried out involving the fishers, seaweed farmers, fishers' spouses, seaweed traders and collectors, seaweed exporters, and seaweed processing companies. Moreover, the staff of the Marine and Fishery Office of South Sulawesi Province, the village head, and selected local Non-governmental Organizations (NGOs) were also interviewed as key informants.

Community survey in Takalar District, South Sulawesi, Indonesia

Results of the survey indicated that the livelihoods of the coastal communities in Takalar District include fishing, aquaculture, and processing of the fishery products, and were supported by the geographical conditions and the availability of natural resources in the area. Geographically, Takalar District is located between the Makassar Strait and the Laikang Bay making the water current in this area relatively calm and allowing marine and brackishwater aquaculture activities to thrive. The commodities cultured by the people of Takalar District include seaweeds, milkfish, crabs, and tiger prawns. Although some residents culture catfish and tilapia in the inland open waters, but seaweed farming is the predominant livelihood in the community. Specifically, the people from Laikang Village rely on seaweed farming as their main livelihood, and their total production continues to increase, making seaweeds an economically important commodity for South Sulawesi. In 2015, Takalar District contributed 31.80 % of total seaweed production in South Sulawesi and 23.04 % to the national production (personal communication, Department of Marine and Fisheries, 2015).

Seaweeds culture in Laikang Village, Takalar District, South Sulawesi, Indonesia

Training on packaging of seaweed products in Central Lombok

The species of seaweeds being cultured in Takalar District are: Euchema cottonii and *Eucheuma spinosum* in marine waters; and *Gracilaria* sp. (*sakul*) and *Caulerpa* sp. (*lawi-lawi*) in brackishwaters ponds. Nonetheless, the culture of *Caulerpa* sp. is still limited because it is still a relatively new commodity so the market opportunity is still limited.

Meanwhile, fishing activities are also being carried out in Takalar District, where fishers use boats less than 5 GT and traditional fishing gears such as gillnet and hook and line. Their catch is usually sold fresh for local consumption, and only a small portion is processed. The processed marine and fishery products in Takalar District includes boiled fish, seaweed sticks, seaweed crackers, shredded seaweed, meatballs, dried fish, crab meat, fish balls, fish crackers, and fish cake (*otak-otak*), among others.

Enhancing Knowledge and Livelihood of Takalar Coastal Communities

Enhancement of community knowledge and institution activity was conducted with the objective of transferring knowledge about the concept and implementation of coastal community development, and strengthening the function and role of local institutions in order to develop the resilience capacities of coastal communities. The activities included: 1) Strengthening coordination with stakeholders, 2) Training on leadership, advocacy and community development, 3) Workshop on Participatory Planning on Resource Management and Conflict Management for Sustainable Livelihood, and 4) Internship and in-house training. Through such activities, a Plan of Action that contains short-, medium- and long-term plans; as well as Marine Fisheries Resource Management Strategies that contain three aspects, *i.e.*, institutional, technical, and adaptive strategies were successfully produced.

Training on seaweeds product processing *(above)*, shell craft making *(right)*

Through this IDB Project, internships and training sessions were organized to enhance the knowledge of the community members as well as to provide the means of generating additional sources of income for the community in Takalar District. The list of internship and training sessions conducted are shown in the **Box**.

Another significant output of the Project was the establishment of a Community Center in Laikang Village. Apart from being a center for seaweed collection, the Community Center would also serve as venue for training, processing of fishery products and the production of shell crafts.

Opening of Laikang Village Community Center

Way Forward

The Strategic Plan of Coastal Resource Management and Community Livelihood of Laikang Village was established for the purpose of promoting sustainable development, environmental management, and ecotourism development. Consisting of short-, medium-, and long-term plans for the development of the coastal community in Laikang Village, this strategic plan is a joint document between Laikang Village community and village policy-makers, and as envisioned, should be realized in the form of activities that support the economic development of Laikang Village. The strategies include, among others, the following:

- Implementation of programs and activities by utilizing existing fund in accordance with financing arrangement of Village Income and Budget (APBDesa) in parallel with the plans generated through Musrenbang Village level.

Box. Internship and training sessions conducted in Takalar District, South Sulawesi			
Activities	Participants	Teaching Method	Results/outputs
A. Internship			
Seaweed products processing in Central Lombok	3 apprentices: 1 senior processor, 1 younger marketing, and 1 very young business manager	Participants directly participated in the production process, then practiced independently: starting from selecting the ingredients, weighing, production, and packaging. The facilitator evaluated the results of participants' works at the end of the work day.	Three people with different characteristics have potential to cooperate in establishing a business of processing seaweed products. Their knowledge relating to business management, starting from business planning to development business, has improved. They also learnt and practiced the production of seven seaweed-based processed products, exceeding target set, *i.e.*, four products. The seven products generated have complied with the quality standards of UD AZHARI.
B. In-house Training			
Training on Seaweed Processing for fisheries products processing SMEs	25 participants comprising fishers' spouses, seaweed farmers and product processors	Using the "Demonstration and Example" method, the training includes how a job or any task is done. This method involves breaking down and demonstrating something through examples, and is easy for the trainer to teach real activities through a planning stage of 'how and why' in doing the works. This is very effective because it is easier to show the participants how to do a task, as the lectures and discussions are introduced with complete learning aids such as pictures, material texts and other visuals.	Successfully produced four types of processed seaweed products, namely: seaweed ice cream, seaweed sweets/candy, seaweed crackers, and sun-dried banana wrapped in seaweeds.
Training on clamshell for SMEs of Fisheries Product Processing	20 participants (17 men and 3 women) comprised fishers, shipbuilders, seaweed farmers, and housewives	Using the "Demonstration and Example" method, the training includes how a job or any task is done. This method involves breaking down and demonstrating something through examples, and is easy for the trainer to teach real activities through a planning stage of 'how and why' in doing the works. This is very effective because it is easier to show the participants how to do a task, as the lectures and discussions are introduced with complete learning aids such as pictures, material texts and other visuals.	Participants showed great enthusiasm and seriousness, and having acquired good understanding of the materials and methods, marketable products were generated. Upon completion of the training, the participants formed several clusters or groups for business activities based on their expertise, shared information on available raw materials for seashell products, as well as on the methods of making shell crafts from washing and shell cutting, molding/fiber manufacturing, final product design, and seashell products marketing.
Training of Seaweed Culture with Verticulture Technique	25 trainers (17 men and eight women) consist fishers, seaweed farmers, and seaweed binding women	Using the "Demonstration and Example" method, the training includes how a job or any task is done. This method involves breaking down and demonstrating something through examples, and is easy for the trainer to teach real activities through a planning stage of 'how and why' in doing the works. This is very effective because it is easier to show the participants how to do a task, as the lectures and discussions are introduced with complete learning aids such as pictures, material texts and other visuals.	The participants learned the vertical culture technique as an improved method for the capacity of seaweed farmers to increase production. The pilot seaweed farming using vertical long line techniques was compared with the long line method.
Training of Mud Crab Development Model	25 fishers and seaweed farmers	Using the "Demonstration and Example" method, the training includes how a job or any task is done. This method involves breaking down and demonstrating something through examples, and is easy for the trainer to teach real activities through a planning stage of 'how and why' in doing the works. This is very effective because it is easier to show the participants how to do a task, as the lectures and discussions are introduced with complete learning aids such as pictures, material texts and other visuals.	The stages in mud crab farming were introduced starting from construction of ponds, and techniques of cultivation, maintenance, harvest and post-harvest. The successful development of this technology is expected to provide an alternative livelihood for the community and eventually reduce poverty, and increased source of fresh mud crabs.

- Implementation of programs and activities by utilizing the existing financial resources in government institutions either central, provincial or district governments that are tailored to their respective programs.
- Implementation of programs and activities by utilizing the existing financing sources in private institutions, national or local level which is tailored to the programs and policies in those institutions.

The goal for the short-term plan (up to 5 years) is the implementation of development activities on coastal resources development and management, including the setting up of facilities and infrastructures to support the livelihood of the community in the Laikang Village. In the short-term period, the priority programs and activities include:

a. Development of livelihood opportunities
b. Livestock raising development
c. Development of waste management
d. Environmental love movement
e. Development and provision of tourism services, processing of marine products
f. Management of non-fishery potentials

For the management of the coastal resources and exploiting the potentials of the coastal resources in Laikang Village, the 'Laikang Coastal Resources Development Forum' was formed with the objective of assisting the Laikang Village head in terms of ideas and inputs, from the planning and preparation until a program is successfully implemented. The project in Laikang Village had already been turned over by the Project to the community.

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Towards Increased Production of Milkfish Fry in the Philippines: SEAFDEC/AQD technology through the lens

Dan Baliao, *Jebrham Navarro*, *John Aldrin Tugo*, and *Elaine Marrie Santiagudo*

Although the Philippines has a long coastline and is surrounded by rich waters, its capture fisheries sub-sector is just second to aquaculture which is the main driver for growth in the fish production industry of the country. In 2019, aquaculture production accounted for 53.20 % of the total Philippine fisheries production and the top two aquaculture commodities that the country produced were seaweeds and milkfish. Even though milkfish is among the top two commodities, this does not mean that there are no problems with its production. One of the major aspects that hinder sustainability is the harrowing concern regarding milkfish seed supply which is highly unpredictable. The local production of milkfish fry could not adequately supply the national demand, leading to the import of fry from nearby countries. To reduce the reliance on imports, the Government of the Philippines through its Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) came up with the "*National Bangus Fry Sufficiency Program*" with the goal of building legislated multispecies hatcheries in strategic locations in the country. DA-BFAR then tapped the services of SEAFDEC Aquaculture Department (AQD) to provide training and technical assistance, especially in undertaking the feasibility studies of proposed sites where hatcheries are to be established. So far, eight out of the 16 sites have had their feasibility studies submitted to DA-BFAR and their respective local government units (LGUs). To date, there are three ongoing hatchery projects that are in various stages of construction. Out of the three, two are for marine and one is for freshwater aquaculture commodities. In the SEAFDEC/AQD compound, multispecies hatcheries have also been constructed to supply the Western Visayas region with high quality milkfish fry as well as other commodities. Apart from building hatcheries, SEAFDEC/AQD has also partnered with the regional office of DA-BFAR in Western Visayas to revive abandoned/unproductive hatcheries which would then serve as milkfish satellite hatcheries once rehabilitation is completed.

The Philippines is among the top fish-producing countries globally, with its aquaculture sub-sector dominating its fish production. For a developing country, aquaculture is seen as a way to produce food and provide livelihood to people in the marginalized sector. In the Philippine Fisheries Profile 2019 of the Bureau of Fisheries and Aquatic Resources under the Department of Agriculture (DA-BFAR, 2020), the total volume of fish production from aquaculture constituted about 53.20 % of the Philippine total fisheries production. The bulk of aquaculture production came from seaweeds (63.60 %), followed by milkfish (17.38 %), tilapia (11.85 %), and then shrimp/prawn (2.81 %). The remaining 4.36 % is the combined production of other commodities such as oysters, mussels, and crabs.

Milkfish (*Chanos chanos*, Forsskal) or bangus in the Philippines, is unofficially dubbed as the "National Fish of the Philippines" due to its immense popularity in the country, as an economically important cultured fish (White, 2016). Its popularity stems from its ability to survive and adapt to many culture conditions leading to increased production, making it a staple food for millions of Filipinos. However, data shows that its aquaculture production has been fluctuating in recent years (**Figure 1**). In 2016, the Philippines produced 398 tonnes (t) of milkfish, followed by a 3.26 % increase to 411 t in 2017. Milkfish aquaculture production drastically went down by 26.27 % to 303 t and then staggeringly went up to 409 t the following year (DA-BFAR, 2017; DA-BFAR, 2018; DA-BFAR, 2019; DA-BFAR, 2020).

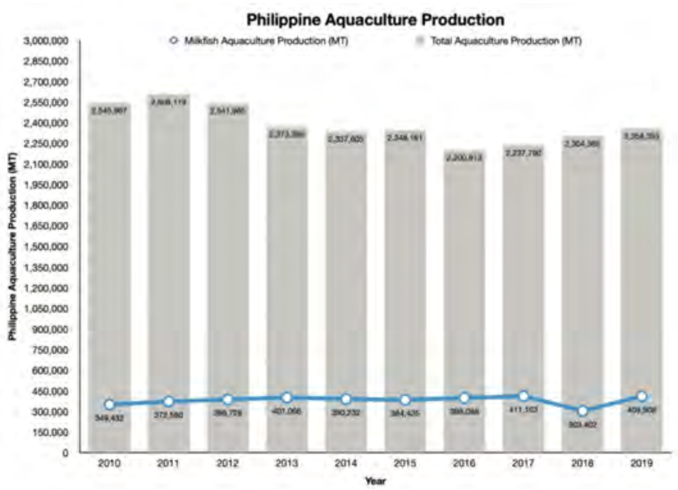

Figure 1. Milkfish aquaculture production in the Philippines over ten years (2010 – 2019) by quantity (t)
Source: DA-BFAR (2010 – 2020)

The erratic production figures can be attributed to the seasonal availability of seed stocks as the Philippine milkfish industry is still highly reliant on wild-caught seed stocks (Santos et al., 2018). According to the Memorandum on Bangus Fry Sufficiency Program of DA-BFAR by *E. Gongona* (personal communication, 2 May 2018), the current combined production of wild-caught fry and captive-bred fry is just 1.1 billion pcs, 1.4 billion pcs short from meeting the annual fry requirement of the country, which is 2.5 billion fry. Fish farmers therefore resorted to importation of fry from nearby countries, particularly Indonesia to make up for the insufficiency.

To address this problem, DA-BFAR came up with the "National Bangus Fry Sufficiency Program" which aims to locally produce an estimated 1.2 billion milkfish fry by putting up hatcheries in strategic locations all over the Philippines and to reduce the reliance of fish farmers on imported fry by as much as 85 %. About 48 hatcheries are needed to realize this program, and each hatchery would need to produce 25 million fry per annum. These proposed hatcheries would need about 3,750 milkfish breeders: 2,500 females and 1,250 males following the ratio of 2 females to 1 male. Apart from solving the scarce fry supply, the program would also try to break the stigma that captive-bred fry are inferior to wild-caught fry in terms of growth, morphology, and survival as DA-BFAR would ensure that the fry produced would be of the highest quality.

Legislated Hatcheries

The constructed hatcheries in the different regions of the Philippines are meant to culture multispecies aquaculture commodities (**Figure 2**). Hatcheries were designed based on the basic requirements of a milkfish hatchery, considering the location and capacity of the region where it will be constructed. Proposed hatcheries would contain broodstock tanks called 'core hatchery,' and if the broodsock tanks are absent, it will function as a 'satellite hatchery.' These proposed hatcheries are versatile enough to accommodate the culture of other economically important aquaculture species such as the black tiger shrimp (*Penaeus monodon*), mangrove crab (*Scylla serrata*), and other commodities that are quickly gaining in popularity, *e.g.* pompano (*Trachinotus blochii*). Doing this would give the receiving local government units (LGUs) the flexibility to choose what species to culture based on their preference and capacity (**Figure 3**). Once established, these hatcheries would then provide the seed requirements for grow-out of their respective regions. Aside from fry production, these hatcheries would also serve as training and demonstration facilities for interested private groups or individuals.

Figure 2. Perspective view of one of the proposed multi-species marine hatcheries

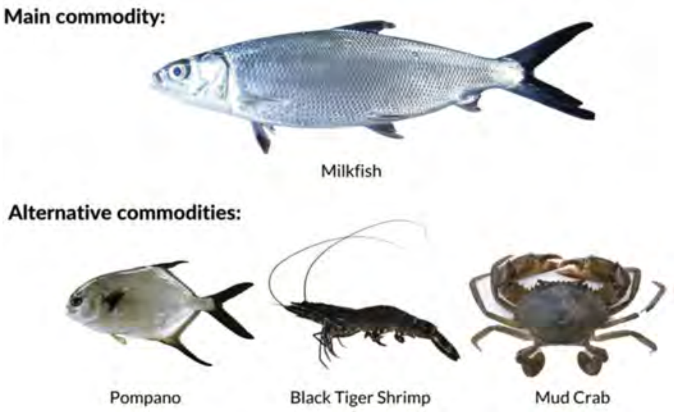

Figure 3. Species alternative to milkfish for culture in the hatcheries

The proposed establishment of the hatcheries was passed as legislation or Republic Act (R.A.) to ensure that it will push through. To enact this program, DA-BFAR has tapped SEAFDEC/AQD to provide training and technical assistance in conducting the feasibility studies for several of these legislated hatcheries. Out of 23 identified legislated hatcheries around the Philippines, SEAFDEC/AQD was tasked to study the feasibility of 16 hatcheries. Out of the 16, SEAFDEC/AQD has already finished conducting feasibility studies for eight sites and has submitted the necessary reports and other documents to DA-BFAR and the receiving LGUs.

To date, construction of three hatcheries in the CARAGA Administrative Region (**Figure 4**) which comprises five provinces in northeastern Mindanao: Agusan del Norte, Agusan del Sur, Dinagat Islands, Surigao del Norte, and Surigao del Sur, is already ongoing, and currently in various stages of completion. Two of these are multispecies marine

Figure 4. Map of Caraga Administrative Region, Philippines, showing the sites of the three hatcheries (★): Lingig (Surigao del Sur), Del Carmen (Surigao del Norte), and Jabonga (Agusan del Norte)

Figure 5. Progress of the construction of the hatcheries in three sites: Lingig (Surigao del Sur), Del Carmen (Surigao del Norte), and Jabonga (Agusan del Norte)

hatcheries located in Lingig, Surigao del Sur and in Del Carmen, Surigao del Norte. The remaining hatchery is a multi-species freshwater hatchery in Jabonga, Agusan del Norte. Progress of the hatchery construction works in these three sites is shown in **Figure 5**.

Meanwhile, the feasibility studies of the sites in Perez, Quezon; Sultan Naga Dimaporo, Lanao del Norte; Surigao City, Surigao del Norte; Hinatuan, Surigao del Sur; and Jose Dalman, Zamboanga del Norte have already been turned over to their respective LGUs for the implementation.

Due to travel restrictions and health risks brought about by the COVID-19 pandemic, the conduct of feasibility studies of the remaining sites was passed on to the regional offices of DA-BFAR. The status of the feasibility studies undertaken by SEAFDEC/AQD for the legislated hatcheries is summarized in **Table 1**.

Table 1. Status of the feasibility studies (FS) of the legislated hatcheries assigned to SEAFDEC/AQD

R.A.	Location	Status
10787	Lingig, Surigao del Sur	FS Completed
10825	Del Carmen, Surigao del Norte	FS Completed
10825	Surigao City, Surigao del Norte	FS Completed
10813	Jabonga, Agusan del Norte	FS Completed
10945	Perez, Quezon	FS Completed
10859	Jose Dalman, Zamboanga del Norte	FS Completed
10860	Sultan Naga Dimaporo, Lanao del Norte	FS Completed
10944	Hinatuan, Surigao del Sur	FS Completed
10856	Bantayan, Cebu	FS to DA-BFAR 7
10858	Nasipit, Agusan del Norte	FS to DA-BFAR CARAGA
10939	Atimonan, Quezon	FS to DA-BFAR 4A
10948	Guinyangan, Quezon	FS to DA-BFAR 4A
10950	Ligao, Albay	FS to DA-BFAR 5
10938	Lopez, Quezon	FS to DA-BFAR 4A
10940	Gumaca, Quezon	FS to DA-BFAR 4A
10947	Plaridel, Quezon	FS to DA-BFAR 4A

Revival of Abandoned Hatcheries

Back in 2019, SEAFDEC/AQD assisted the DA-BFAR Regional Office 6 (DA-BFAR 6) in profiling the hatcheries in Western Visayas (**Figure 6**), which comprised the provinces of Aklan, Antique, Capiz, Guimaras, Iloilo, and Negros

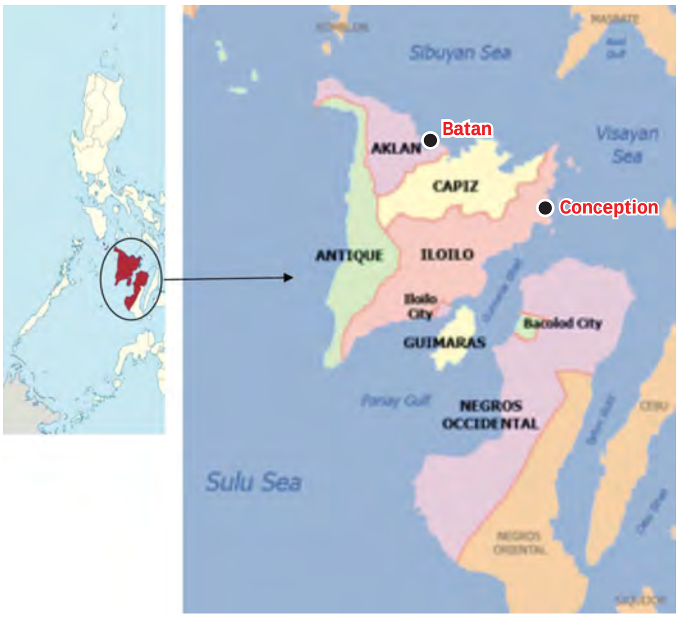

Figure 6. Map of Western Visayas showing the location of Batan in Aklan, and NIPSC Concepcion Campus in Concepcion, Iloilo, where the abandoned hatcheries are planned to be revived and or rehabilitated into milkfish hatcheries

Occidental. The hatchery profiling was aimed at determining which hatcheries are operational or non-operational. Usually the hatcheries become abandoned or rendered non-operational due to the demise of hatchery owners or inadequacy of finances to continue the hatchery operations or bankruptcy. After profiling, DA-BFAR 6 selected two abandoned hatcheries that were considered candidates for revival or rehabilitation into milkfish satellite hatcheries.

The main criteria for selection include tank stability, accessibility of its location, and ownership rights. One of the selected abandoned hatcheries is located in Batan, Aklan, while the other is located inside the Northern Iloilo Polytechnic State College (NIPSC) Concepcion Campus in Concepcion, Iloilo (**Figure 6**). The ultimate goal of reviving these hatcheries would be to maximize the milkfish production potentials of the Western Visayas Region. The hatchery in Batan is privately-owned and was used to culture shrimp postlarvae. However, shrimp diseases were too much to handle in the past, leading to the termination of hatchery operations. The hatchery has almost all of the necessary amenities in rearing milkfish larvae to fry. However, a phycology laboratory that is essential to provide a continuous supply of natural food to the growing larvae during larval rearing operations shall be constructed.

The tanks and other facilities on-site were renovated, cracks were repaired, roofing installed, repainting carried out, and others (**Figure 7**). SEAFDEC/AQD has advised the construction of a phycology laboratory, and so far, the hatchery rehabilitation is almost complete, and SEAFDEC/AQD has already sent 1.1 million milkfish larvae and 30 L of rotifers to jumpstart the hatchery operations. Meanwhile, the non-operational hatchery in Concepcion, Iloilo, had not even operated from the start. However, some of the facilities were slightly used to culture tilapia (*Oreochromis* sp.) probably for experimental purposes.

Figure 7. Rehabilitated hatchery tanks in Batan, Aklan; and in Concepcion, Iloilo

The abandoned hatchery at NIPSC has two portions: outdoor and indoor. The tanks located outside were demolished as these were not fit for rearing milkfish larvae, and new concrete tanks were later built, making it more suitable for milkfish larval rearing operations. Inside, the hatchery houses several tanks and a reservoir. Some of these were rehabilitated, and a filter tank was constructed inside. Similar to the previous hatchery, a phycology laboratory needs to be constructed. To date, construction and repair of the necessary facilities were already done apart from the phycology laboratory construction (**Figure 7**). Once rehabilitation is completed, this would become a fully functional milkfish satellite hatchery that can accept eggs and larvae from nearby core hatcheries. It will be capable of rearing fry, which would hopefully translate to increased milkfish production in Western Visayas.

New Facilities at SEAFDEC/AQD

Aside from assisting the promotion of the "National Bangus Fry Sufficiency Program" of DA-BFAR, SEAFDEC/AQD is also keen on doing its part to produce the seed requirements and address several seed shortages of key commodities in the country. Recently, SEAFDEC/AQD has finished the construction of two multispecies hatcheries, one catered for marine species (**Figure 8**) and the other for freshwater species (**Figure 9**), at its Tigbauan Main Station (TMS) in Iloilo Province.

The newly built marine hatchery is expected to produce seeds of priority marine species such as milkfish, pompano, grouper (*Epinephelus* sp.), and others. At the same time, the newly built freshwater hatchery is set to produce the fry of catfish (*Clarias* spp.), giant freshwater prawn (*Macrobrachium rosenbergii*), and tilapia. Meanwhile, the newly constructed milkfish broodstock facility (**Figure10**) would house the additional milkfish breeders acquired by SEAFDEC/AQD for the production of the much needed additional eggs to ramp up seed production at the other SEAFDEC/AQD facilities at its Tigbauan Main Station in Iloilo, Philippines.

Figure 8. The newly constructed marine multispecies hatchery at SEAFDEC/AQD Tigbauan Main Station, Iloilo, Philippines

Figure 9. The newly constructed freshwater multispecies hatchery at SEAFDEC/AQD Tigbauan Main Station, Iloilo, Philippines

Figure 10. The newly completed hatchery systems at SEAFDEC/AQD Tigbauan Main Station, Iloilo, Philippines

Ultimately, this multimillion-pesos project (**Figure 10**) spearheaded by the current SEAFDEC/AQD Chief would serve as a model for the proposed multispecies hatcheries all over the Philippines. It will show what those hatcheries are capable of, how they should operate, and how much they can produce. These hatchery systems would help boost the efforts of the Philippine Government to ensure that there is available supply of seeds, *e.g.* fry, fingerlings of economically important aquaculture commodities to enhance the country's fish production from aquaculture.

Way Forward

In its bid to help address the aquaculture seed shortage of its host country the Philippines, SEAFDEC/AQD would continue to collaborate with DA-BFAR in implementing relevant projects in the future. SEAFDEC/AQD would also try to help produce high-quality fry using ripe technologies developed by its researchers and scientists. As simple as they may seem, innovations in culture technologies are also slowly being applied to increase production. Recently, SEAFDEC/AQD has installed water heaters in its milkfish broodstock tanks to enhance egg production during colder months of the year, and it has proved to be successful. However, production numbers do not match the output during warmer months. However, it is a welcome development as SEAFDEC/AQD strives to aid its host country in achieving food security.

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Assessing the Effects of the Innovative Fungicide Pyraclostrobin Capsule Formulation on Silver Barb (*Barbonymus gonionotus*) in Rice Paddy: the case of Thailand

Anon Sirisuriyakamonchai , Payorm Cobelli, Rungrudee Jongseubsak, Kraiwut Kateloy, Krishna Varma Kalidindi, and *Peter Dohmen*

Fish culture in rice paddies offers one of the best means of contemporaneous production of grain and animal protein at the same piece of land (Schuster, 1955). Whenever water is stagnated within bunds for rice culture, fish, which naturally occur in the irrigation canals, nearby tanks and pools, enter the rice paddies and grow there until rice harvest. Thailand is one of the countries that culture fish in rice paddies (Swingle & Shell, 1972). One of the common fish cultured in rice paddies is the silver barb (*Barbonymus gonionotus*) which is distributed throughout the country. This carp species feeds on plant matters (*e.g.* leaves, weeds, *Ipomea reptans*, and Hydrilla), thus, it has been used to prevent excessive weed growth in reservoirs throughout the country (Froese & Pauly, 2021). Also, this fish is famous for food, and it is an important cultural heritage of Thailand. In the old days, the people of Thailand believed that this fish was a symbol of abundance and strength as it could survive in any water sources and normally grew to full size around the same time that rice was ready for harvesting. For such reason, this period is commonly known as *kao mai pla man*, which means "new rice and delicious fish" (Bangkok Post, 2013).

Nowadays, however, this practice of fish culture in rice paddies has drastically reduced because of the introduction of modern technologies such as the use of large amounts of chemicals as fertilizers and pesticides in rice paddies that make it almost impossible for contemporaneous production of rice and fish. Therefore, the researcher, *Mr. Anon Sirisuriyakamonchai*, from the Department of Fisheries of Thailand conducted a study to compare the effects of the standardized and innovative formulations of the fungicide Pyraclostrobin on fish in the rice paddy.

Rice is the most important staple food for the majority of people in the world (Bandumula, 2018). It is mainly grown in subtropical and tropical regions with sufficient rainfall. Accordingly, rice paddies are often connected to important wetland areas and aquatic ecosystems; and rice paddy itself is an aquatic ecosystem (Halwart & Gupta, 2004). However, a number of fungus, bacteria, viruses, nematodes, and mycoplasma-like organisms cause diseases to rice plants. Among the fungal diseases, rice blast (*Pyricularia grisea*), brown spot (*Bipolaris oryzae*), stem rot (*Sclerotium oryzae*), sheath blight (*Rhizoctonia solani*), and sheath rot (*Sarocladium oryzae*) are the most alarming (International Rice Research Institute, 2006) and considered as serious constraints to rice production which can significantly reduce rice yield.

Fungicides are used to protect plants from diseases and minimize yield losses (Balba, 2007; Smart, 2003). For many crops worldwide, primarily in cereals and maize, the highly efficient strobilurin fungicide used is Pyraclostrobin (Ambrus, 2004) which is also effective against rice fungal diseases (M. Li *et al*., 2018). The Pyraclostrobin standardized formula is an effective fungicide, however, it has adverse effects to the aquatic ecosystem and is highly toxic to aquatic organisms (Cui *et al*., 2017; European Commission, 2004; Hooser *et al*., 2012; Lewis *et al*., 2016; Liu *et al*., 2018; Morrison *et al*., 2013; Zhang *et al*., 2017, 2020). In aquatic ecosystems, fish are the most sensitive organisms to Pyraclostrobin when applied according to label recommendations. Nevertheless, the demand for efficient fungicides for rice crops is still high (Uppala & Zhou, 2018), which is why significant efforts have been carried out to develop an innovative Pyraclostrobin formulation.

Silver barb, *Barbonymus gonionotus* (Bleeker, 1849)
(Source: FishBase)

In developing the innovative Pyraclostrobin formulation, the basic principle is to encapsulate the active substance (B. Li *et al*., 2017; M. Li *et al*., 2018), so that when the encapsulated formulation is applied, the capsules dry up on the plant surfaces, and subsequently, open and release the active substance. In water, however, the capsules remain intact and sink on the sediments where the active substance is slowly released; and due to its high soil adsorption coefficient (K_{oc}) of 6,000–16,000 ml/g (European Commission, 2004), it easily binds with the sediments where it is degraded. The capsulated formulation reduces the aquatic toxicity of the active ingredient while maintaining biological performance.

This concerned study was aimed at comparing the effects of Seltima and Headline on silver barb in rice paddy. Seltima is a new capsule suspension (CS) formulation of Pyraclostrobin that demonstrates to reduce toxicity on fish in laboratory and semi-field studies (M. Li *et al*., 2018), while Headline is one of the widely used Pyraclostrobin emulsifiable concentrate (EC) standard formulations for dry land crops.

Study area

The study was conducted in a rice paddy in Suphan Buri Province which is located in the central part of Thailand (**Figure 1**) where the alluvial area is intensively cultivated, from August to October 2019. During the rainy season, rice covers the major areas of this region, which accounts for about one-fifth of the total cultivated rice land of the country. The average farm size is large, and a large proportion of the rice land has access to irrigation facilities, allowing many farmers to grow two rice crops during the year. Almost 75 % of the dry-season rice grown under irrigated conditions is located in this region. Farm operations are almost entirely mechanized, and farmers adopt the direct-seeding method of crop establishment to save labor. This region produces mostly long-grain rice and supplies the main rice surplus of the country (Global Rice Science Partnership, 2013).

Figure 1. Study area in Suphan Buri, Thailand

Experimental setup

For the experiment, a total of 12 plots in the rice paddy were used for three treatments (T1, T2, and T3) and each treatment had four replicates (R1, R2, R3, and R4). Each plot was 1.0 m^2 (100 cm × 100 cm) and sealed with mud and plastic sheets to prevent water leakage. The water level in the plots was maintained at 10 cm depth, and the plots that lost water were filled with water from the surrounding fields. **Figure 2** shows the randomized complete block design of the plots with the distance of 3–4 m around each plot to avoid contamination.

On 14 August 2019, seedlings of the rice variety RD41 were transplanted into each plot with 20 cm space between plants and 25 cm between rows (**Figure 3**). The experimental plots

T2 R1	T1 R1	T3 R1
T2 R2	T3 R2	T1 R2
T3 R3	T1 R3	T2 R3
T2 R4	T3 R4	T1 R4

Figure 2. Randomized complete block design of experimental plots

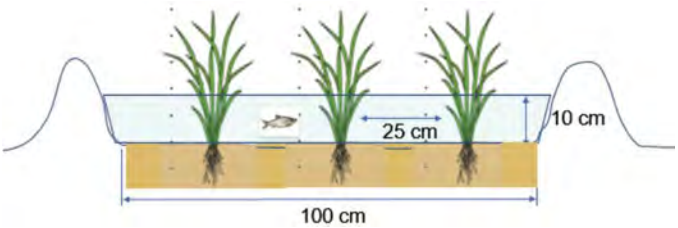

Figure 3. Setup of each experimental plot

were maintained until 56 days after transplant (DAT), the recommended growth stage for the application of Seltima in Thailand. The rice paddy was fertilized twice: the first time was 20 DAT with 16-20-0 (N-P-K) 156.25 kg/ha, and the second time was 50 DAT with 46-0-0 at 62.5 kg/ha. The weeds were removed by hands and insects were controlled using chlorantraniliprole 5.17 % SC at 312.5 ml/ha during 23 DAT and 52 DAT.

Test solutions

Two Pyraclostrobin fungicidal products were used as test solutions for the experiment, namely: Seltima CS (BAS 500 23 F, Batch 0020611003, containing 100 g/l active substance) and Headline EC (25 % EC, BAS 500 13 F, Batch 090918, 0018774134, containing 250 g/l active substance). Each test solution (*i.e.* 10 ml sample of Seltima and 4 ml sample of Headline) was suspended in the electric spray tank filled with 4.0 l water to obtain the 100 g/ha Pyraclostrobin solution. The spray tank was shaken well, then 40 ml of the respective test solutions were sprayed within three seconds directly to the water in the designated plots. T1 plots were the control and sprayed with water. T2 plots were sprayed with Seltima test solution and T3 plots were sprayed with Headline test solution, at the rate of 0.074 ± 0.014 mg/l and 0.086 ± 0.033 mg/l, respectively. A windshield was used in each plot while spraying the test solutions.

To determine the active substance concentrations of the test solutions, 500 ml of water was sampled from each plot at 0 h and 72 h. Only for T1 plots, the water samples collected at 72 h were pooled to one sample. The water samples were collected from the surface down to 8–10 cm of the water column to avoid sediment contamination; and stored in glass bottles which were then sealed and stored in containers with ice and transferred to the analytical laboratory. The water samples were analyzed using UHPLC/MS-MS with 0.002 mg/l limit of detection (LoD) and 0.006 mg/l limit of quantification (LoQ).

Test organisms

Juvenile *B. gonionotus* with a body length of 4–6 cm was used as the test organism. The fish were procured from Nakhon Pathom Province, Thailand approximately 36 h before the exposure. Upon arrival at the study area, the 200 fish were kept in the pond (2 m × 2 m with 30 cm water level) in the rice paddy and not provided with food until exposure. At the start of the experiment, ten fish were impartially introduced to each plot 1–2 h before the application of test solutions. Then, the plots were covered with nets to prevent access of predators which are mainly bird species. Visual inspections of the fish were made at 2 h, 6 h, 24 h, 48 h, and 72 h for signs of toxicity (abnormal appearance and behavior) and mortality. The fish were considered dead if there was no visible movement or respiration. The dead fish were removed from the plots at each observation time. At the end of the experiment (at 72 h), the water was drained and rice plants were completely removed from all plots. Live fish were recovered using a net and their conditions were checked. Missing fish were recorded as missing data.

Physical-chemical parameters

The water quality (level, temperature, dissolved oxygen (DO), and pH) were measured in each plot prior to the application of test solutions and at 24 h, 48 h, and 72 h. The ambient air temperature was measured at 1 h, 24 h, 48 h, and 72 h. To test the differences among water quality of T1, T2, and T3 plots, one-way analysis of variance (one-way ANOVA) was used at a significant level of $\alpha = 0.05$ and the number of dead fish between Seltima and Headline was measured by Fisher's exact test. Moreover, rainfall was measured to examine its influence on the Pyraclostrobin concentration during exposure by placing a measuring cylinder at an elevated position between the plots. Also, the soil composition of the rice paddy was analyzed by the hydrometer method.

Results and Discussion

The water quality in the plots during the course of the experiment is shown in **Table 1**, **Table 2**, and **Table 3**. The average water temperature was 28.8 °C with a range from 28 °C to 30 °C which was high as expected under the local weather condition. The average pH of the water was 7.4 and varied slightly in a range between 7.1 and 7.7. The average DO was 5.4 mg/l which was generally low. However, the plots with low DO levels had lower mortality rates compared to other plots with the same treatment. For statistical analysis, it was found that there was a normal distribution and variance. The water quality measurements were not different in each experimental unit. The ambient air temperature was 32 °C at 1 h, 31°C at 24 h, 30 °C at 48 h, and 31 °C at 72 h. During the experiment, it rained only at 24 h with a rainfall level of 22 mm. The rice paddy soil was composed of 70 % clay, 17 % silt, and 13 % sand. The Fisher's exact test indicated the lack of significant difference between dead fish in T1 and T2 ($p = 0.05$) as shown in **Table 4** and the highly significant difference of dead fish between T1 and T3 ($p < 0.01$) as well

Table 1. Physical-chemical parameters of water quality in T1, T2, and T3 plots

	Observation time (h)	Average water level (cm)	Average temperature (˚C)	Average pH	Average DO (mg/l)
T1	0.0	10.6	28.8	7.4	7.4
	24.0	9.5	28.8	7.3	5.4
	48.0	12.6	28.8	7.4	6.7
	72.0	11.0	28.8	7.3	3.4
	Average	10.9	28.8	7.4	5.7
T2	0.0	10.9	28.8	7.3	4.4
	24.0	8.5	28.3	7.4	5.8
	48.0	10.2	28.9	7.4	5.6
	72.0	9.1	28.7	7.4	3.5
	Average	9.7	28.7	7.4	4.8
T3	0.0	10.6	28.7	7.3	5.4
	24.0	9.0	28.9	7.5	6.1
	48.0	11.8	29.0	7.6	7.0
	72.0	9.5	28.8	7.4	4.7
	Average	10.2	28.8	7.4	5.8
General average		10.3	28.8	7.4	5.4
Range		6.0–14.0	27.3–29.9	7.1–7.7	1.8–10.3

Table 2. Test of homogeneity of variances of water quality in T1, T2, and T3 plots (α=0.05)

Parameters	Levene statistic	df1	df2	Significance
Water level (cm)	0.27	2	45	0.77
Temperature (˚C)	1.61	2	45	0.21
pH	1.87	2	45	0.17
DO (mg/l)	0.62	2	45	0.54

Table 3. ANOVA of water quality in T1, T2, and T3 plots (α=0.05)

		SS	DF	MS	F	Significance
Water level (cm)	Between groups	12.05	2.00	6.02	2.46	0.10
	Within groups	110.14	45.00	2.45		
	Total	122.19	47.00			
Temperature (˚C)	Between groups	0.29	2.00	0.14	0.83	0.44
	Within groups	7.73	45.00	0.17		
	Total	8.01	47.00			
pH	Between groups	0.07	2.00	0.03	1.85	0.17
	Within groups	0.79	45.00	0.02		
	Total	0.86	47.00			
DO (mg/l)	Between groups	9.63	2.00	4.82	1.06	0.36
	Within groups	205.06	45.00	4.56		
	Total	214.69	47.00			

Table 4. The Fisher's exact test on dead fish between T1 and T2

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-square	0.219[a]	1	0.640	0.792	0.421
Continuity correction[b]	0.041	1	0.839		
Likelihood ratio	0.220	1	0.639	0.792	0.421
Fisher's exact test				0.792	0.421
N of valid cases	77				

[a] 0 cells (0.0%) have an expected count less than 5. The minimum expected count is 8.88.
[b] Computed only for a 2 × 2 table

Table 5. The Fisher's exact test on dead fish between T1 and T3

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-square	49.259[a]	1	0.000	0.000	0.000
Continuity correction[b]	45.973	1	0.000		
Likelihood ratio	61.894	1	0.000	0.000	0.000
Fisher's exact test				0.000	0.000
N of valid cases	76				

[a] 0 cells (0.0%) have an expected count less than 5. The minimum expected count is 13.26.
[b] Computed only for a 2 × 2 table

Table 6. The Fisher's exact test on dead fish between T2 and T3

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-square	44.485a	1	0.000	0.000	0.000
Continuity correction[b]	41.402	1	0.000		
Likelihood ratio	56.322	1	0.000	0.000	0.000
Fisher's exact test				0.000	0.000
N of valid cases	79				

[a] 0 cells (0.0%) have an expected count less than 5. The minimum expected count is 13.82.
[b] Computed only for a 2 × 2 table

as between T2 and T3 ($p < 0.01$) are shown in **Table 5** and **Table 6**.

Active substance

The analytical measurements of the water samples from the plots are shown in **Table 7**. Based on the application rate of 100 g/ha active substance of test solution in the plot with the water level of 10 cm, the theoretical concentration would be 0.1 mg/l. However, the rice plants in the plots intercepted the sprayed test solutions. Consequently, the initial data were below the theoretical concentrations without plants but were within the expected ranges under the more realistic conditions of this semi-field study. The initial measurements in T1 plots confirmed the absence of contamination. The data in T2 plots were in the same range as those in T3 plots. On the other hand, the large variations of data in T3 may have been caused by inhomogeneous water sampling during collection and pooling of samples, as the low value in the R1 plot and the

Table 7. Active substance concentration of test solutions in T1, T2, and T3 plots at 0 h and 72 h

Treatment	Replicate	Active substance (mg/l)	
		0 h	72 h
T1	R1	< LoD	-
	R2	< LoD	-
	R3	< LoD	-
	R4	< LoD	-
T2	R1	0.073	< LoD
	R2	0.065	< LoD
	R3	0.065	< LoD
	R4	0.094	< LoD
T3	R1	0.041	< LoD
	R2	0.097	< LoQ
	R3	0.120	0.008
	R4	0.086	< LoQ

high value in the R3 plot were not reflected in the respective fish mortality data.

At the end of the experiment at 72 h, there were no detectable Pyraclostrobin concentrations that could be found in the water samples from T2 plots treated with Seltima. This is in line with the expected behavior of this product that the Pyraclostrobin containing capsules sink to the sediment and the slowly released Pyraclostrobin will bind to the sediment where it is rapidly degraded (European Commission, 2004). In T3 plots which were applied with Headline treatment, Pyraclostrobin concentrations decreased largely to levels below the LoQ due to degradation and dissipation to sediment.

Impacts on fish

Healthy fish were hard to find in the plots due to water turbidity and they tend to hide under the rice plants, whereas the impacted and dead fish were easily spotted. The abnormal behavior and appearance observed in fish over time are shown in **Table 8**. At 2 h, the fish in T3 have shown slow movement and erratic swim. Whereas, from 24 h to 72 h, it

Table 8. Abnormal appearance and behavior of fish in T1, T2, and T3 plots over time (SM: slow movement; ES: erratic swim; FI: fungal infection; the number in parenthesis is the number of fish)

	Replicate	0 h	2 h	6 h	24 h	48 h	72 h
T1	R1	-	-	-	-	-	FI (1)
	R2	-	-	-	-	-	-
	R3	-	-	-	FI (1)	-	FI (1)
	R4	-	-	-	-	FI (2)	FI (2)
T2	R1	-	-	-	-	-	-
	R2	-	-	-	-	-	-
	R3	-	-	-	FI (1)	-	-
	R4	-	-	-	-	-	FI (3)
T3	R1	-	SM (1)	-	-	-	-
	R2	-	ES (1)	-	-	-	-
	R3	-	-	-	-	-	-
	R4	-	-	-	-	-	-

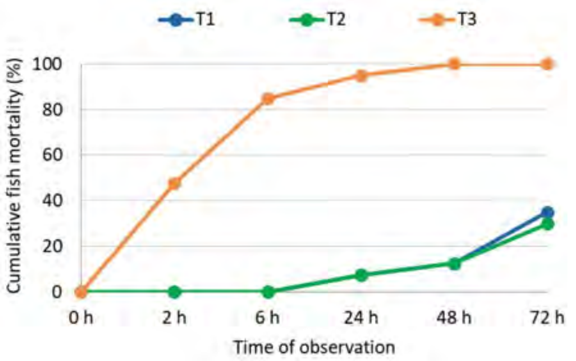

Figure 4. Cumulative fish mortality (%) over time in T1, T2, and T3 plots

was observed that fish in T1 and T2 had a fungal infection. For the cumulative fish mortality, 7.5 % of fish were dead at 24 h and increased over time in both T1 and T2 plots (**Figure 4**). In T3 plots, 85 % were dead at 6 h, 95 % mortality occurred at 24 h, and no fish survived at 48 h. Most of the impacted and dead fish in T1 and T2 plots could be attributed to fungal infection. The harsh condition in the pond where the fish were kept before the experiment was likely responsible for the poor health condition. Nevertheless, the results of this study demonstrated the safety of the fungicidal product Seltima to fish under realistic worst-case conditions, when the condition and behavior of fish in T2 plots did not differ from those in T1 plots.

For the semi-field study in Thailand under realistic worst-case conditions, the fish were exposed in the rice paddy at earlier rice plant growth stages (BBCH 40 to 49; lesser degree of plant interception) than recommended on the label of Seltima (BBCH 43 to 69; higher degree of plant interception) and lesser Pyraclostrobin, which resulted in higher plant interception and less product, and even decreased the toxicity of the water. Even under these worst-case conditions in China, Indonesia, and Thailand there was only a marginal impact of the Seltima CS formulation on fish, if at all. Considering the reduced exposure to the substance in natural water bodies outside the paddy field (Bullock, 2020), it can be presumed that Seltima applications will be of low risk to fish and other or less sensitive aquatic organisms (European Commission, 2004) in natural ponds and other bodies of water adjacent to rice fields.

Conclusion and Recommendations

The results of this study indicated that even under the worst-case conditions, the Seltima CS formulation caused only a marginal impact on the silver barb. On the other hand, the Headline standard formulation was highly toxic to the fish. Hence, the Pyraclostrobin capsule formula that was developed with the same efficiency as the standard formulation does not severely affect the aquatic ecosystems. Therefore, it is recommended that countries in the Southeast Asian region and other rice-growing countries should apply rice fungicidal products that are harmless to aquatic ecosystems, particularly when safer alternatives are available, and avoid using those highly toxic products.

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Mitigating the Impacts of Salinity Intrusion due to Climate Change on the Tra Catfish Farming in Coastal Provinces of the Mekong Delta, Viet Nam

Anh Lam Nguyen and *Nghiep Ke Vu*

The present state of our knowledge of the earth's climate change and tectonic plate movements suggests that sea level rise would greatly affect the Mekong Delta. Farming of the tra catfish (*Pangasianodon hypophthalmus*) is intensively done in Viet Nam, particularly along the Mekong River branches, and especially in Tien and Hau Rivers, and their associated tributaries. The contribution of the tra catfish farming industry to the economy and food security of Viet Nam is crucial as this sub-sector is one of the biggest employers in the country's Mekong Delta region. Against such a backdrop, a review was undertaken to determine the impact of sea level rise caused by climate change on tra catfish farming, assess the capabilities of tra catfish farmers in dealing with potential changes in the climate, and propose adaptation strategies useful to farmers and policy makers. Tra catfish farmers may have gained knowledge on climate change from mass communications media but they still have low perceptions on the gradual impacts of climate change, such as sea level rise. Their experience related to climate change has been shaped mainly by extreme climatic events. Nonetheless, representatives from the Tra Catfish Farmers, companies and key informants in Soc Trang Province pointed out that saltwater intrusion would continue to be one of their highest concerns in the future, and added that, changes in the farming techniques for tra catfish would be one of the most important adaptation measures to cope with climate change and saline water intrusion.

When the plausible impact of salinity intrusion induced by three climate change scenarios and associated sea level rise levels (SLR) of +30, +50 and +75 cm on the tra catfish farming sub-sector were simulated in a study, the initial results indicated that more areas in the coastal provinces of Viet Nam would be affected by salinity intrusion. Moreover, those areas that are already affected would experience longer periods of higher salinity levels, and as a consequence of the rising salinity levels due to SLR+75 cm, the window appropriate for the culture of tra catfish in the coastal areas would be greatly reduced. Facing the risk of salinity intrusion induced by sea level rise on the tra catfish farming industry in the Mekong Delta, a framework was proposed for decisions on the plausible autonomous and planned adaptation(s). The proposed suitable adaptive measures of tra catfish farmers under the autonomous adaptation category could include: (i) changing pond culture practice(s) (spontaneous adaptation), and (ii) stocking a salinity-tolerant pangasius if available (spontaneous adaptation). In the planned adaptation category, the appropriate solutions could include: (i) developing a salinity-tolerant strain of pangasius through the intervention of government/public agencies or private companies (active adaptation), and (ii) shifting to farming other salinity-tolerant species (spontaneous adaptation). Nonetheless, the latter adaptations may be chosen by only few farmers as it would require investments in terms of new know-how and networks, and in restructuring the culture ponds.

Nowadays, the striped catfish (*Pangasianodon hypophthalmus* Sauvage, 1878), commonly referred to as tra catfish (**Figure 1**), is the most important aquatic species being farmed in Viet Nam from the social and economic points of view. In 2015, the tra catfish farming sub-sector of Viet Nam produced 1.11 million tonnes (t) of fish in a pond area of 5623 ha. Such production had gradually increased not only in terms of quantity by up to 1.58 million t but also in terms of culture areas of up to 6675 ha in 2019 (VASEP, 2020), as shown in **Table 1**. Most of the tra catfish produced in Viet Nam is exported to 132 countries and territories (**Figure 2**), earning for the country's coffers of about USD 2.261 billion in 2018 (VASEP, 2020).

Figure 1. Striped catfish (*Pangasianodon hypophthalmus* Sauvage, 1878) also known as tra catfish in Viet Nam
Source: https://tepbac.com/species/full/32/ca-tra.htm)

Table 1. Annual increases of tra catfish production and culture area in the Mekong River Delta in Viet Nam

Countries surveyed	2015	2016	2017	2018	2019
Culture area (ha)	5,623	5,893	6,078	6,418	6,675
Production (million tonnes)	1.11	1.19	1.25	1.42	1.58

Source: http://vasep.com.vn/san-pham-xuat-khau/ca-tra/tong-quan-nganh-ca-tra

Recently, the Mekong Delta Region of Viet Nam (**Figure 3**) suffers the impacts of climate change through sea level rise, which is expected at 1.0 cm/year until 2100 (Grinsted *et al.*, 2009) and reduced river flow.

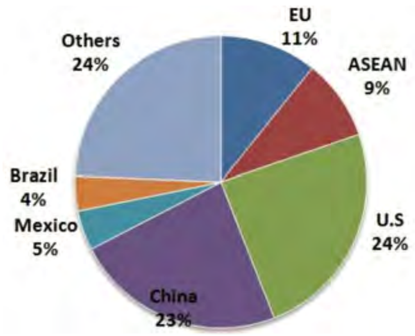

Figure 2. Countries of destination of tra catfish export from Viet Nam in 2018 (value)
Source: http://vasep.com.vn/san-pham-xuat-khau/ca-tra/tong-quan-nganh-ca-tra)

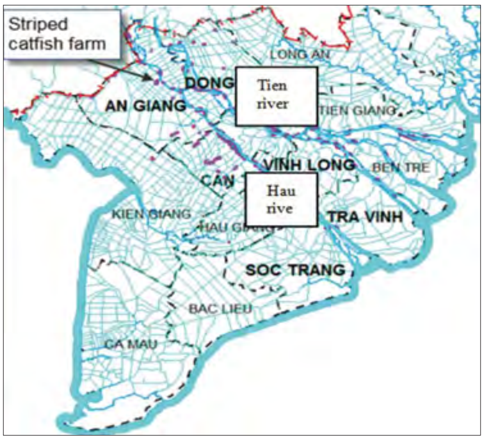

Figure 3. Mekong River Delta in Viet Nam showing Tien and Hau Rivers

The potential expansion of catfish farms in Viet Nam (**Figure 4**) is dependent on tidal regime and salt water intrusion would negatively affect the tra catfish culture industry (Department of Aquaculture, 2008) considering that water salinity higher than 4 ‰ is not suitable for tra catfish culture (Department of Aquaculture, 2008; De Silva and Phuong, 2011). In the Mekong River Delta of Viet Nam, the water used for tra catfish culture comes from Tien and Hau Rivers and their canal systems. Phan *et al*. (2009) reported that reduced production in catfish farms had been noted in areas located downstream, which was attributed to diurnal changes in salinity, albeit small. As a consequence of climate change, the production areas for the tra catfish culture in the Mekong Delta might have to be altered for some parts of the presently used areas may become no longer suitable for the culture of tra catfish.

Figure 4. Tra catfish farms in the Mekong River Delta of Viet Nam

Although temperature increase may also affect the culture of tra catfish, it is not much of a concern because tra catfish has a large temperature comfort zone (Department of Aquaculture, 2008). So that only the two main factors, *i.e.* water level rise and salinity intrusion induced by sea level rise, are critical and hence, while temperature increase due to global climate change will not have strong impact on tra catfish farming. Increased seawater intrusion in coastal areas or increased flooding in upstream regions caused by sea level rise and exacerbated by reduced river flow in the dry season or increased water discharge during the rainy season, would altogether increase salinity and water level significantly, affecting the farmed catfish from salinity stress as well as from risks related to flooding when water levels are higher than the pond dyke, or pond dyke could be destroyed. Therefore, farm location and the extent to which tra catfish can adapt to brackish water or the extent to which a pond can undergo flooding are the factors that affect the decision-making process of tra catfish aquafarmers. The most appropriate adaptive measures could be difficult to choose and therefore will have to be accompanied by relevant socio-economic changes within the aquafarming community as well as for those servicing this aquafarming sub-sector. Nonetheless, the results of several studies on the impact of salinity intrusion caused by climate change on tra catfish farming in the coastal provinces of the Mekong Delta and the adaptation strategies adopted by the tra catfish farmers are summarized in this article.

Salinity intrusion

Anh *et al*. (2014) simulated the salinity intrusion in the two branches of the Mekong River (Tien and Hau Rivers) based on the climate change and sea level rise scenarios of Viet Nam (Ministry of Natural Resources and Environment (MONRE), 2009) with the expected sea level rise of 30 cm in 2050, 46 cm in 2070, and 75 cm in 2100 using the MIKE 11 model, which was developed by the Danish Hydraulic Institute (DHI, 2003). The model makes use of data on water level, rainfall, and salinity from 24 hydro-meteorological stations (*i.e.* Kratie, Phnom Penh, Tonle Sap, Tan Chau, Chau Doc, Long Xuyen, Ha Tien, Rach Gia, Ca Mau, Ganh Hao, Bac Lieu, Soc Trang, Can Tho, Tra Vinh, My Tho, Vinh Long, Cao Lanh, Sa Dec, My Thuan, Ben Tre, Tan An, Moc Hoa, and Tan Son Nhat), and considered the boundaries for 68 downstream-end data of tidal water level and salinity, and seven upstream discharge boundaries with updated data on water discharge.

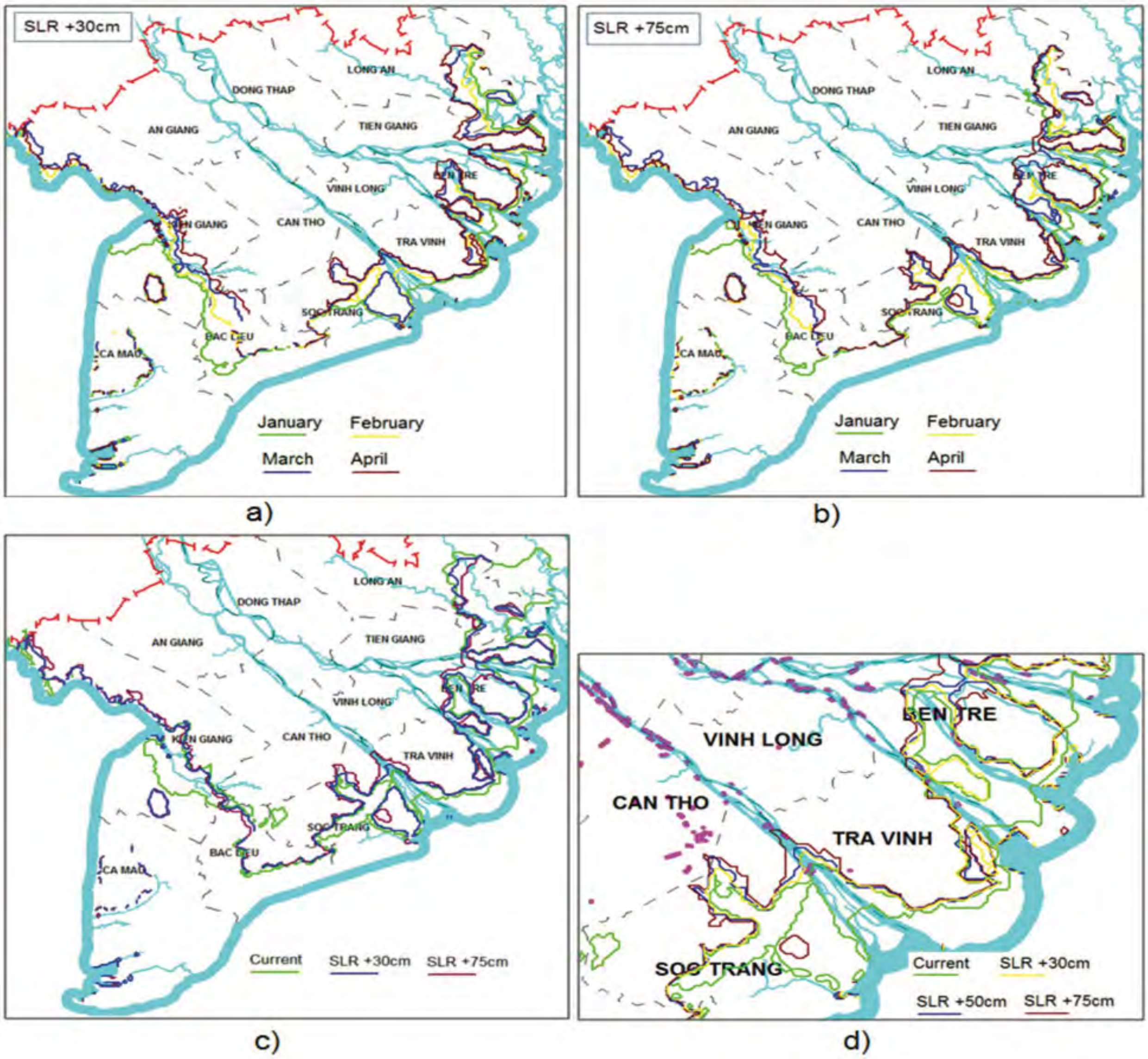

Figure 5. Coastal areas in the Mekong River Region of Viet Nam affected by salinity intrusion (4 ‰) from January to April for (a) SLR+30 scenario (a), and (b) SLR+75 scenario; in April for two scenarios and the baseline (c), and (d) effect of salinity intrusion on the striped catfish farms located in Ben Tre, Tra Vinh, and Soc Trang Provinces.

Source: Anh et al. *(2014)*

The input data for the model comprised the boundaries, as well as databases on hydrological and meteorological conditions. The hydraulic data included the hydrology of the Mekong River downstream from Kratie boundary, including the land levels above sea and the hydraulic elements of the river and canal systems. The model also included the irrigation and water control sluice systems.

As shown in **Figure 5**, salinity levels rose from January to April, where the saline front of 4 ‰ shifts inward 29 km and 32 km in Hau River during the end of March and April, respectively. For the SLR +50 cm scenario, the saline front of 4 ‰ in Hau River reaches 10 km inland from the sea in January then extends up to 24 km in February, 35 km in March, and 38 km in April. For the SLR +30 cm scenario, the central part of Soc Trang and the coast lines of Ben Tre will be affected by the intrusion of salinity concentration of 4 ‰ (Anh *et al*., 2014).

When the salinity map is overlaid on the map of the striped catfish farm locations as of 2009 for Ben Tre, Tra Vinh and Soc Trang Provinces, it was known that the effect of salinity intrusion on the farms is local. Tra Vinh, which is located in the southwestern area, is projected to suffer while the conditions for farms in the northeast would not significantly change. In Ben Tre, most farms have already dealt with the 4 ‰ salinity level phenomenon but the periods subjected to this salinity might become longer and farms located further upstream (*i.e.* to the west) might have to deal with such pattern too. In Soc Trang, all farms have already dealt with these prolonged periods (Anh *et al*., 2014).

Climate change concerns of striped catfish producers in the Mekong Delta, Viet Nam

Anh *et al*. (2015) investigated the perceptions on and adaptations to impacts of climate change on 235 tra catfish farmers in the Mekong Delta, Viet Nam including 30 farmers from Tra Vinh and Soc Trang coastal provinces. The semi-structured household survey was applied to collect data, and using the Chi-Square test, the correlation or association between variables was determined and the logit regression model was employed to examine the factors that influence the farmer's perceptions and adaptation. Results of this study showed that less than half of the respondents were concerned about climate change and sought suitable adaptation measures to alleviate its impacts. Improving information on climate change and introducing early warning systems could enhance the adaptive capacity of the catfish (pangasius) farmers, and in particular, help those farmers who are not concerned yet. Although most of the farmers rely strongly on technical support from government agencies, those in the coastal provinces seem not to express any interest to be trained by these institutions (**Table 2**). From the start, farmers from the coastal provinces had been confronted with seasonally high and gradually increasing salinity levels, but they had established and applied some forms of autonomous measures, such as delaying the cropping period, decreasing the stocking rates, or stocking larger fish that could tolerate higher salinity levels. These apparently contrasting results have urged the relevant agencies to assess the effectiveness of some adaptation measures, such as breeding salinity-tolerant pangasius (Anh *et al*., 2015).

In 2020, under the project of the Ministry of Education and Training of Viet Nam, a study was conducted to determine the impacts of climate change on the tra catfish farming in Soc Trang Province. The survey method made use of face-to-face interview using a semi-structured questionnaire of 97 aquafarmers who were members of individual fish nursing-growing households, fish farm managers of companies and key informants in Soc Trang Province. The results indicated that most of the aquafarmers were aware of the effects of saltwater intrusion and extreme weather to tra catfish culture and considered it difficult to overcome saltwater intrusion. In addition, the largest portion of the farmers indicated that abnormalities in the weather and climate extremes have occurred to some extent and saltwater intrusion was the most problematic situation. They expressed the concern that in the future, saltwater intrusion would still be the highest concern for tra catfish farming. Nevertheless, some groups considered that changing the techniques for nursing – growing tra catfish could be a possible and most important adaptation measure to cope with climate change and saline intrusion (Boi *et al*., 2020).

Adaptation to salinity intrusion

Using the decision tree framework, Anh *et al*. (2016) analyzed the possible options for the sustainability of pangasius farming in the Mekong Delta Region of Viet Nam, which could be adapted to minimize the impacts of projected climate change. After summarizing the risks of the impacts, the farmers' autonomous and planned public adaptations were analyzed using primary and secondary data.

Changing pangasius farming practice

Tra catfish farmers in the coastal areas have been encouraged to extend the nursing period of fish fingerlings, thus reducing the grow-out period in ponds during the months of high salinity intrusion (Anh *et al*., 2015). This period will result in slightly higher cost for transport, as juveniles will be heavier and perhaps at an increased risk (De Silva & Phuong, 2011).

In the Mekong Delta Region of Viet Nam, tra catfish farmers started to experiment on the use of recirculating aquaculture systems (RAS) for the nursery and grow-out phases, which could also be regarded as an autonomous adaptation. Although the results seem promising, the full costs and benefits are not yet known (Nhut *et al*., 2013). In the RAS, water intake is very restricted except for the last weeks of the grow-out period. Thus, RAS simultaneously reduces water pollution and contributes an added benefit for the mitigation of environmental impacts of the pangasius farming sub-sector (Bosma *et al*., 2011), a bone of contention of many environmental lobby groups (De Silva *et al*., 2010), and ultimately also contribute to the mitigation of the impacts of climate change too.

Table 2. Tra catfish farmers' agreement (%) on sources of support to adaptation of climate change, and the types of support

Areas surveyed	Source of support				Type of support		
	Government Institutions	Local Government Units	Private Sector	Friends/ Family Members	Technical	Financial	Capacity Building
All six provinces surveyed for the study	10.20	4.70	6.00	17.00	53.20	20.90	19.60
Upstream provinces	14.30	9.20	5.10	22.40	53.10	24.50	39.80
Mid-stream provinces	8.40	1.90	8.40	15.90	52.30	21.50	6.50
Downstream provinces	3.30	0.00	0.00	3.30	56.70	6.70	0.00

Source: Anh et al. *(2015)*

Shifting to another species

Another option in dealing with saltwater intrusion for tra catfish farmers in the coastal provinces is to also opt for the culture of other aquatic species (Anh *et al*., 2014). However, this option would require the development of new adaptive capacity by aquafarmers, and probably even changes in the farm infrastructure, in particular that of pond construction. A pond with water depth of 3.0 to 4.0 m is preferred for pangasius grow-out but such deep ponds are unsuitable for most of the other commonly farmed salinity tolerant species, such as the Asian sea bass or shrimps. Besides, pond restructuring would be necessary especially for ponds that are located directly next to rivers or main canals, and this is likely to be very costly as lowering the water level will increase, for example, the pressure on the dykes, while for other ponds, lowering pond depth may be realized by using lower water levels. Nonetheless, the technical and economic aspects of the feasibility of shifting to another species need further and thorough study (Anh *et al*., 2016).

Breeding salinity-tolerant pangasius

Many aquafarmers, who have been confronted with the risk from salinity intrusion prefer to continue producing pangasius rather than shifting to another species because they believe that only by farming catfish, can revenues be maintained at high level, enabling them to recover their investments (Anh *et al*., 2015). In this connection, De Silva and Soto (2009) suggested the development of a salinity tolerant strain of catfish as such a tolerant strain will require minimal changes in the farming techniques and in the related infrastructures, and would not require the development of new market chains (De Silva and Phuong, 2011.

According to Trong (personal communications), the generic cost of a salinity-tolerant catfish breeding program, starting with 150 individuals of wild broodstock of various origins in the Mekong River, is about US$ 120,000 (**Table 3**). However, due to the generation interval the actual cost in the long run, could be fourfold, *i.e.* US$ 480,000. The cost per kg of pangasius produced in the coastal provinces, estimated at 10 % of the total 1.2 million tonnes, would be US$ 0.004 kg^{-1}. This is slightly more than 0.4 % of the present production cost (US$ 1.1 kg^{-1}) and this appears to be a feasible investment. Whether or not such a program can successfully breed a salinity-tolerant pangasius, however, remains to be seen. The relatively long time frame (four years) of such a program and the large amount involved would require the continuous and persistent involvement of the public and private sectors (Anh *et al*., 2016). However, a most recent study by Boi *et al*. (2020) revealed that the farmers applied their own autonomous adaptation measures because the salinity tolerant fish breeding program is still at an experiment stage.

Conclusion and Recommendations

It is a fact that some of the expected impacts of climate change in Viet Nam are unavoidable, the most threatening of which, especially for the Mekong Delta Region, is sea level rise. In the projections of water level and salinity intrusion induced by three different sea level rise scenarios that had been simulated, results showed that the pangasius aquafarms in the coastal region are threatened by more frequent and higher levels of salinity concentration. The analysis of the perceptions of the tra catfish aquafarmers revealed that the impacts they experienced are due to extreme climatic events, although they failed to perceive the gradual climate changes, such as sea level rise. However, almost all tra catfish aquafarmers considered salinity intrusion as the most threatening. Through a decision-making framework, the appropriate adaptation and/or mitigation measures were assessed, and some autonomous adaptations identified by the pangasius aquafarmers include shifting to other salinity tolerant species or stocking a salinity tolerant pangasius. Nevertheless, the aquafarmers prefer to continue farming pangasius to recover their investments. It should be noted however that the development of a salinity tolerant strain of pangasius requires a strategic planned

Table 3. Generic cost (US$) of a salinity-tolerant catfish breeding program in Viet Nam (respecting the principles of an effective population size as established by Ponzoni *et al*. (2011))

	Year 1	Year 2	Year 3	Year 4
Fixed cost of infrastructure (rental of a 1.5 ha farm with 1.1 ha of ponds)*	7,200	7,200	7,200	7,200
Salary	4,700	6,400	6,000	4,250
Materials: broodstock and feeds	4,000	6,800	16,100	16,000
Accessories, disposable tools	480	2,850	950	950
Electricity, gasoline, diesel	320	1,700	320	320
Equipment	1,400	250	12,700	0
Maintenance cost	700	2,100	1,600	1,400
Total	**18,800**	**27,300**	**44,870**	**20,120**

**Cost of land:* about US$ 30,000 and infrastructure: US$ 23,0000; interest rate of 8% and depreciation of infrastructures over 20 years, accounted for (Exchange rate: 21,000 VND to 1.00 US$)
Source of primary data: Dr. Trinh Quoc Trong, Director of National Breeding Centre for Southern Freshwater Aquaculture, Viet Nam (personal communication)
Source: Anh et al. *(2016)*

intervention of the government and private sectors to maintain and improve the tra catfish farming industry of the country and the associated livelihoods of the tra catfish aquafarmers.

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Promoting the Installation of Fish Passage in Potential Barriers in the Lower Mekong River Basin

Yuttana Theparoonrat

Under the Smart Infrastructure for the Mekong (SIM) Program of the United States Agency for International Development (USAID), the Lower Mekong Fish Passage Conference was organized in Vientiane, Lao PDR in November 2016 to demonstrate how applied research can be used to enhance policy and decision-making across the Lower Mekong River Basin. Attended by more than 160 participants from 14 countries including global experts in riverine development, fish passage, and aquatic ecosystem management, the Conference came up with key messages that included: 1) demonstration projects applied in the field, tested, and showcased facilitate large-scale adoption and acceptance of end users and donors; and 2) partnerships among the researchers, local people, district/provincial governments, and national management agencies lead to greater success (Baumgartner *et al.*, 2017). Along the line of such key messages, SEAFDEC in collaboration with the US Department of Interior (US-DOI) has been carrying out the activities of the project "Implementing the Lower Mekong Fish Passage Initiative in Cambodia, Thailand, and Vietnam" from 2018 until 2021 with the goal of enhancing the capacity of the SEAFDEC Member Countries in the Lower Mekong River Basin to design, construct, implement, and assess fish passage. Through this Project, one demonstration fish passage was installed in each of the participating countries.

The Mekong River (**Figure 1**) is one of the great rivers of the world flowing through six countries, namely: China, Myanmar, Thailand, Lao PDR, Cambodia, and Viet Nam with a distance of nearly 5,000 km from its source on the Tibetan Plateau in China to the Mekong Delta. The basin is one of the richest areas of biodiversity in the world, with more than 20,000 plant species and 850 fish species. In the Lower Mekong River Basin, about 80 % of the nearly 65 million people depend on the river and its rich natural resources for their nutrition and livelihoods. However, due to development infrastructures and climate change resulting in environmental degradation and loss of biodiversity, the Lower Mekong River Basin is threatened by worsening floods and droughts (Mekong River Commission, 2021).

In river systems around the world, water management structures or barriers such as weirs, dikes, dams, road prisms, irrigation canals, among others are built for flood control and agricultural development. However, most of these barriers are too high for fish to pass, thus, obstruct their migratory paths. Migration is a crucial part of the lifecycle of many riverine species to access spawning, feeding, and nursery habitats.

In order to address the adverse impacts of barriers on the migration of riverine species and rehabilitate the aquatic environment, fish passages (also known as fishways, fish ladders, or fish steps) are installed around barriers to facilitate fish migration. Fishways enable fish to pass the barrier by swimming and leaping up a series of relatively low steps into the waters at the other side of the barriers. Water flow over the fish ladder has to be strong enough to attract the fish to the ladder, but should not be too strong to wash the fish back downstream or exhaust them to the point of being unable to continue their journey upstream.

In the Southeast Asian region, the techniques to install effective fish passage had already been established and largely developed in Lao PDR. However, for other countries in the region, their capacity is still limited to be able to apply these techniques. Therefore, in order to support the countries in the Lower Mekong River Basin, SEAFDEC through its Training Department (TD) and partners organized several activities on knowledge transfer under this Project.

Figure 1. Upper and Lower Mekong River Basin
Source: Mekong River Commission, 2011

Fish Passage Master Class

As an initial activity of the Project, two sessions of Fish Passage Master Class were organized at SEAFDEC/TD in Samut Prakan, Thailand with support from the Australian Centre for International Agricultural Research (ACIAR), Crawford Fund, USAID, and Mekong River Commission (MRC), during 7–9 and 13–16 November 2018. While the first session focused on GIS Techniques and Fish Passage Barrier Assessment, the second session discussed the Fish Passage Engineering, Design, Construction, Ecology and Monitoring. The Master Class sessions had a total of 52 participants comprising engineers and fishery managers from fisheries and irrigation agencies in Cambodia, Lao PDR, Myanmar, Thailand, and Viet Nam as well as representatives from SEAFDEC, MRC Secretariat, and the National Mekong Committees (**Figure 2**), while the resource persons were from the Institute for Land Water and Society of Charles Sturt University, University of South Australia, Australasian Fish Passage Services (AFPS), and United States Department of the Interior (US-DOI). The Master Class sessions were aimed at enhancing the capacity of the participants to apply the techniques to install effective fish passage as well as to establish the network among irrigation and fisheries practitioners.

Figure 2. Participants of the Fish Passage Master Class observing a fish passage prototype

Installation of Demonstration Fish Passage

The working teams in the respective participating countries, comprising personalities who have expertise in biology and engineering as well as local knowledge, undertook the barrier assessment procedures (**Figure 3**) and followed the steps to construct the demonstration fish passage (**Box**) with technical assistance from the USAID in partnership with ACIAR.

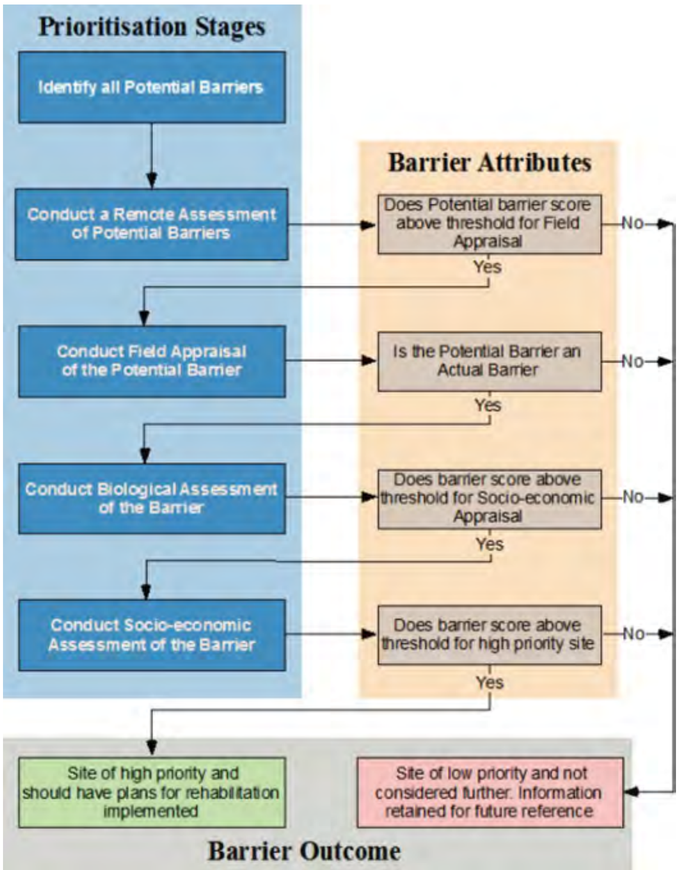


Figure 3. Flowchart of the process of barrier prioritization
(Source: Marsden et al., 2014)

Cambodia

The Inland Fisheries Research and Development Institute (IFReDI) of Cambodia assessed the barriers in the Pursat River in May–June 2018. Based on the assessment, the Kbal Hong Weir (Latitude 12°32'53" N, Longitude 103°51'18" E) was selected as the most suitable barrier to install the demonstration fish passage. During the provincial consultation workshop organized by IFReDI in October 2018, the key stakeholders supported the installation of fish passage. Designed by Charles Stuart University and Australasian Fish Passage Service, Australia (**Figure 4**), the demonstration fish passage (**Figure 5**) was completed in May 2019 and turned over by USAID to the Government of Cambodia during the handover ceremony in Pursat Province in October 2019.

The upstream and downstream areas of the fish passage installed at Kbal Hong Weir were monitored by IFReDI from May to November 2019, while water parameters (*e.g.* depth, flow, DO, pH, temperature) were measured. Also, fishes moving across the fish passage were collected using traps placed at different chambers of the fish passage baffles, and the species, abundance, and body length of collected fish were recorded.

Box. Steps for fish passage installation *(Source: Marsden et al., 2014)*
Step 1: Locate potential barriers to fish migration - identifying all barriers that obstruct fish migration to be included in the barrier prioritization
Step 2: Conduct remote assessment of priority barrier - investigating the spatial and temporal habitat characteristics associated with each potential barriers identified in Step 1 without the need to visit the site through incorporation of data in a desktop GIS process
Step 3: Conduct field appraisal of highest priority potential barriers - undertaking field appraisals of the highest ranked potential barriers based on the remote assessment to determine whether the site is an actual barrier and define the actual characteristics of the barrier that cannot be determined by remote assessment
Step 4: Conduct refined biological assessment - identifying the highest priority barriers in terms of their effect on the biological productivity of a catchment
Step 5: Conduct socioeconomic assessment - identifying the most cost-effective barrier including expenses for repairs, with the greatest benefit to the local community
Step 6: Select sites for rehabilitation - identifying potential restoration sites that qualify based on the assessment criteria including ecological, socioeconomic, ownership, and maintenance factors by using tools such as GIS
Step 7: Implement a design process - assembling a team of experts who will undertake a multi-disciplinary process to design the site-specific and successful fish passage
Step 8: Undertake construction - constructing the fish passage according to the final design agreed by the design team, and any changes to the final design must be referred back to the team so that biological, engineering, and operational modifications can be made
Step 9: Operate and maintain fish passage - conducting inspection, maintenance, and repair regularly to retain the functionality of fish passage
Step 10: Evaluate the effectiveness of the fish passage rehabilitation - ensuring that the whole fish community (species and size classes) are successfully entering, traversing, and exiting the fish passage

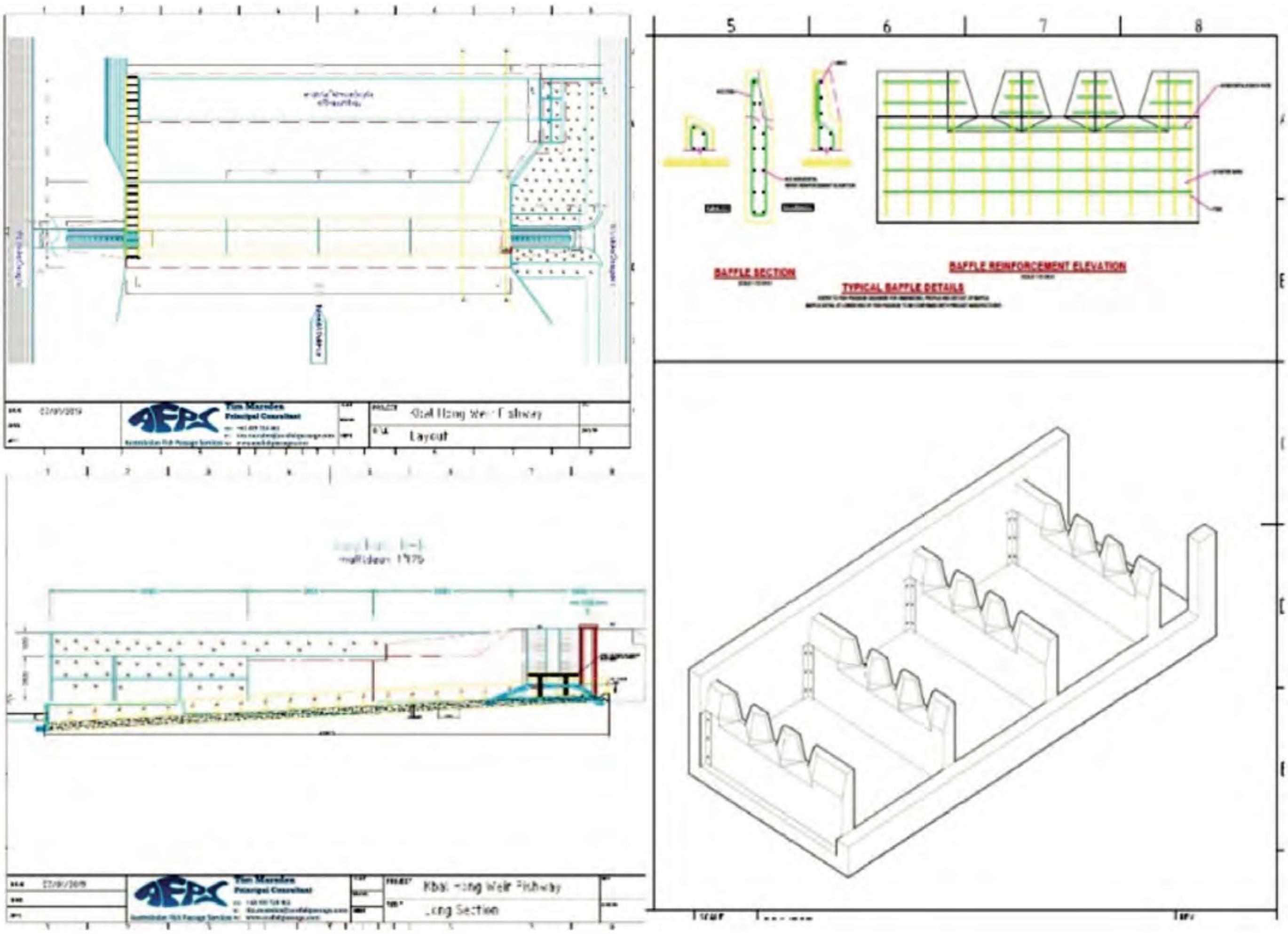


Figure 4. Design of the demonstration fish passage installed at Kbal Hong Weir in Pursat River, Pursat Province, Cambodia

Initial results indicated that there were fewer fishes captured when the water level was receding. With regard to fish migration, there was lesser at night while more fishes migrate at daytime or early morning. More than 60 fish species were recorded and the top five abundant species comprise: *Clupeichthys aesamensis*, *Parambassis apogonoides*, *Mystacoleucus greenwayi*, *Barbonymus gonionotus*, and *Macrobrachium niponese* (**Figure 6**). The demonstration fish passage installed at the Kbal Hong Weir was considered as one of the most effective in the Mekong Region and a product of effective regional collaboration.

Figure 5. Kbal Hong Weir in Pursat River, Pursat Province, Cambodia *(above)* and the installed demonstration fish passage *(below)*

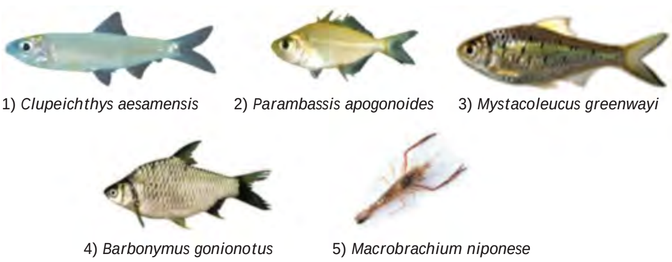
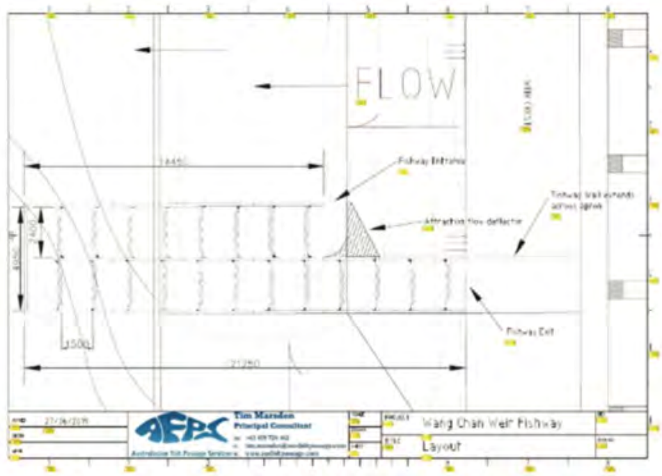


Figure 6. Top five abundant species collected from the demonstration fish passage installed in Kbal Hong Weir in Pursat River, Cambodia

Thailand

Based on the assessment made by the Department of Fisheries (DOF) of Thailand and the Royal Irrigation Department of Thailand of the existing barriers in Hauy Lung River in Udonthani Province during June–September 2018, the Hauy Wang Chang Weir (Latitude 17°48'35" N, Longitude 103°05'26" E) was selected as the suitable barrier for the installation of demonstration fish passage. A meeting was organized with the Sangkhom Municipality Committee to inform them on the proposed construction and seek their approval and support of the fish passage. Based on the design (**Figure 7**) prepared by the Australasian Fish Passage Services, the fish passage was constructed from December 2019 to 3 April 2020 (**Figure 8**). On 22 June 2021, the US-DOI transferred the ownership of the demonstration fish passage to the local government of Sangkhom Sub-district through an official letter.

The efficiency of demonstration fish passage installed at Hauy Wang Chang Weir was investigated, the water flow speed was measured using submerged-orifice channel between the baffle, and fish sampling was done using fish trap placed at



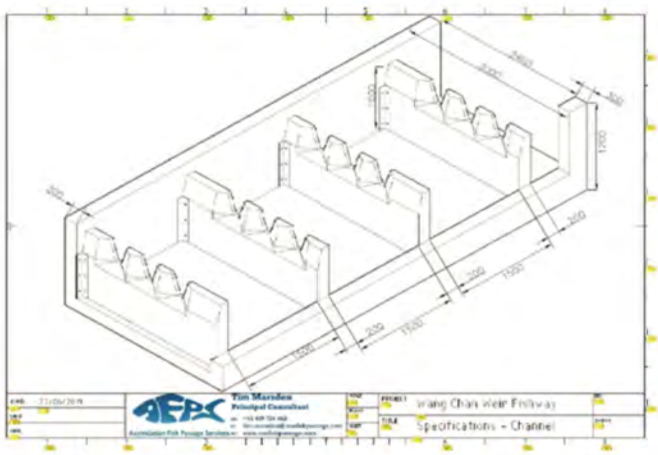


Figure 7. Design of the demonstration fish passage installed at Wang Chang Weir in Hauy Lung River, Udonthani Province, Thailand

Figure 8. Hauy Wang Chang Weir in Hauy Lung River, Udonthani Province, Thailand *(above)* and the installed demonstration fish passage *(below)*

the last exit pool of the fish passage. The results showed that the water flow speed at the second pool at the exit and second pool from the entrance of the fish passage was 1.1 m/sec, while the difference in water level (head loss) at each pool was 10 cm. From the fish samples, seven species were identified, namely: *Labriobarbus siamensis*, *Trichopodus pectoralis*, *Mystus mysticetus*, *Esomus longimana*, *Rasbora spilocerca*, *Channa striata*, and *Rasbora aurotaenia* (**Figure 9**). However, since travel across Thailand had been disrupted due to the COVID-19 situation of the country, monitoring of fish migration at the fish passage at Hauy Wang Chang Weir was halted and would be continued once the COVID-19 situation has improved.

Viet Nam

The Provincial Department of Agriculture and Rural Development (DARD) in Dac Lac Province, Viet Nam conducted the barrier assessment on 19–26 November 2018. After the assessment and consultation with various agencies, the Ea Tul Weir (Latitude 12°49'53" N, Longitude 107°53'45" E) was selected as the site for the installation of demonstration fish passage. The fish passage design prepared by the Provincial DARD was approved by the USAID-DOI and AFPS (**Figure 10**), but construction of the demonstration fish passage at Ea Tul Weir (**Figure 11**) which was supposed to be during July–December 2020 was postponed to June 2021 due to the COVID-19 pandemic.

Way Forward

The Project has successfully delivered the installation of demonstration fish passages at the potential barriers in target rivers in Cambodia, Thailand, and Viet Nam. The lessons learned demonstrated that partnership is crucial for the successful implementation of fish passage by engaging the local communities, local officers, local and national governments, and partner agencies. Although the COVID-19 pandemic had disrupted the monitoring and construction of the demonstration fish passages in Thailand and Viet Nam, respectively, these activities would be resumed when the COVID-19 situation improves. Despite the challenges, the key findings of the evaluation of the performance of the installed demonstration fish passage serve as scientific evidence for future endeavors in adopting fish passage installation as well as for effective fishery resources rehabilitation in the Lower Mekong River Basin.

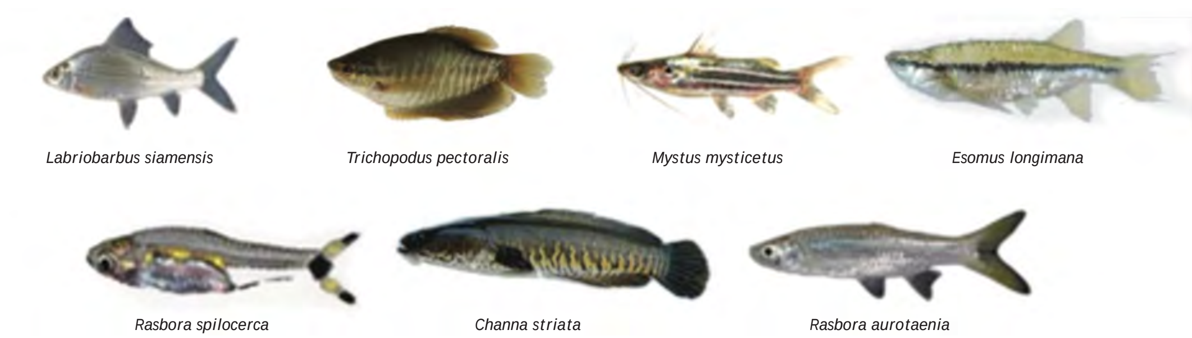


Figure 9. Fish species sampled from the demonstration fish passage installed at the Hauy Wang Chang Weir in Hauy Lung River, Udonthani Province, Thailand

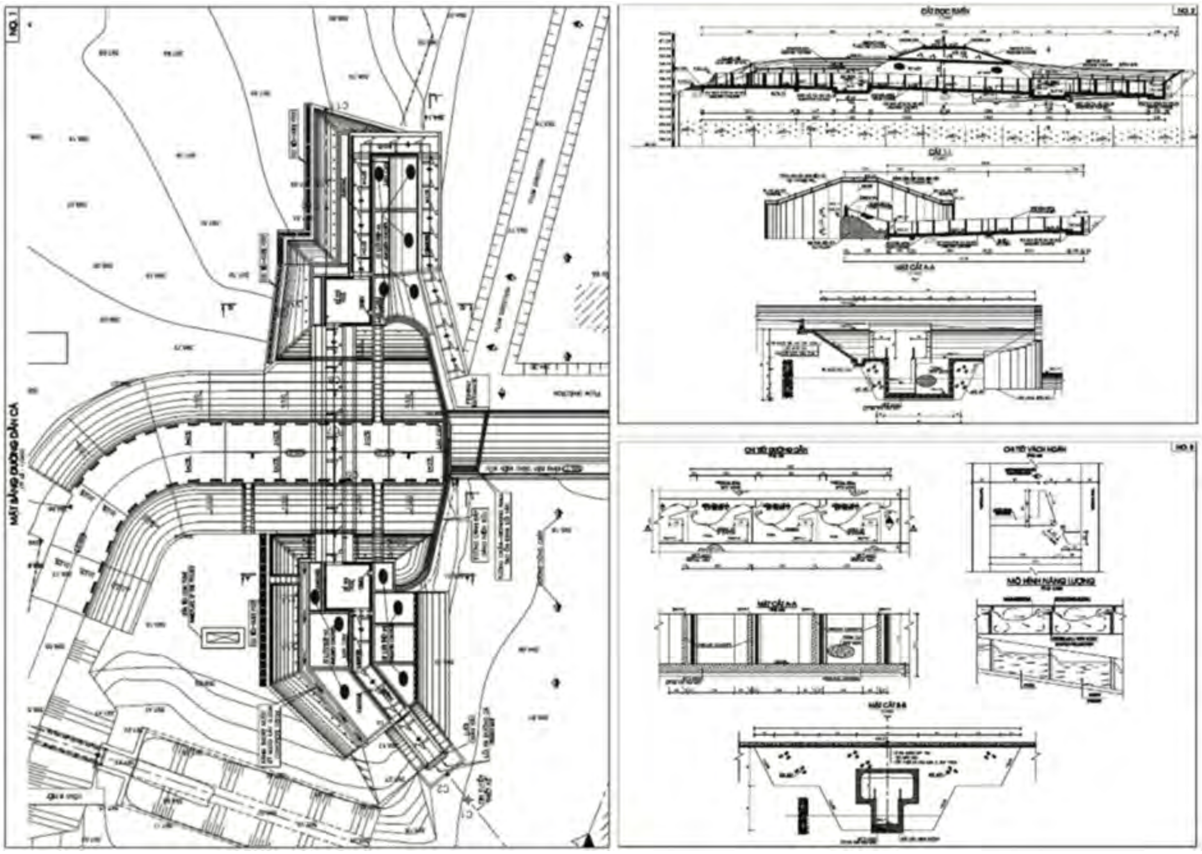


Figure 10. Design of the demonstration fish passage for installation at Ea Tul Weir in Srepok River, Dac Lac Province, Viet Nam

Figure 11. Ea Tul Weir in Srepok River, Dac Lac Province, Viet Nam *(above)* and the demonstration fish passage being installed *(below)*

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CALENDAR OF EVENTS

Date	Mode/Venue	Event	Organizer(s)
2021			
15 July	Rayong Province, Thailand	Stakeholders Consultation Meeting on Assessment of the Sustainability of Currently Used Fishing Technologies and Operations in Thailand and Options for Innovation and Improvements	SEAFDEC/TD
19–23 July	Online training	Training Course on Fish Population Dynamics and Fisheries Management Using R	SEAFDEC/TD
20 July	Online meeting	Online Meeting on Survey Results of SEAFDEC/TD HRD and Implementation of Ecosystem Approach to Fisheries Management (EAFM) in Learning Sites	SEAFDEC/TD
19–20 August	Virtual conference	8th International Conference on Fisheries and Aquaculture 2021	Indonesia & Thailand
23–27 August	Online training	Training Course on Fisheries Management Tools for EAFM	SEAFDEC/TD
8 September	Online workshop	GEF Project Preparation Grant (PPG) Inception Workshop of the Project "Promoting the Blue Economy and Strengthening Fisheries Governance of the Gulf of Thailand through the Ecosystem Approach to Fisheries" (GoTFish Project)	FAO & SEAFDEC
23-24 September	Shanghai, China	Global Conference on Aquaculture Millennium +20	FAO/NACA/MARA
21–22 September	Online meeting	1st Regional Technical Consultation on Fishery Statistics and Information in Southeast Asia	SEAFDEC Secretariat
28–30 September	Online workshop	Teleworkshop on Development and Improvement of Regional Fishing Vessels Record (RFVR) for Combating IUU Fishing in Southeast Asia	SEAFDEC/TD
28-30 September	Online training	Online Regional Training on Gender Integration in Small Scale Fisheries in Southeast Asia	SEAFDEC/TD
5–8 October	Online Training	Online Training on Implementing Adaptive Fisheries Management and the Use of the Fish Path Decision Support Tool	SEAFDEC/TD
26-29 October	Online training	Regional Training Course on Implementation of Port State Measure for Inspection	SEAFDEC/TD
27–28 October	Online workshop	Regional Workshop on Effective Practice Supporting the Livelihood and Well-being of Small-scale Fishers in Southeast Asia	SEAFDEC/TD
October (Tentative)	Online training	Regional Training Course on Geographic Information System (GIS) for Aquaculture	SEAFDEC/TD
15–17 November	Virtual meeting	44th Meeting of the SEAFDEC Program Committee Meeting (PCM)	SEAFDEC Secretariat & AQD
22-26 November	Online training	Regional Training Course on the Relationship Between Ocean Environment Variability and Marine Resource Abundance and Oceanographic Sampling	SEAFDEC/TD
24–25 November	Virtual meeting	24th Meeting of the Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic Partnership (FCG/ASSP)	SEAFDEC Secretariat
29 Nov & 1 Dec	Virtual meeting	22nd Meeting of SEAFDEC Information Staff Program (ISP)	SEAFDEC Secretariat
November (tentative)	Online training	Training Course on Community-based Freshwater Aquaculture for Remote Rural Areas of Southeast Asia	SEAFDEC/AQD
November (tentative)	Online training	Regional Training Course on the Relationship Between Ocean Environment Variability and Marine Resource Abundance	SEAFDEC/TD
November (tentative)	Online training	Training Course on Feeds and Feeding Management	SEAFDEC/AQD
Nov/Dec (Tentative)	Malaysia (TBC)	Workshop on Seerfish in the Malaysian Waters by using ASPIC in collaboration with DOF Malaysia	SEAFDEC/MFRDMD
Nov/Dec (Tentative)	Kuala Terengganu, Malaysia	Workshop on Landing Data Analysis of Sharks and Rays by Species to Determine Value of Maximum Sustainable Yield (MSY)	SEAFDEC/MFRDMD
Nov/Dec (Tentative)	Kuala Terengganu, Malaysia	Workshop on Conservation of Sharks and Rays Through Parasites' Perspective	SEAFDEC/MFRDMD
1-3 December	Online	Tilapia health: quo vadis?	FAO
2 December	Virtual meeting	SEAFDEC Department Chiefs' Meeting	SEAFDEC Secretariat
7 December	Webinar	APFIC Webinar Series: Women and men in small-scale fisheries and aquaculture in Asia: barriers, constraints and opportunities to-wards equality and secure livelihoods	APFIC

Southeast Asian Fisheries Development Center (SEAFDEC)

What is SEAFDEC?

SEAFDEC is an autonomous intergovernmental body established as a regional treaty organization in 1967 to promote sustainable fisheries development in Southeast Asia. SEAFDEC currently comprises 11 Member Countries: Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

Vision

Sustainable management and development of fisheries and aquaculture to contribute to food security, poverty alleviation and livelihood of people in the Southeast Asian region

Mission

To promote and facilitate concerted actions among the Member Countries to ensure the sustainability of fisheries and aquaculture in Southeast Asia through:

i. Research and development in fisheries, aquaculture, post-harvest, processing, and marketing of fish and fisheries products, socio-economy and ecosystem to provide reliable scientific data and information.
ii. Formulation and provision of policy guidelines based on the available scientific data and information, local knowledge, regional consultations and prevailing international measures.
iii. Technology transfer and capacity building to enhance the capacity of Member Countries in the application of technologies, and implementation of fisheries policies and management tools for the sustainable utilization of fishery resources and aquaculture.
iv. Monitoring and evaluation of the implementation of the regional fisheries policies and management frameworks adopted under the ASEAN-SEAFDEC collaborative mechanism, and the emerging international fisheries-related issues including their impacts on fisheries, food security and socio-economics of the region.


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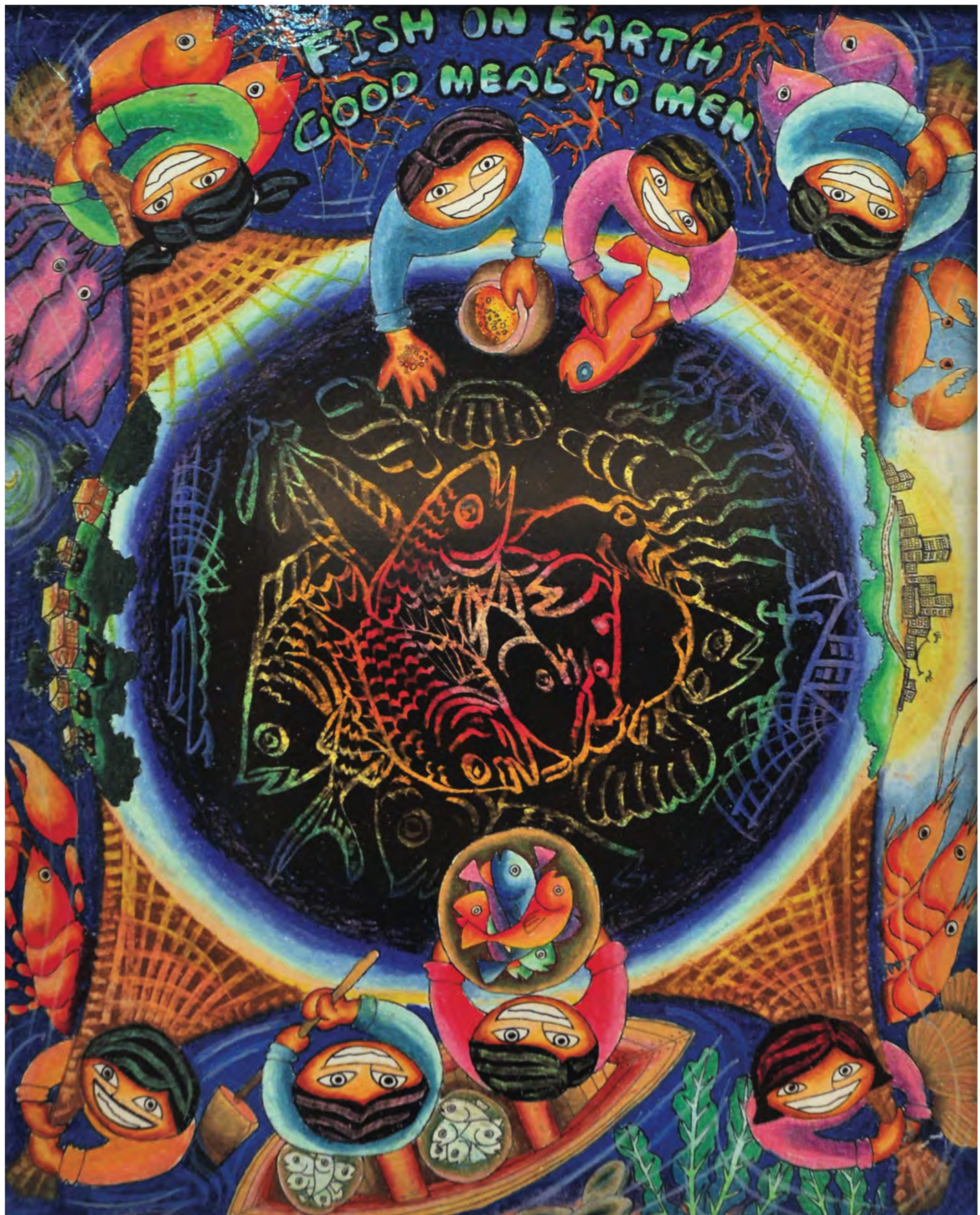

The third prize winner, *Laurice Anne Lima*, from the national drawing contest in Philippines

National Drawing Contests were organized in all ASEAN-SEAFDEC Member Countries as part of the preparatory process for the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" held by ASEAN and SEAFDEC in June 2011 in Bangkok, Thailand, in order to create awareness on the importance of fisheries for food security and well-being of people in the region.