FISH for the PEOPLE

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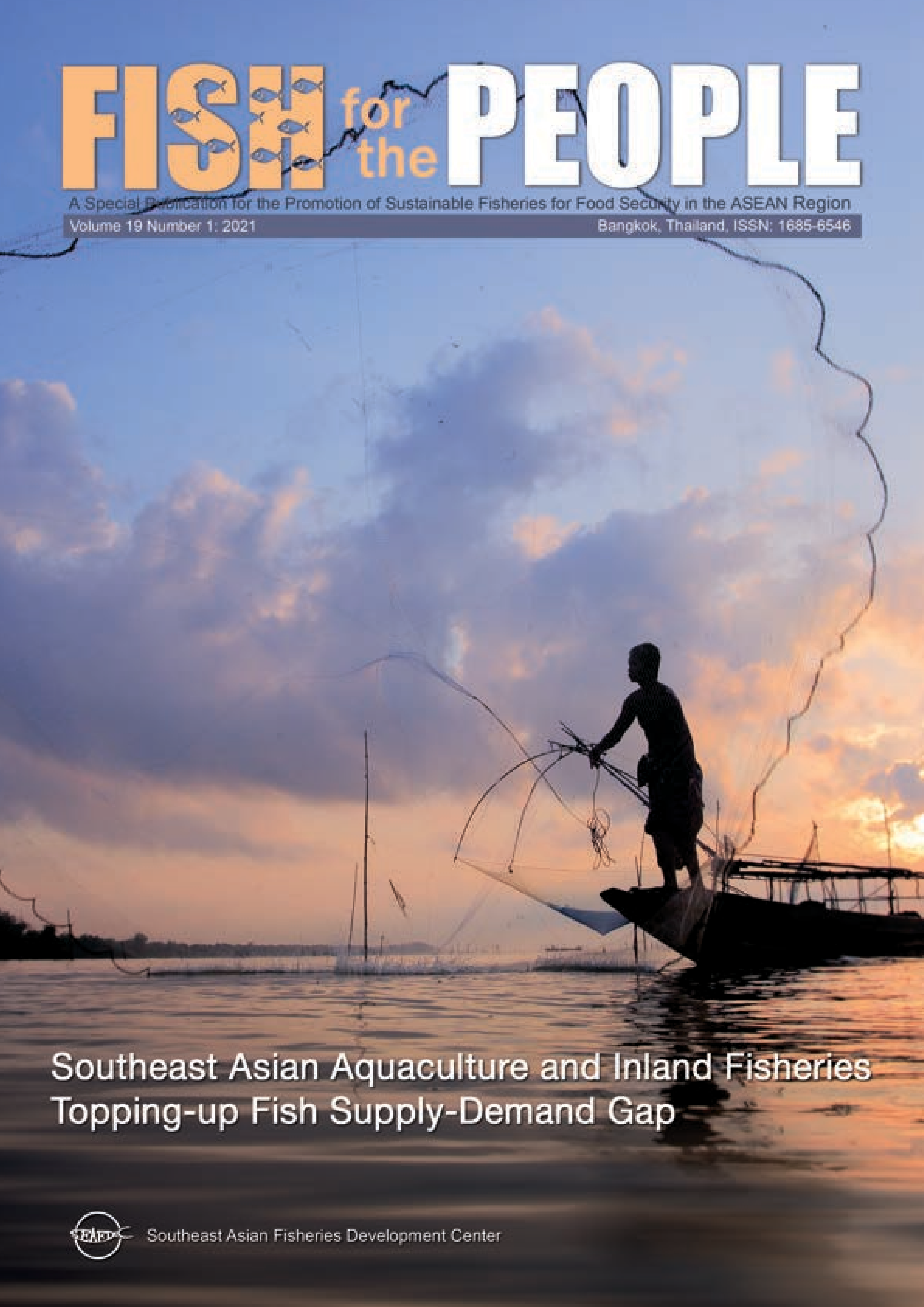

Southeast Asian Aquaculture and Inland Fisheries Topping-up Fish Supply-Demand Gap

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Editorial

Fisheries have always been playing significant role in the Southeast Asian people's way of life, especially in terms of ensuring their food security, sustaining incomes, and improving their socioeconomic conditions. In Southeast Asia, efforts of the countries in sustainably developing their respective fisheries had paid off as the countries have succeeded in improving their production from fisheries and many have emerged as major exporters of fish and fishery products. This implies that the contribution of Southeast Asian fisheries to food security is not only limited to peoples within Southeast Asia but also all over the world.

With anticipated increases in the world's human population from 7.8 billion in 2020 to 8.5 billion in 2030, and 9.7 billion in 2050, the world's food producing sectors including fisheries would have to assure that there is sufficient food including fish to supply the demand of the growing populations. As far as the fisheries sector of the region is concerned, the Southeast Asian Fisheries Development Center (SEAFDEC) has been promoting the sustainable development and management of all the subsectors of fisheries to make sure that there would always be fish on people's tables. While efforts are being made to allow the marine fisheries sub-sector to recover from almost devastation and collapse due to past exploitations that were not responsibly carried out, focus is now given on the sustainable development of aquaculture and inland fisheries, with the expectations that these sub-sectors could top up the gap in the supply-demand channels of the fish supply chain.

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.

In order to achieve the gigantic tasks of ascertaining food security for future generations, the aquaculture sub-sector of Southeast Asia is committed to increase production by significantly mitigating and managing aquatic diseases that harm not only the aquatic resources but also human health. This has led to the promotion of the ecosystem approach to responsible and sustainable aquafarming by the Philippine-based Aquaculture Department of SEAFDEC. Meanwhile, for the region's inland fisheries sub-sector, responsible utilization and management of inland fishery resources is being promoted by the SEAFDEC Inland Fishery Resources Development and Management Department based in Indonesia. Considering that the sustainability of inland fisheries depends much on the quality of the aquatic habitats and ecosystems, it has become necessary to enhance the governance of inland fisheries through the application of the ecosystem approach to fisheries management as well as co-management. It is expected that such sustainable practices in aquaculture as well as inland capture fisheries sub-sectors would have to proceed even beyond the time when the marine fisheries sub-sector would have already been able to catch up with these other sub-sectors in terms of increased production of fish for the people.

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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.

Installing Reforms in the Southeast Asian Region toward Sustainable Development of Aquaculture and Inland Fisheries: SEAFDEC perspective

Malinee Smithrithee, Koichi Honda, Virgilia T. Sulit, and *Shiela Villamor Chumchuen*

The Southeast Asian Fisheries Development Center (SEAFDEC) has been working incessantly for the sustainability of fisheries in the Southeast Asian region. Such efforts had been clearly manifested in the progress and development of fisheries in the region that prompted the ASEAN Member States (AMSs) to adopt the series of decennial ASEAN-SEAFDEC Resolutions and Plans of Action on Sustainable Fisheries for Food Security for the ASEAN Region in 2001, 2011, and 2020, which have served as policy frameworks and priority actions for the AMSs to support their efforts towards attaining sustainability in fisheries development and enhancing the contribution of fisheries to food security and socioeconomic advancement. As a result from such efforts, many Southeast Asian countries have become major exporters of fish and fishery products to the world's fish market. Nonetheless, it is feared that such feat might not be sustained in the long run considering the fate of marine capture fisheries, where its production had been dwindling due to the unhealthy condition of the marine fishery resources brought about by uncontrollable non-responsible fishing activities resulting in their over-exploitation and devastation. In order to address such concerns, it had become necessary to institute reforms within SEAFDEC as well as in the regional arena, which could include harnessing the potentials of aquaculture and inland fisheries towards sustainable development. Amidst such a situation, SEAFDEC and the AMSs are not feeling desperate as these other fisheries sub-sectors could provide the gleam of hope because of their potentials that could be tapped to sustain the region's fishery production and eventually supply the rising demand for food fish by the increasing population. In view of the potentials that such sub-sectors could offer, SEAFDEC has always made sure that the sustainability of inland fisheries and aquaculture is embedded in its plans, programs and activities, as indicated in the 2001 and 2011 ASEAN-SEAFDEC Resolutions and Plans of Action on Sustainable Fisheries for Food Security for the ASEAN Region. Moreover, in the latest ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030, Resolution Numbers 14 and 15, and Plan of Action Numbers 40-47 specifically focused on the sustainable development of inland fisheries, while Resolution Numbers 16-18 and Plan of Action Numbers 48-69 are devoted to sustainable development of aquaculture. By putting greater attention on the sustainable development of inland fisheries and aquaculture, the stakeholders from the region are ensured of food security in the years to come, while allowing the marine fishery resources to recover from their current state of decline and restore their capacity to rebuild and be able to provide again sufficient food fish for the people.

The Southeast Asian Fisheries Development Center (SEAFDEC) was established in 1967 to serve as a platform for the promotion of fisheries to improve the food situation in Southeast Asia (Silapajarn & Sulit, 2018). In order that SEAFDEC could fulfill such mission, the Marine Fisheries Training Department and Marine Fisheries Research Department (SEAFDEC/MFRD) were simultaneously established in 1967 in Thailand and Singapore, respectively, with the former which became more popularly known as the Training Department (SEAFDEC/TD) tasked to offer training on modern fishing technologies and the latter, which became operational in 1968, to conduct research on marine fishery resources evaluation and oceanographic surveys in the waters of Southeast Asia.

More than six years later, when it was deemed necessary to promote the sustainable development of fish culture in the region towards increased production to supplement the production from marine capture fisheries, the Aquaculture Department (SEAFDEC/AQD) was established in the Philippines in 1973. Almost during such time, a plan was conceived to transfer the marine research function of MFRD to the proposed Marine Fishery Resources Development and Management Department (SEAFDEC/MFRDMD) that was suggested to be established in Malaysia in 1990 but became operational only in 2002. With such development, the function of MFRD shifted to undertaking research on fisheries post-harvest technology and processing, initially focusing on fish preservation and upgrading of the quality of the region's traditional fish products. After more than 10 years, and cognizant of the role that inland fisheries play for the socioeconomic development and food security of the people of Southeast Asia, and the need to tap the vast inland water resources available in the region, the SEAFDEC Council of Directors agreed to establish the Inland Fishery Resources Development and Management Department (SEAFDEC/IFRDMD) in 2014 in Indonesia.

It should be recalled that in the history of Southeast Asian fisheries development, fishing activities in the region before the 1980s were confined in near-shore areas and in territorial seas that lay only 12 nautical miles from the shore, and fishers made use of simple implements and non-motorized or non-mechanized fishing vessels. Most of their landings were intended mainly for domestic consumption with few countries producing fishery products bound for the export market. Nonetheless, some national planners at that time had the view that the fishery resources could be inexhaustible so that big national plans were made with such perception in mind. Embracing the latest fishing technologies coming from the modern world, many Southeast Asian countries were able to enhance their fishing capabilities, and started investing heavily on fishing vessels and fishing gear. These had proved them right as the returns of investments were huge and increases in landings from marine capture fisheries had ensued.

Nevertheless, overfishing became prominent that eventually led to declines in landings that were felt more by the fishers rather than by the policy-makers. When the United Nations Convention on the Law of the Sea (UNCLOS) was signed into force in December 1982 signaling the expansion of the exclusive economic zone (EEZ) to 200 nautical miles from the shore, many coastal countries, including those in Southeast Asia welcomed such development as it could mean stretching their control over the expanded fishing areas. Many countries therefore intensified their fishing activities by deploying more fishing vessels to sea, only to find out later that this was detrimental to the fate of the fishery resources, as fewer fish had been caught later.

Way back in 1997, FAO (1997) confirmed that while the population of Southeast Asia has been rapidly growing, the countries in the region would need to increase their domestic protein supply from fish by tapping the potentials of aquaculture and inland fisheries considering that marine fishery resources have been generally fully exploited. FAO added that in the early 2000s, some of the Southeast Asian countries had been among the top ten fisheries producers from aquaculture (*i.e.* Indonesia, Thailand, Philippines, Viet Nam), and in inland capture fisheries, *e.g.* Indonesia, Cambodia, Myanmar (FAO, 2000; FAO, 2002).

In the Southeast Asian scenario, the fishery statistics indicated that although after 1976–1980, the annual production in terms of number appeared to have been increasing but the annual increases had been very minimal (**Table 1** and **Table 2**). Meanwhile, the United Nations had estimated that the world's population by 2030 would be about 8,501 million and that Southeast Asia's population would be about 717 million (**Table 3**). Considering that the average annual consumption of fish in the AMSs is 33.4 kg/capita, this means that in 2018, the amount of fish available for consumption in the AMSs should be 21,877,000 t, and about 22,177,00 t in 2020. By 2030, the amount of fish available for consumption of the people in the AMSs should be about 23,957,800 t. It is therefore necessary that the fisheries sector of Southeast Asian should be sustainably developed and be able to fulfill the gigantic task of producing sufficient quantity of fish to supply the demand of the region for food fish.

Such circumstances had led to a general situation which necessitated reforms in the fisheries sector, especially in terms of developing the ways and means of promoting sustainable management of the fishery resources. Thus, SEAFDEC instituted reforms within the organization by establishing and advocating measures directed towards the sustainable development and management of fisheries in the Southeast Asian region. Under such reforms, the marine fishery resources had been allowed to recover by developing and instituting measures for their sustainable development and management, *e.g.* countermeasures to eliminate illegal, unreported and unregulated (IUU) fishing (Smithrithee *et al.*, 2020). Meanwhile, the sustainable development of

Table 1. Fisheries production of Southeast Asia by five-year period* in thousand t

	1976a	1980a	1986a	1990a	1996a	2000a	2006a	2010b	2016b	2018b
Marine capture fisheries	3,832	5,894	6,893	8,083	9,868	12,550	13,939	14,874	17,247	18,330
Inland capture fisheries	485	904	874	1,015	1,717	996	2,107	2,377	3,126	3,337
Aquaculture	310	815	928	1,564	2,679	3,320	8,348	14,187	25,183	24,872
Total	**4,627**	**7,613**	**8,695**	**10,662**	**14,264**	**16,866**	**24,394**	**31,438**	**45,536**	**46,539**

**Except for 2016–2018*
Source a: *SEAFDEC (1976, 1980, 1986, 1990, 1996, 2000, 2006a)*
Source b: *SEAFDEC (2010, 2016, 2018)*

Table 2. Average annual rate (%) of increase in fisheries production of Southeast Asia: by five-year period*

	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2018
Marine capture fisheries	7.00	2.90	2.94	3.62	4.28	2.00	1.26	2.76	1.97
Inland capture fisheries	9.28	-0.69	2.78	8.18	-14.48	10.55	2.27	5.80	2.11
Aquaculture	2.48	2.49	8.13	8.32	3.86	12.05	8.23	8.83	-0.42
Total	**7.85**	**2.35**	**3.69**	**5.05**	**3.09**	**6.17**	**4.48**	**6.33**	**0.86**

**Except for 2016–2018*

Table 3. Total population of the world and Southeast Asia in 1990-2030 in million (UN estimates)

	1970	1980	1990	2000	2010	2018	2020	2030
World's population	3,683	4,433	5,327	6,143	6,957	7,714	7,795	8,501
Population of Southeast Asia	285	359	445	524	594	655	664	717

aquaculture and inland capture fisheries had been given more focus in the plans and programs of SEAFDEC (Pongsri *et al*., 2011; Pongsri *et al*., 2015a; Pongsri *et al*., 2015b; Platon *et al*., 2007; Ayson *et al*., 2015; Prisantoso & Sulit, 2014; Wibowo *et al*., 2018).

Institutional Reforms

First and foremost in the 1990s, SEAFDEC enhanced its collaboration with the Association of Southeast Asian Nations (ASEAN) to be able to intensify the promotion of sustainable fisheries development in the whole Southeast Asian region. This also called for the expansion of the membership in SEAFDEC which originally included Japan, Malaysia, Thailand, Singapore, and Philippines, by inviting all the other ASEAN Member States (AMSs) to become members of SEAFDEC in order that all the AMSs would benefit from the technologies developed and promoted by SEAFDEC. So, by 2003, all the AMSs and Japan comprise the members of SEAFDEC, *i.e.* Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

Meanwhile, the worldwide concern about the sustainability of natural renewable resources led to the adoption in 1992 of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil. UNCED reflected a global consensus for more ecosystem-based sustainable development across all sectors of human activity, as means of improving the human welfare of present generations without sacrificing that of the future. UNCED also called for a substantial shift in governance, improved scientific support to decision-making, and a substantial increase in strategic information (FAO, 1992).

On the part of SEAFDEC, various reforms were carried out for the sustainable development and management of fisheries, which were instituted in collaboration with the AMSs and with major technical and financial support provided by the Government of Japan through the JTF (Tsubata, 2008; SEAFDEC, 2008; Ishii *et al*., 2017; SEAFDEC, 2020a). As shown in the **Box**, such reforms include progress and development in the region's fisheries that also dovetail to propelling inland fisheries and aquaculture of the Southeast Asian region towards sustainability.

Box. Major reforms instituted by SEAFDEC and the AMSs for the sustainable development of fisheries in the Southeast Asian region
General institutional reforms
Promotion of the Strategy and Action Plan of the Resolution on SEAFDEC Strategic Plans Cognizant of the way forward of SEAFDEC towards intensifying the promotion of sustainable fisheries development in the Southeast Asian region, the SEAFDEC Council of Directors during their Thirtieth Meeting in 1998 adopted the Strategy and the Action Plan of the Resolution on SEAFDEC Strategic Plans, to serve as guides in realizing the goal set by the SEAFDEC mandate, and in enhancing the collaboration of SEAFDEC with the ASEAN. Against the backdrop of such enhanced collaboration, SEAFDEC has been working with the AMSs in generating policy guidelines and recommendations for the sustainable development of fisheries taking into consideration the provisions stipulated in the Strategy and the Action Plan.
Establishment of the ASEAN-SEAFDEC Fisheries Consultative Group The aforesaid enhanced collaboration facilitated the establishment in 1998 of the ASEAN-SEAFDEC Fisheries Consultative Group (FCG) as a mechanism for the implementation of joint ASEAN-SEAFDEC plans, programs and activities for the sustainable development and management of fisheries in the Southeast Asian region. The implementation of the relevant plans, programs and activities has been financially supported from the Government of Japan through the Japanese Trust Fund (JTF).
Regionalization of the Code of Conduct for Responsible Fisheries At the international arena, FAO had been promoting the implementation of the global Code of Conduct for Responsible Fisheries (CCRF) which was adopted by the FAO member states in 1995. In order that the CCRF could be adopted in the Southeast Asian region considering its specific context, *e.g.* culture, fisheries structures, ecosystems, SEAFDEC embarked on the Project Regionalization of the Code of Conduct for Responsible Fisheries (RCCRF) in 1998. With support from the JTF, the RCCRF Project came up with the Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Fishing Operations (SEAFDEC, 2000a); Responsible Fisheries Management (SEAFDEC, 2003); Responsible Aquaculture (SEAFDEC/AQD, 2001; SEAFDEC, 2005a); and Responsible Post-Harvest Practices and Trade (SEAFDEC, 2005b). Moreover, to elucidate on the management of inland fisheries, the Project RCCRF also developed the Supplementary Guidelines on Co-management using Group User Rights, Fisheries Statistics, Indicators, and Fisheries *Refugia* (SEAFDEC, 2006b). To ensure that the AMSs would be able to adopt the regionalized CCRF, SEAFDEC provided capacity building of the human and institutional resources of the AMSs with financial support from the Government of Sweden through the Swedish National Board of Fisheries (Wanchana, 2007).
Promotion of the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security in the New Millennium In an effort to address the issues on unsustainable fisheries practices in the region that could negatively impact on the availability of sufficient fish supply for food security and socioeconomic well-being of peoples in the Southeast Asian region, the ASEAN and SEAFDEC adopted the Resolution and Plan of Action (RES&POA-2001) on Sustainable Fisheries for Food Security in the New Millennium (SEAFDEC, 2001) during the ASEAN-SEAFDEC Millennium Conference "Fish for the People" in November 2001. The RES&POA-2001 had served as guidelines in formulating programs and activities, *e.g.* Special Five-year Program on the Contribution of Sustainable Fisheries for Food Security for the AEAN Region in the AMSs leading to the revision of fisheries regulations of the respective AMSs towards sustainability. The RES&POA-2001 also included provisions on the sustainable development and management of aquaculture and inland fisheries in the AMSs
Establishment of the ASEAN-SEAFDEC Strategic Partnership As means of strengthening the ASEAN and SEAFDEC cooperation and collaboration for the promotion of sustainable fisheries development under the ASEAN-SEAFDEC FCG, the ASEAN-SEAFDEC Strategic Partnership (ASSP) was established upon the signing of the Letter of Understanding (LOU) in 2007 that provided the formal complementary framework for the ASEAN and SEAFDEC to work together and support the ASEAN in fulfilling its vision of "becoming a leader in sustainable tropical fisheries for the people" and in the economic integration of the fisheries sector. Signed by the Secretary-Generals of the ASEAN and SEAFDEC, the LOU stipulates the agreed principle to continue using the existing FCG mechanism to consult, deliberate and agree on the ASEAN-SEAFDEC fisheries programs, activities and policies.

Box. Major reforms instituted by SEAFDEC and the AMSs for the sustainable development of fisheries in the Southeast Asian region *(Cont'd)*

Promotion of the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020

Although significant progress had been attained by the AMSs in promoting sustainable fisheries and in improving the people's livelihoods for food security, ten years after the adoption of the RES&POA-2001, the continued deterioration of the ecosystem and the environment brought about by climate change, and social and economic factors, necessitated the AMSs to keep abreast of the changing environment to be able to address the emerging challenges in fisheries development, and enhance the competitiveness of the region's fish and fishery products in the world market. Thus, the AMSs and SEAFDEC adopted the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2020 (RES&POA-2020) during the ASEAN-SEAFDEC Conference "Fish for the People 2020: Adaptation to a Changing Environment" in June 2011 (SEAFDEC, 2011). The RES&POA-2020 has since then served as policy guidelines during the following decade, and as priority actions towards ensuring fisheries sustainability for food security and improving the livelihoods of the peoples in the region. The RES&POA-2020 has stipulated sufficient provisions on the sustainable development of aquaculture and inland fisheries.

Fostering joint commitment to combat IUU fishing in Southeast Asia

Considering the stringent measures imposed by importing countries on the export of fish and fishery products by checking on their source to make sure that such products do not come from IUU fishing activities, the ASEAN and SEAFDEC convened a consultation in 2016 where expression of support and commitment of the AMSs was conveyed through the signing the Joint ASEAN-SEAFDEC Declaration on Combating IUU Fishing and Enhancing the Competitiveness of ASEAN Fish and Fishery Products (SEAFDEC, 2016). The signed Joint Declaration is a testimony of the commitment of the AMSs to work together in addressing the emerging issues spawned by the practice of irresponsible fishing, especially IUU fishing activities.

Promotion of the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030

After the ten-year implementation of RES&POA-2020, and upon considering the results of a review carried out by the AMSs with support from SEAFDEC and JTF, the AMSs and SEAFDEC came up with the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 (RES&POA-2030) that accommodated the emerging issues and challenges in the fisheries sector of Southeast Asia (SEAFDEC, 2020b). The adopted RES&POA-2030 is being used as a regional framework for the sustainable development of fisheries and enhancing the contribution of fisheries to food security and livelihoods of peoples in the Southeast Asian region in the next decade.

Major reforms in marine capture fisheries

Promotion of the concept of Ecosystem Approach to Fisheries Management

The concept of Ecosystem Approach to Fisheries Management (EAFM) had been advanced by SEAFDEC in the Southeast Asian region with support from the JTF, initially focusing on the management of marine fishery resources, through capacity building by enhancing the understanding of the region's fisheries management officers on the appropriate fisheries management approaches for the sustainability of the fishery resources (SEAFDEC, 2017a). The concept has been extended by SEAFDEC to cover the inland fishery resources, as well as aquaculture through the concept of what is known as the Ecosystem Approach to Aquaculture Management.

Establishment of regional approaches and tools to combat IUU fishing in the Southeast Asian region

Recognizing that the increasing demand for fish driven by rapid human population growth and coupled with the deteriorating state of the marine fishery resources, had contributed to the continued practice of illegal fishing by many fishers in the Southeast Asian region, SEAFDEC established the general direction for combating IUU fishing in the region in collaboration with the AMSs and with support from JTF. Various approaches had been developed to address such concern (Smithrithee *et al.*, 2020), starting with the promotion of the ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain (Ali *et al.*, 2015) developed by MFRDMD in collaboration with the AMSs. Then, TD also embarked on the establishment of the Regional Fishing Vessels Record (RFVR) and RFVR database for fishing vessels 24 m in length and over, the promotion of the adoption of the Regional Plan of Action on Fishing Capacity to manage fishing capacity in Southeast Asia (SEAFDEC, 2017b), strengthening of the monitoring, control and surveillance (MCS) and regional MCS networks, intensifying the promotion of port State measures, and promoting catch documentation and traceability of fish and fishery products among others. While efforts are now being made by TD to link the RFVR with the FAO Global Record of Fishing Vessels, Refrigerated Transport Vessels and Supply Vessels (Global Record) to avoid duplication of efforts and information, discussion is also underway among the AMSs and SEAFDEC for the possibility of expanding the RFVR to cover fishing vessels less than 24 meters in length.

Major reforms in fisheries post-harvest and processing

Promotion of guidelines on food safety measures to ensure the quality and safety of fishery products for food security in Southeast Asia

While before, traditional fishery products of the AMSs had been generally produced by backyard processing industries and consumed domestically, the increasing demand for fishery products necessitated the improvement of these traditional fishery products to comply with the safety and quality standards, and requirements for fish and fishery products traded in the world market. In this regard, MFRD developed and promoted the appropriate guidelines on food safety measures, *e.g.* good manufacturing practices (GMP), standard sanitation operating procedures (SSOP), and with support from JTF, MFRD assisted the AMSs in implementing such measures by incorporating the Hazard Analysis Critical Control Point (HACCP) plans in their GMP programs (Yeap & Chow, 2011). This has enabled the processing industries of the AMSs to meet the safety and quality assurance requirements for their traditional fishery products. The processing industries had also developed fishery products using freshwater fishes from inland fisheries as raw materials to fill the gap caused by the dwindling supply of raw materials from marine capture fisheries.

Promotion of the regional system of monitoring and analysis of contaminants in seafood

In order to enhance the understanding of stakeholders in the AMSs of the levels of chemical contaminants in fish and fishery products in Southeast Asia, and to transfer the developed testing technologies and methodologies to the region through capacity building of their human and institutional resources, MFRD in collaboration with the AMSs and with support from JTF, conducted series of surveys to monitor and analyze the presence of chemical contaminants and drug residues in fish and fishery products of the region (Ong, 2020). Moreover, surveys on biotoxins were also carried out to monitor the incidence of biotoxins contamination of the region's fish and fishery products. This resulted in the publication of the series of Technical Compilations of Biotoxins Monitoring in the ASEAN Region that also include monitoring of the toxic harmful algal blooms (HABs), *e.g.* red tide. The Technical Compilations (Tan & Saw, 2008; Neo *et al.*, 2012; Ong & Chai, 2019) had served as reference and learning tool for concerned stakeholders especially the policy-makers in the region on the occurrences and incidences of biotoxins and on HABs. Meanwhile, the regional capability of the national testing laboratories of the AMSs had been improved making them capable of monitoring and analyzing contaminants in seafood.

Box. Major reforms instituted by SEAFDEC and the AMSs for the sustainable development of fisheries in the Southeast Asian region *(Cont'd)*
Major reforms in aquaculture
Getting out of the fish meal trap While the aquaculture industry in Southeast Asia continues to expand and aim for increased production, aquaculture operations had been viewed as a threat to marine capture fisheries because of the rampant use of fish by-catch in aquaculture feeds. By using the fish catch meant for human direct consumption for aquaculture feeds, this resulted in over-exploitation and eventual degradation of the marine fishery resources. With support from JTF, AQD had enhanced its R&D activities since early 2010s to find fishmeal substitutes in aquafeed formulations by using locally-available plant and other non-fish based protein sources in order to minimize the pressure on the marine fishery resources (Mamaug, 2016; Aya, 2017). Assessing the sustainability and cost-effectiveness of the various alternative protein sources and ingredients for aquafeeds is also being pursued by AQD.
Promotion of prompt and effective aquatic animal health management In early 2010s, several new transboundary aquatic animal diseases (*e.g.* EMS/AHPND) have emerged resulting in widespread devastation of the aquaculture industry, especially the shrimp industry of Southeast Asia (Tendencia & Estilo, 2017). As means of addressing this concern, SEAFDEC with support from JTF, enhanced regional cooperation for the adoption of recommendations on policy issues that include harmonization of legislations and regulations related to aquatic animal health management, *e.g.* legislation on transboundary movement of live aquatic animals, compliance with good aquaculture practices, strengthening cooperation and collaboration arrangements with various international and regional organizations and agencies concerned with aquatic animal health management. The series of international and regional consultations came up with the Regional Technical Guidelines on Early Warning System for Aquatic Animal Health Emergencies (SEAFDEC, 2020c), which is being promoted in the AMSs for the prompt and effective aquatic animal health management. AQD would strengthen the adoption of the Guidelines in the AMSs through its planned Regional Technical Consultation on Aquatic Animal Health Emergencies to be organized in 2022.
Promotion of the Regional Guidelines to support development of traceability system for aquaculture products Considering the significant volume of cultured fish and fishery products exported by the AMSs annually to regional and international markets, the traceability of such products should be ensured to enhance the competitiveness of such products and facilitate trade with major importing countries. As traceability has also become a requirement for exporting these products to global fish market, the international community had called for the establishment of a reliable traceability system that would ensure the safety and quality of the products. This led to the development by MFRD in collaboration with the AMSs and with support from JTF, of the Regional Guidelines on Traceability System for Aquaculture Products in the ASEAN Region (SEAFDEC, 2017c) to serve as common reference for the AMSs in the implementation of traceability systems for aquaculture products as well as for the development of national programs on traceability of aquaculture products.
Major reforms in inland fisheries
Establishment of a regional center for inland fisheries Recognizing that the sustainable development of inland fisheries in Southeast Asia is crucial for food security and for improving the well-being of the peoples of the AMSs, and considering the crucial role that inland fisheries could play for the region's socioeconomic development of the vast inland resources, the SEAFDEC Council of Directors agreed to establish a regional center for inland fisheries in September 2014 under the umbrella of SEAFDEC (Pongsri *et al.*, 2015; Wibowo *et al.*, 2018). Known as the Inland Fishery Resources Development and Management Department (IFRDMD) of SEAFDEC, it is tasked to provide the platform for the proper development and management of the inland fishery resources of the Southeast Asian region.
Promotion of the sustainable development of inland fisheries in Southeast Asia Confirming that inland fisheries could play a significant role in enhancing the region's socioeconomic development for the region's food security by sustainably utilizing the vast inland resources that are available for sustainable development and also tapping the numerous species of indigenous fishes that inhabit the region's inland waters (Isa *et al.*, 2011), IFRDMD with support from JTF, has currently undertaken the colossal task of developing the guidelines and tools relevant to the sustainable development of fisheries. These include among others, basic data collection system for routine monitoring of different types of inland habitats, assessment and management of inland fishery resources, monitoring the state and levels of exploitation of inland fishery resources, and scientific basis for the proper development and management of inland fishery resources (Wibowo *et al.*, 2018).
Promotion of an efficient system of data collection on inland fisheries The development of inland fisheries is crucial for sustaining the socioeconomic conditions of many countries in Southeast Asia. However, information on the actual contribution of inland fisheries to food security is not readily available, making it difficult to assess the importance and value of inland fisheries, and constitutes a big challenge for its development. Even if data are available, these are not sufficient enough for any analysis (Muthmainnah *et al.*, 2020). Considering that the importance of catch statistics from inland capture fisheries had not been given much attention before, IFRDMD has been exploring all the possible ways for developing an effective and efficient system of collecting data from inland capture fisheries. Such effort had resulted in the development and promotion of a novel application-based system on android mobile phones for collecting data from inland capture fisheries. Although initially promoted in Indonesia at the moment, this system would be introduced to other AMSs, especially in Lao PDR, Cambodia, Myanmar, and Viet Nam where the amount of catch from inland capture fisheries could be significant.

Way Forward

While the marine fishery resources of the Southeast Asian region is allowed to recover from degradation and restore their potentials for future utilization, SEAFDEC would continue to exert efforts in developing the strategies for the sustainable development of aquaculture and inland capture fisheries, considering that these two sub-sectors have the potentials that could be tapped to increase fish production. Such development is expected to lead to increased fisheries production, stabilizing the supply-demand gap in food fish brought about by the dwindling production from marine capture fisheries.

Through the plans and programs of AQD, promotion of responsible aquaculture would be enhanced as this has always been the long-term strategy for the economic development in the region. However, there is a need to continue efforts in addressing the major concerns and knowledge gaps in the sustainability of aquaculture. These concerns could include, among others: the availability of good quality seeds for culture; maintaining environmental integrity through responsible aquaculture; sustaining healthy and wholesome aquaculture; adapting to the impacts of climate change; and meeting social and economic challenges (Ayson *et al*., 2015). In other words, as Platon *et al*. (2007) aptly explained in their discourse, AQD should continue to make sure that aquaculture remains sustainable, technically feasible and economically-viable, as well as environment-friendly and socially equitable. Moreover, Ishii *et al*. (2017) also added that, such future actions would also include addressing the major concerns in the occurrence and spread of aquatic diseases through the promotion of proper aquatic health management to make sure that the region would continue to generate healthy and wholesome fish and fishery products from aquaculture.

This also confirms that SEAFDEC would continue to promote the adherence of the AMSs to the Regional Technical Guidelines on Early Warning System for Aquatic Animal Health Emergencies (SEAFDEC, 2020c) to prevent the rapid spread of aquatic diseases that could impact on the sustainable development of the region's aquaculture sub-sector. By adhering to the wholesomeness of aquaculture, the region's aquaculture production could be increased while the competitiveness of the region's fish and fishery products from aquaculture is enhanced.

Furthermore, it has also become crucial for aquaculture operations to reduce their dependence on fishmeal for aquafeeds production to allow the fishery resources to rebuild and rehabilitate their potentials. This strategy calls for the replacement of fishmeal in the production of aquafeeds using less expensive alternative protein sources, *e.g.* plant-derived materials, agricultural wastes, food processing byproducts (Mamauag, 2016; Aya, 2017). Therefore, AQD would continue its R&D efforts toward producing cost-effective aquafeeds as well as developing affordable processing techniques for converting these alternative feed ingredients into effective raw materials for aquafeed production (Ishii *et al*., 2017).

In the current scenario of the inland capture fisheries of Southeast Asia, where its sustainability is being confronted with various concerns, the plans and programs of IFRDMD aimed at the sustainable development and management of inland fishery resources would be pursued vigorously. Muthmainnah & Makmur (2017) surmised that there is a need to effectively address such concerns in order that considerable quantity of quality freshwater fish could be generated from inland fisheries. Considering that the most crucial concern is the dearth of realistic data and information on the benefits that could be gained from responsible utilization of aquatic habitats and water resources to sustain food security and livelihoods of peoples, it has become imperative that the development of practical methodologies for the valuation of the aquatic ecosystem services, and intensification of the awareness building on such aspects should be sustained in the AMSs. There is also a need to adopt the most efficient and effective fisheries management measures applicable for inland fisheries, *e.g.* co-management, community-based fisheries management, rights-based management. Nonetheless, adoption of the concept of the ecosystem approach to fisheries management (EAFM) could encompass all those previously suggested management measures, as the EAFM gives due consideration to the socioeconomic aspects of fisheries management (SEAFDEC, 2017a). As for the other challenges that could also impede the sustainable development of inland fisheries, *e.g.* insufficient data and information, especially on the actual production from the fisheries; environmental degradation due to pollution caused by land-based activities; overexploitation of inland fishery resources by fishers unmindful of the need for food fish by future generation; rapidly increasing population leading to severe conflict on the use of water and resources, IFRDMD would continue to work towards developing the most appropriate approaches to address such concerns and ensure the sustainability of the inland fishery resources (Muthmainnah *et al*., 2017).

With regard to the severe competition on the use of water resources among the various economic and development sectors coupled by the massive water infrastructure development programs of many governments that include construction of dams and weirs to fulfill their urbanization and industrialization plans, IFRDMD would continue to promote the significance of constructing fish ways, also known as fish passes or fish passages on dams and weirs, and enhance the awareness of stakeholders on the important role that such fish ways play in improving water connectivity to sustain the inland fishery resources (Pongsri *et al*., 2016; Ditya *et al*., 2021). Without having these fish ways would create depletion or even population collapse of many freshwater fishes as their migration patterns could be disrupted.

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Enhanced Biosecurity Measures for Sustainable Aquaculture: shrimp hatchery operations

Leobert D. de la Peña, Dan D. Baliao, Roger Edward P. Mamauag, Janice T. Genilza, and *Jebrham C. Navarro*

Long before the COVID-19 pandemic, the Broodstock Facility and Shrimp Hatchery Complex of SEAFDEC Aquaculture Department (AQD) in Tigbauan, Iloilo, Philippines, has already been practicing the best quarantine protocols. The gold standards to ensure the production of disease-free and high-quality shrimp are being developed by AQD under the program "OPLAN *Balik Sugpo*" or Operation Plan for Black Tiger Prawn Revival. Initiated in 2017, this Program generally aims to bring back the *Penaeus monodon* industry of the Philippines and help farmers revive their hopes and venture again into shrimp culture. Under the Program, the disease prevention scheme is currently undergoing verification for responsible management of shrimp broodstock obtained from the natural environment at AQD's Broodstock Facility, and for the care of the post-larval stage at AQD's Shrimp Hatchery Complex.

In the Southeast Asian region, the shrimp aquaculture industry capitalizes on the rising demand for shrimp in domestic and international markets, as the world's human population continues to grow. This lucrative industry racks up billions of US dollars in export income annually, making it a consistent money-maker for aquaculture farmers from 2008 to 2017 (**Figure 1**). However, the industry is very delicate and fragile as the culture species solely rely on their innate immunity to protect against pathogens. The lack of adaptive immunity in shrimps (Amar & Faisan, 2012) and the emergence of new diseases or the recurrence of old ones can entirely wipe out shrimp production, which could lead to the collapse of the industry.

Cultured shrimps are vulnerable to diseases that result in physical abnormalities, stunted growth, reduced fecundity, and mortality. Several causative agents include the bacteria like *Vibrio harveyi* and *V. splendidus*, which cause bacterial and viral diseases such as the baculovirus which gives rise to the white spot syndrome virus (WSSV) disease and parvovirus that brings about the infectious hypodermal and hematopoietic necrosis virus (IHHNV) disease (Lavilla-Pitogo *et al*., 2000; de la Peña *et al*., 2015). The susceptibility of shrimps to a number of pathogens means that shrimp farms should definitely include biosafety procedures in their culture practices.

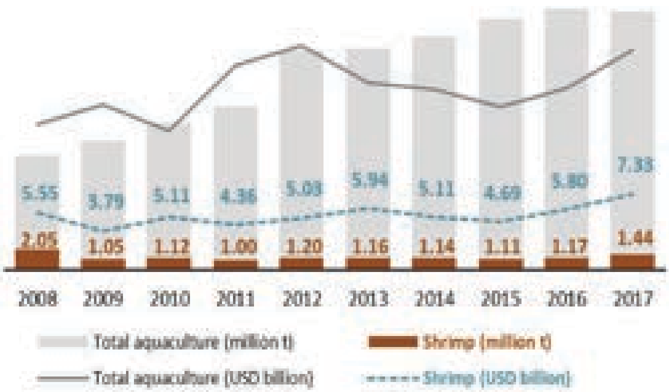

Figure 1. Shrimp culture and aquaculture production of the Southeast Asia region in 2008-2017 by quantity (million t) and value (USD billion) (excluding freshwater prawn)
Source: *Southeast Asian Fisheries Development Center (2020)*

Adding fuel to the fire, the rapid intensification of shrimp farming in recent years to produce more shrimp without regard for good aquaculture practices (GAqP) has allowed disease outbreaks to occur, ultimately translating to reduced production and financial losses. For example, the Philippines used to be at the forefront of *P. monodon* culture in the Southeast Asian region. However, the country's *P. monodon* industry quickly collapsed at its peak largely due to intensified and irresponsible farming, pollution, environmental degradation, and disease outbreaks (Golez, 2009; Rosario & Lopez, 2005).

OPLAN *Balik Sugpo*

In the past, milkfish has dominated the Philippine aquaculture scene, and shrimps and prawns were just seen as incidental crops (Gicos, 1993; Primavera, 1992). Farmers soon realized the market potential of shrimp particularly the black tiger shrimp (*P. monodon*). So, the Philippines, in the 1960s started exporting black tiger shrimps to Japan which then led to a boom in production due to the high demand of shrimps overseas (Hishamunda *et al*., 2009; Rosario & Lopez, 2005).

During the 1970s, the life cycle of *P. monodon* was first completed in captivity by SEAFDEC/AQD using eyestalk ablation to induce maturation. As time goes by, more research and development milestones have been achieved by AQD. Extension manuals on pond culture of *P. monodon* were published, as the mass production of spawners through eyestalk ablation in marine pens was achieved. The technology on mass production of fry was also developed and disseminated through regular training courses leading to the establishment of small-scale hatcheries not only in the Philippines but also in the Southeast Asian region.

In the 1980s, the production of spawners through ablation was achieved in land-based tanks giving rise to the publication of the manual on broodstock management and a technical report on the biology of the shrimp, *P. monodon*. In addition, an effective and cost-effective diet for grow-out was developed, and when the 1990s came, a microparticulate diet was formulated for the shrimp larvae, while the mangrove-friendly shrimp farming techniques were developed. In late 1990s, however, when diseases hit the shrimp hatchery hard due to intensification of stocks and irresponsible culture practices in ponds, there was a huge decline in the country's *P. monodon* that devastated the Philippine shrimp industry affecting the shrimp growers and making the hatchery operators cease their fry production.

At present, AQD is embarking on several activities to revive the shrimp industry of the Philippines under the program "OPLAN *Balik Sugpo*" which aims to produce high-quality *P. monodon* postlarvae (PL) to supply the shrimp farmers for grow-out culture. AQD has enhanced the existing culture procedures particularly applying strict biosecurity measures and instilling GAqP in its shrimp hatchery operations. Under the Program, the current disease prevention scheme (**Figure 2**) includes verification for the management of the shrimp broodstock obtained from the natural environment at AQD's Broodstock Facility, and the resulting PL for rearing at AQD's Shrimp Hatchery Complex.

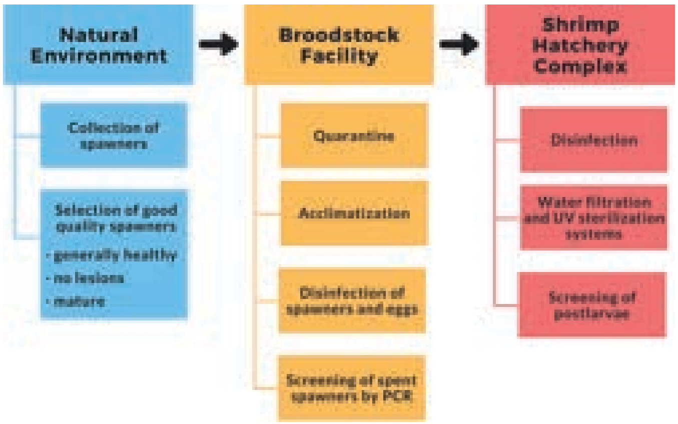

Figure 2. Disease prevention scheme of the program "OPLAN *Balik Sugpo*" of SEAFDEC/AQD

Natural Environment

Broodstock (spawner) of shrimps are usually acquired from the wild by means of trawling between 12 m and 55 m water depth. The good spawners are selected, which should be generally healthy, have no cuts or damages, and most importantly, mature enough to spawn overnight (*i.e.* each gravid female shrimp holding 200,000–1,000,000 eggs). Then, the selected spawners are transported in fry bags supplied with aerated seawater to AQD's Broodstock Facility.

Broodstock Facility of AQD

The Broodstock Facility of AQD for shrimps is located at the Tigbauan Main Station of SEAFDEC Aquaculture Department in Iloilo, Philippines.

Disinfection of staff and guests

At AQD's Broodstock Facility, the staff must wear personal protective equipment (PPE) including face masks, gloves, scrub suit, laboratory gown, and boots (**Figure 3**). The doors of the Broodstock Facility are also installed with alcohol dispensers and foot baths. The staff as well as guests may be carrying with them pathogens from the outside so they should also frequently sanitize to minimize the exposure of the shrimp spawners to pathogens.

Figure 3. A staff at AQD's Broodstock Facility in complete personal protective equipment

Disinfection of spawners and eggs

Upon arrival, the spawners are housed at the Broodstock Facility which is located in a building separate from the Shrimp Hatchery Complex to avoid cross-contamination of pathogens. The spawners acquired from the wild are possible carriers of diseases, thus, they are subjected to strict quarantine procedures at the Broodstock Facility to make sure that the contamination of pathogens is controlled.

For acclimatization, the spawners are placed in white basins filled with aerated water adjusted to equalize with the salinity of the water in the transport bag. When both of the water salinities have equalized, the spawners are allowed to remain in the basin for two hours. After acclimatization, the spawners are disinfected for 15 min with 50 ppm formalin or povidone-iodine added to the water in the basin (**Figure 4**). Then, after

Figure 4. A hatchery staff adding formalin to disinfect the spawners

checking for gonadal maturity, one spawner is placed in each fiberglass spawning tank and allowed to spawn overnight. Then the individual spawning tanks are covered with black nets and black sacks to avoid entry of other organisms and contamination between the tanks.

Each spawning tank is equipped with a set of materials including dipper, scoop net, harvesting box, and others to be used during the spawning operations. After spawning, the eggs are washed, this has long been practiced, to reduce the accumulation of bacteria and viruses when the eggs hatch into nauplii (Licop, 1988). It is said that the capsule that encloses an egg might contain bacteria and viruses during spawning. During hatching, the capsule breaks and the eggs turn into nauplii. If the eggs are not washed and disinfected, the nauplii may engulf the bacteria and viruses as their mouths begin to open. In the current practice, egg washing procedure has been enhanced to make sure that the eggs are free from pathogens before hatching into nauplii. The eggs are washed with running UV-sterilized seawater for five minutes in the first basin, and then transferred to a second basin with aerated seawater added with 50 ppm of povidone-iodine solution. Finally, the eggs are placed in a third basin and rinsed again with running UV-sterilized seawater for five minutes to eliminate the pathogens that could have attached on the surface of the eggs.

Screening of spent spawners and eggs

In earlier times, disease detection in shrimp farms was difficult to carry out, and in most cases it was already too late when diseases are detected. Nowadays, disease surveillance has been improved with the advent of polymerase chain reaction (PCR). The tissue samples of spent spawners and egg samples are sent to the Laboratory for pathogen detection through reverse transcription polymerase chain reaction (RT-PCR) technique to determine the presence of pathogens and diseases, such as WSSV, IHHNV, EHP, AHPND, monodon baculovirus (MBV), yellow head virus (YHV), and others.

AQD Shrimp Hatchery Complex

At the Shrimp Hatchery Complex of AQD (**Figure 5**), the biosecurity practices and facilities had been enhanced and modified to keep up with the increasing demand for shrimp fry, prevent the occurrence of diseases, mitigate the potentially harmful damage caused by the pathogens, and reduce mortality rates.

Figure 5. Shrimp Hatchery Complex of SEAFDEC/AQD at the Tigbauan Main Station, Iloilo, Philippines

Disinfection of staff and guests

Aside from isolation and routine testing of spawners, eggs, and fry, biosecurity measures in hatcheries are now focused also on the staff and guests who should be responsible in minimizing the exposure of fry to pathogens. Before entering the facilities at AQD's Shrimp Hatchery Complex, the staff and guests are required to take a shower at the disinfection building and wear PPE. Alcohol dispensers and foot baths are also installed near the doors of the hatchery facilities for disinfecting hands and shoes, as this could help eliminate pathogens that may have been carried by the staff and guests from outside.

Water filtration and UV sterilization systems

The hatchery is utilizing additional technologies to make sure that microscopic pathogens like bacteria and viruses could not reach and affect the stocks. The seawater pipe and aeration systems have been improved and equipped with ultraviolet (UV) light sterilization system. As shown in **Figure 6**, the pumped seawater would have to undergo several filtration systems before reaching the larval rearing tanks. First, the pumped water from the sea passes through the sand filter before reaching the 180-ton concrete reservoir. Then, the seawater from the reservoir passes through the UV sterilizer to make sure that pathogens are eliminated or become limited

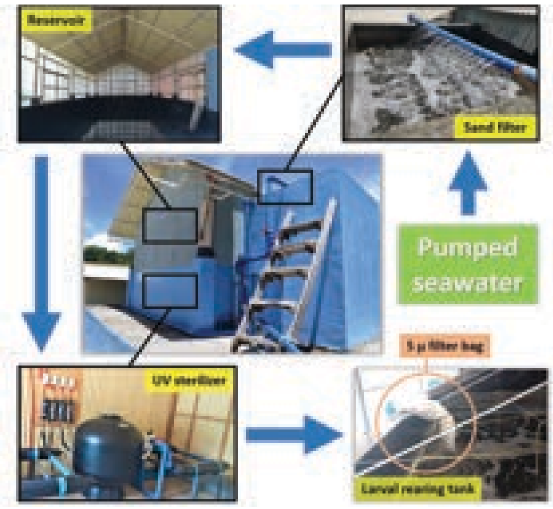

Figure 6. Water filtration and UV sterilization systems at the Shrimp Hatchery Complex of SEAFDEC/AQD

before reaching the larval rearing tanks which are installed with 5 μm filter bag. Finally, the sterilized water is used for rearing the stocks and culturing the natural food for the larvae.

Screening of postlarvae

Using clean and covered pails, all nauplii are harvested and transported from the Broodstock Facility to the Shrimp Hatchery Complex in an order that takes into account the results of the PCR analysis. First, all the nauplii of spawners with negative PCR test results are harvested and stocked in Module 2 of the larval rearing facility. Subsequently, the nauplii of pathogen-positive spawners are harvested and stocked in Module 1 of the larval rearing facility. All the larval rearing tanks are covered with black sacks to avoid entry of other organisms and avoid contamination between the tanks. Cleaning and disinfection of facilities and equipment are also performed to remove all pathogens present in a certain area that might affect the cultured shrimp. All stocked shrimp larvae are reared and treated equally. Particular staff is assigned to feed and monitor the stocks in each module. Daily monitoring of larvae is carried out to detect any problems and diseases that might occur. Samples from the stocked nauplii and the rearing water are subjected to bacterial analyses twice a week for surveillance to detect the presence of luminous bacteria, other *Vibrio* species, and other pathogens.

To ensure that no pathogen escapes detection, the fry are subjected to routine RT-PCR testing for WSSV, MBV, IHHNV, YHV, APHND, and EHP when they reach PL 5, PL 10, and PL 15. This protocol also ensures that none of the fry are potential disease carriers when sold to aquafarmers for grow-out culture.

If results come back positive, the fry is harvested and stocked in Module 1. This practice is deemed sustainable because none of the pathogen-positive nauplii are discarded, but instead, reared and monitored to become high quality and disease-free fry (**Figure 7**).

Figure 7. High quality and disease-free *Penaeus monodon* fry produced at the Shrimp Hatchery Complex of SEAFDEC/AQD

Way Forward

During 2019–2020, SEAFDEC/AQD produced around 3.06 million high quality and disease-free *P. monodon* fry. Relating to the OPLAN *Balik Sugpo*, the disease-free fry produced from the hatchery had been stocked in ponds at Dumangas Brackishwater Station of AQD for the verification run using environment-friendly culture techniques. This yielded about 15 t of black tiger shrimp, which was a step forward to reviving the black tiger shrimp industry starting in Iloilo, Philippines, and hopefully to the whole country and throughout the Southeast Asian region in the future.

The OPLAN *Balik Sugpo* program also focuses on other important factors such as feeds and disease treatments for the successful revival of the black tiger shrimp industry in the country. In the 5-year road map (**Figure 8**) presented by SEAFDEC/AQD during the Shrimp Road Map Updating Workshop conducted by the Philippine Bureau of Fisheries and Aquatic Resources, the program "OPLAN *Balik Sugpo*" would continue with the verification of the improved hatchery and grow-out technologies at the local level and eventually at the national level.

SEAFDEC/AQD has also started with the development of cost-effective feeds for shrimps using locally sourced materials and would proceed with its field verification by the end of 2021. Meanwhile, a vaccine for WSSV is being developed but its development is still at the R&D stage. By 2024, all of the endeavors under the Program should hopefully be ready for rollout. Then, the SEAFDEC Member Countries could request for the transfer of the technology through training and other relevant information activities, through the SEAFDEC mechanisms.

Figure 8. SEAFDEC/AQD 5-year road map for black tiger shrimp under the program "OPLAN *Balik Sugpo*"

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Maintaining River Connectivity for Enhanced Inland Fisheries Productivity

Yoga Candra Ditya, Arif Wibowo, Dwi Atminarso, Almirah Ramadhanti, and *Nana Dahlia*

In many countries in Southeast Asia, massive infrastructure expansion not only on land but also in waterways has been among the main focus of the governments' current national development plans. This is understandable because the priorities of most governments now dovetail towards expanding connectivity for improved economic growth, poverty alleviation, crop productivity, water availability, and power generation. Such development is exemplified in the case of Indonesia, especially in Java and Sumatera Islands, where infrastructure development has been raised to high levels including the establishment of intensive water infrastructures. Reports have shown that more than three thousand dams and weirs have been built so far in Indonesia and the Government of Indonesia has continued to construct 65 large weirs from 2019 until 2024. Construction of weirs in Indonesia is mainly intended for agricultural irrigation although recently, weirs are also being used for flood prevention. Indonesia has been endowed with fertile soil, and most of its people rely heavily on rice production to supply the staple food required primarily for local consumption. Therefore, a better irrigation system that secures water during the entire year is necessary, and this is fulfilled by constructing dams and weirs where water can be retained in the catchment area during the rainy season, and stored so that during the dry season, water is available to be utilized for irrigating the agricultural lands, for enhancing the economic outlook of the country.

It is true that the construction of infrastructures in waterways contributes to enhanced economic growth but such water infrastructures could also contribute to the depletion of the inland fishery resources because most of fish migration routes could be interrupted by the constructed barriers. Currently, the most common water infrastructures constructed are weirs, which are built of solid concrete and meant to control the amount and flow of water in rivers for agricultural irrigation purposes as well as for flood prevention and control. In the process however, weirs could prevent not only the deep waters to drain but also the outflow of soil, silt or sand, resulting in non-circulation of the water and depleting it of oxygen, and eventually affecting adversely the whole ecosystem. Weirs could also block the migration routes of some fishes, leading to the disruption of the life cycle of fishes that cannot swim upstream to spawn leading to possible disappearance of some freshwater fish species. Nonetheless, such predicaments had been addressed as some weir construction now comes with fish passes that provide entrance and exit to fish during the completion of their life cycles.

Inland fisheries are among the most important contributors to the economic development of many Southeast Asian countries, alleviating poverty and ensuring food security in rural communities. The sustainability of inland fisheries is however dependent on the quality of the freshwater fishery resources, aquatic habitats, and the ecosystem as a whole. In attaining such sustainability, mitigation strategies are necessary to strike a balance between maintaining the quality of the freshwater fishery resources and aquatic habitats, and ensuring the acceptable construction of infrastructures such as dams or weirs for economic development. Nowadays, some problems have been associated with dams/weirs construction, including the possible blocking of the connectivity of fish migration, sedimentation in still water, reduction in water quality and nutrients, habitat alterations, and diversion of water supply to irrigation systems and power generation.

One of the strategies adopted to address the blocking of fish migration connectivity, is the construction of fish passes, also known as fishway, or fish ladder, or fish passage depending on the design, in dams and weirs to reconnect the upstream and downstream waters of rivers. Fish passes facilitate the migration of fish from downstream to upstream or from upstream to downstream to complete their life cycles. Fish that swim from downstream can enter the fish pass inlet located downstream of a dam. Construction of fish passes is now being promoted globally to maintain river connectivity notwithstanding the construction of infrastructures for economic development. However, the appropriate design of a fish pass is dependent on the local fishery resources that live in certain aquatic habitats. Therefore, it is necessary to understand the fish migration behavior and the swimming ability, especially of the native freshwater fish species, prior to the construction of fish passes.

Global Water Infrastructure Development

In the world today, there are about 16.7 million units of man-made reservoirs that can store about 16,201 km^3 of water and inundating a total area of more than 400,000 km^2, and another 59,071 units of more than 15 m high large dams had been constructed (Lehner *et al*. (2015); ICOLD (2018); FAO (2018); Funge-Smith (2018)) as shown in **Table 1**. These infrastructures irrigate about 261 million ha or about 18 % of the total agricultural lands that account for 40 % of the total yield from agriculture. These water infrastructures are known to affect the rivers by changing their hydrology and resulting in the inability of fish to complete their life cycle. An example of a newly constructed big weir in Indonesia is shown in **Figure 1**. Meanwhile around the world, construction of large reservoirs and dams continues as shown in **Figure 2** and **Figure 3**.

Table 1. Total water infrastructures in the world

Water infrastructures	Output
Total man-made reservoirs	16.7 million units
Total number of large dams above 15 m	59,071
Total volume of water stored in reservoirs (km^3)	16,201
Total area inundated by reservoirs (km^2)	> 400,000
Amount agricultural lands irrigated	18 % (261 million ha) Producing 40 % of crop yield

*(**Source:** Lehner et al. (2015); ICOLD (2018); FAO (2018); Funge-Smith (2018))*

Figure 1. Perjaya Weir, Martapura, Indonesia
(Source: BBWS VIII Sumatera Documentation)

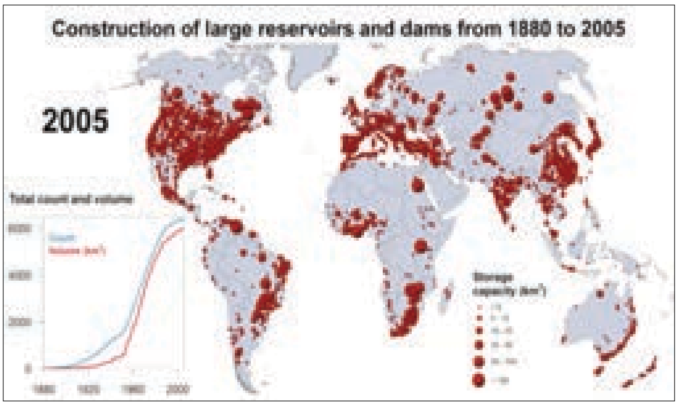

Figure 2. Development of reservoirs in the world (1880-2005)
*(**Source:** Global Hydrolab, 2014)*

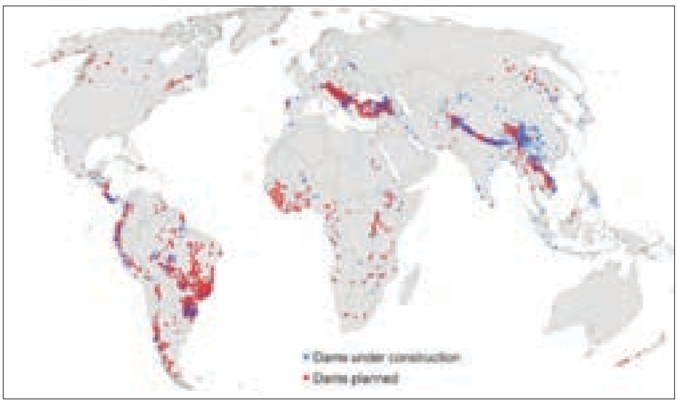

Figure 3. Global trend in planned dam construction
*(**Source:** Plumer, 2014)*

Main Objectives of Water Infrastructures

The benefit of water infrastructures such as weirs and dams, is that they tend to balance development with conservation of environmental resources. Specifically, aside from conforming to the UN Sustainable Development Goals (SDGs) 2030, these structures also ensure food security by serving as habitats for fishery resources that bring about fisheries products and food ingredients; socioeconomic development by providing the source of electric power and domestic water supply; environmental protection through their ability to adjust water levels so that the occurrence of flooding is prevented; financial security by generating the means for ecotourism and water sports, earning income for the communities and the country; and sustainable aquaculture development by serving as hosts for floating fish cages where aquatic species could be raised in large quantities providing additional incomes to communities.

Along the lines of the UN SDGs 2030, the President of Indonesia issued President Decree of Republic of Indonesia No. 59/2017 concerning SDGs Implementation and Achievements in Indonesia, and the strategic plan for local and national development which include the sustainability of fisheries.

Issues Associated with Water Infrastructure Development

Generally, weirs could be considered as beneficial water structures, especially their function in generating power, improving navigation in rivers, controlling floods, and serving as spillway for dams. However, the resulting impoundments across rivers could also have negative effects on the aquatic environment, like increased in siltation that leads to reduced oxygen in the water harming the aquatic species and choking the invertebrates that inhabit in the waters, and degrading the fish spawning grounds. Most importantly, weirs could disrupt the migration routes of fish species that travel upstream or downstream as part of their life cycles.

Table 2. Problems and solutions related to weirs and reservoirs development in Indonesia

Problems	Potential solutions
Blocking connectivity of rivers disrupting the migration routes of freshwater fishes while completing their life cycles	Construction of fish passage
Sedimentation in water	Installation of sediment traps
Deteriorating water quality and nutrients	Promotion of Pesticide Control and Land Use Management
Habitat alteration	Maintaining floodplains in upstream and downstream areas
Diversion of irrigation systems	Adoption of Spillway Management

*(**Source:** Baumgartner & Wibowo, 2018)*

Similar concerns had also been raised with regard to the development of water infrastructures in Indonesia. The problems and corresponding possible solutions are summarized in **Table 2**.

Nevertheless, most of the proposed solutions have not yet been fully researched in Indonesia. For example, as what was found out at the Irlandia and Barotrauma Spillway in Ireland, migrating eels are being chopped by turbines in weirs (**Figure 4**). These incidents could also happen in weirs and dams in Indonesia. Therefore, there is a need to monitor such situations in the constructed weirs and dams in Indonesia, and report similar incidences to concerned agencies in order that solutions that address such issues are established.

Figure 4. Incidences where eels are cut into pieces and killed by turbines installed in weirs
*(**Source:** O'Connor, 2016)*

It is therefore necessary for Indonesia to establish some policies that could regulate and properly manage the generation of water supply. Such regulations are important considering that there are many uses of inland waters and there are significant economic commodities that could be derived from the inland water resources. Without proper management, the country might gradually lose such resources. Moreover, the connectivity of rivers should be maintained to protect, conserve, and secure biodiversity in inland water resources.

Importance of Inland Fisheries for Economic Development

Inland fisheries had been recognized as an economically important sub-sector of the fisheries in Southeast Asia because of its contribution to income generation and food security of the peoples. Although mostly seasonal, inland fisheries are operated in waters shared by the other development sectors, notably irrigation, public or domestic water supply, and power generation. For the purpose of these other development sectors, various cross-river infrastructures are constructed such as dams and weirs, among others. However, more often than not, such construction does not take into consideration the possible impacts of these cross-river infrastructures to the fishery resources. It is therefore with such a backdrop that fish passes should be constructed together with those cross-river infrastructures to maintain the connectivity of the habitats of fishery resources (Pongsri *et al*., 2016).

Considerations on the Types of Fish Passes

A fish passage or fishway is a channel designed to facilitate fish to pass through man-made transverse construction (Katopodis & Eng, 1992). The presence of infrastructures across rivers that are not equipped with fish passes would result in ecosystem imbalance in rivers, impacting on the fishery resources. According to Maryono (2008), fish passes could be of two types, *i.e.* natural and technical types. Natural fish passes could be circular weirs (bypass channel fishway), constructed fish ramps, or constructed river bed ramp and slope. The technical types could include: pool passes, vertical slot (vertical slot passport), denile passes/counter flow passes, fish locks, fish lifts, and so on (**Figure 5**).

Choosing the type of fish pass to be constructed depends on government priorities and in accordance with the conditions of the river and the transverse cross-river infrastructures (**Table 3**). Nonetheless, consideration should be taken in constructing fish passes as a technical solution, to minimize the negative impacts of reduced connectivity between the upstream and downstream waters. On the possible impacts of dams on biodiversity, as in the case of Indonesia, some concerns had been raised that include: limited number of studies and study sites, use of limited fishing gears, no standardized methods applied over the long term, surveys that depend on fishers' catch with few on biodiversity, insufficient information on nocturnal/diurnal and demersal behavior of aquatic species. In this regard, there is a need to conduct more detailed research on fish biodiversity in order to generate data that could be used to mitigate the impacts of future river development projects.

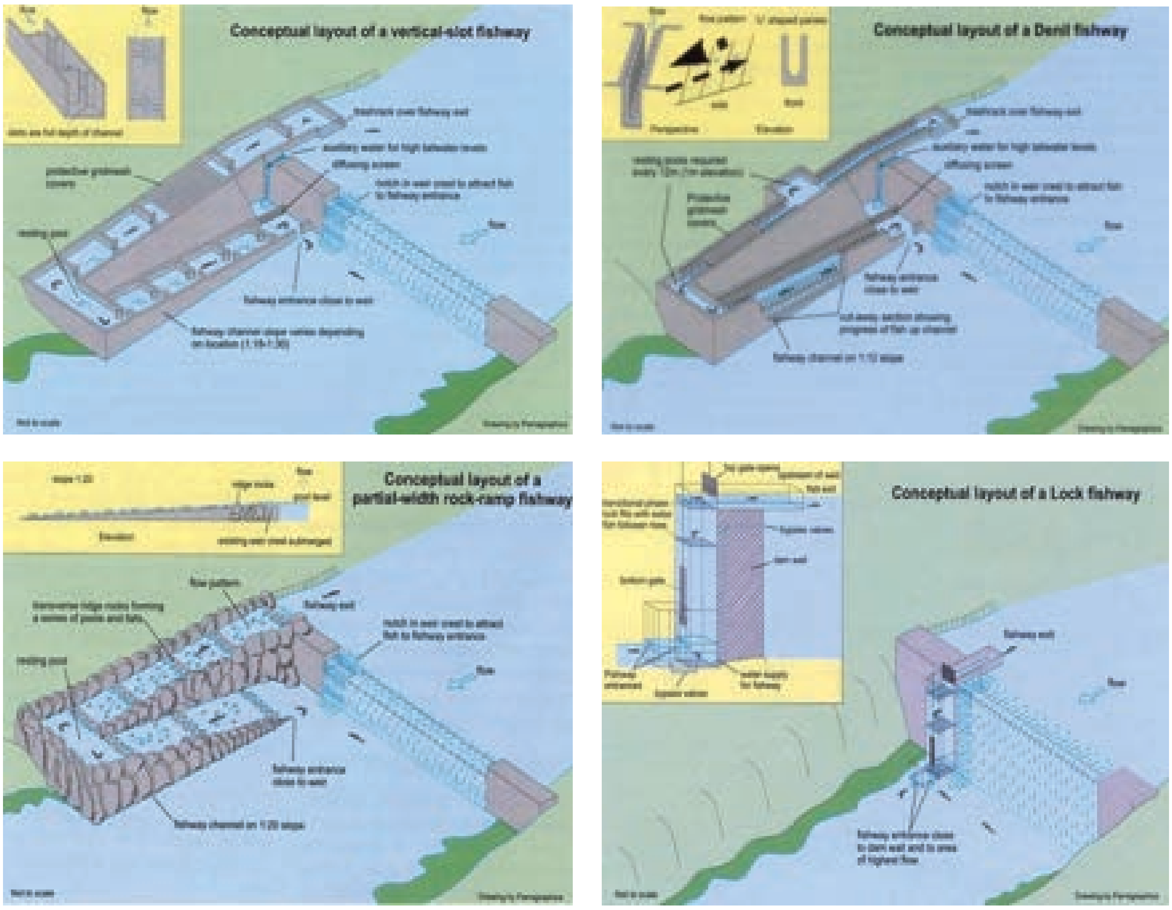

Figure 5. Some examples of fish passes *(clockwise from top left)*: vertical-slot fishway, denile fishway, lock fishway, and rock-ramp fishway
*(**Source:** Department of Primary Industries, 2020)*

Table 3. Scheme for ranking priority in fishway construction

No.	Criteria	Priority factor 5	Priority factor 3	Priority factor 1	Score
1	River size	Large	Medium	Small	...
2	Location in system	Tidal/core habitat	Non-tidal/non-core habitat	Montane (elevated area or highland)	...
3	Threatened species	Endangered	Threatened	None	...
4	Upstream habitat	Abundant	Moderate	Limited	...
5	Downstream obstruction	None	Rare	Many	...
6	Proportion obstructed	More than 66 %	Between 33 % and 66 %	Less than 33 %	...
7	Drownout passage	Rare	Occasional	Frequent	...
8	Barrier type	Crested	Pipe	Culvert	...
9	Fishway cost	Low	Medium	High	...

*(**Source:** Thorncraft & Harris, 2000)*

Case study in Indonesia

In the case of Indonesia where the report of the World Factbook (2017) indicated that the country is the fourth most populous in the world and its population is expected to increase in the next few years, one of the solutions established by the Government to ensure food security is to build water infrastructures to sustain economic development with attendant efforts to address their adverse effects on the other ecosystems, such as decreased productivity of inland fishery resources. Although there are also several other factors also contribute to the decreased productivity of inland fisheries that are also being addressed, which include human population growth, habitat degradation, hydrological changes, overfishing, pollution coming from industrial and household wastes, introduction of invasive aquatic species as competitor of local aquatic species, and climate change.

Plans for the construction of four fishways had been approved in Indonesia. The Perjaya Weir in Martapura located in Poso, which has not yet been equipped with fish path or fish route, but for the other three weirs, fishways have already been constructed. These are the Perjaya Weir in Ogan Komering Ulu (South Sumatera Province), Batang Hari Weir in West Sumatra, and Wawatobi Weir in South Sulawesi (Maryono, 2008). Results of the study conducted on the fishery resources in Komering River, have shown that before the fish pass was constructed, there were 50 species, after 15 years there were 48 species, and now there are only 40 species. The same findings were also recorded at Citarum River, where the mahseer fish species had disappeared after ten years.

One of the largest water infrastructures that have been developed in Indonesia is Perjaya Weir which supports the agriculture sector of South Sumatera. Despite being utilized for irrigation system, the Perjaya Weir has also recently been opened for recreational purposes attracting local and non-local tourists, especially during national holidays. Surrounding the weir, are many stalls offering variety of fruits and vegetables, as well as fish stands where fishers sell fresh native fish caught from the river, such as giant featherback (*Chitala* sp.), Hampala barb (*Hampala macrolepidota*), snakehead (*Channa striata*), "seluang" (*Rasbora* sp.), catfish (*Hemibargus nemurus*), and others.

C. striata is one of the famous fishes in South Sumatera with high nutritional value, and protein that can reach up to 25.2 % and 6.2 % albumin. The fish is believed to accelerate the healing process in patients after surgeries. In addition to the high nutritional content, *C. striata* can also be processed into delicious ready-to-eat meals such as fish cake (pempek),

Figure 6. Fish passage in Perjaya Weir, Martapura, Indonesia
*(**Source:** Nizar, 2014)*

Figure 7. Sulewana Weir, Poso, Indonesia

fish soup (pindang), and others. Nevertheless, there is one weakness of the fish pass constructed in Perjaya Weir, where fishes have difficulties to swim upstream and downstream as the exit gate is very close to the irrigation tunnel with fast water current, and baffles which were designed for salmon (not for the native fishes) to pass (**Figure 6**).

For the Sulawena Weir located in Poso, Indonesia (**Figure 7**), although there is an existing fish pass, this was designed for upstream migration of fishes. In such a situation, eels while migrating downstream will have to swim near the turbine at the middle of the river, risking their safety.

Issues and Concerns

There are many reasons why despite the number of weirs and dams constructed in Indonesia, only three had been equipped with fish passes. These include: limited knowledge about fish passage; inadequate water space for inland fisheries; insufficient information on the ability of various species of fish to make use of fish passage; limited coordination between concerned government agencies and stakeholders; and national priority set only on food security of people without taking into consideration the protection and conservation of the fish species. Along this line, the SEAFDEC Inland Fishery Development and Management Department (IFRDMD) and the Research Institute for Inland Fisheries and Extension (RIIFE) based in Palembang, Indonesia, and with funding support from the Australian Water Partnership (AWP), have been promoting the concept of a fish pass as an engineering solution to maintain connectivity in existing weirs and dams throughout Indonesia. The AWP is an international cooperative initiative that helps developing countries in the Indo-Pacific region, and beyond, to work towards the sustainable management of their water resources, and actively supporting the UN SDGs.

SEAFDEC/IFRDMD and RIIFE have mapped three potential sites in Indonesia for this study. These include the Perjaya Dam in South Sumatera, another one in Java Island to observe the movements of eel species, and a third dam in Poso, Sulawesi Island. In order to share knowledge about the fish passage, especially the efforts of IFRDMD, RIIFE, and other agencies working on irrigation, the Workshop "Water Resources Management to Secure Aquatic Biodiversity for Sustainable Development" was organized online on 5 October 2020, hosted by the Sulewana Weir in Poso, Indonesia, and participated by representatives from Indonesia's Ministry of Marine Affairs and Fisheries, BBWS VIII, Public Works and Irrigation Office of South Sumatera Province, East Ogan Komering Ulu Fishery Office, IFRDMD, RIIFE, and fishers.

The Workshop recommended that the development of water infrastructures to increase rice production could be continued but at the same time, such development should not harm the fishery resources. The participants (**Figure 8**) also expected

Figure 8. Participants in the Workshop on Water Resources Management to Secure Aquatic Biodiversity for Sustainable Development

to spread the knowledge gained during the Workshop to other stakeholders to increase fish production and minimize the impact of water infrastructures on the other economic sectors.

Appropriate Design of an Effective Fish Pass

According to Bunt *et al*. (2012), the effectivity of a fish pass consists of attraction and passage efficiencies, and constitutes the proportion of a fish stock present downstream that enters and successfully negotiates the facility with minimal delay. An effective fish pass design requires extensive integration of biological and hydraulic data (Castro-Santos *et al*., 2009). Variation of fish morphology should be considered especially among large fish species. The hydraulic structure and the morphology of fish should be considered to produce selective fish passes, since several morphological characters such as body length, body shape, and structure of fins affect the swimming functions and performance of fish. Mallen-Cooper (1999) suggested that the following steps could be taken into account for assessing the efficiency of fish passes, and for adapting the measures and possible adjustments for non-salmonids: 1) identification of the migratory fish species; 2) testing the experimental fish passes for various fish species (using different settings such as slope, flow velocity, turbulence); design and construction of fish passes based on the test results; and assessment of the fish passes. The capacities of fishes to swim and leap depend on the species and size of individual fishes, their physiological condition and the ambient temperature of the water (Larinier, 2002). To be effective, a fish pass must allow target fishes to successfully pass through it, therefore knowledge of swimming capabilities of fishes is crucial for effective fish pass designs (Katopodis *et al*., 2019).

Furthermore, fish species often get stressed or suffer injuries and loss of scales during migration. A primary measure of successful migration is that the fishes arrive at their habitats with sufficient energy reserve to spawn successfully. Stress in fish is known to affect the timing of reproduction, behavior during spawning, and the survival of offspring (Schreck *et al*., 2001). These factors should be considered part of a more generalized approach in defining the ideal fish pass, and in optimizing the designs with respect to both biological and operational ideals. According to Castro-Santos *et al*. (2009), the ideal fish pass must take into consideration the following factors: 1) any individual of any native fish species wishing to move upstream or downstream must be able to pass through the fish pass without experiencing any delays; 2) their entry in the fish pass must be immediately followed by successful passage; 3) no temporal or energy lost during migration; 4) no stress, disease, injury, predation, or other fitness-relevant costs associated with passage; and 5) costs of construction and operations of fish pass must be minimum.

Nonetheless, fish pass structures should be designed on a site-specific basis and rely on the comprehensive knowledge to adapt the structures to local conditions. Knowledge of the response of fish to certain conditions and factors that attract and repel them is critical for a successful fish pass design (Williams *et al*., 2012).

Insights on Fishways in the Lower Mekong River Basin

Mekong fish species migrate for several purposes, including spawning, feeding, and taking refuge (in deep pools), in both directions upstream and downstream. Migration takes place throughout the year and throughout the life cycle of fish (*i.e.* as larvae, juveniles, sub-adults, and adults). Migration peaks occur at the onset and during the wet season. For the approximately 30 fish species in the Mekong River, there are certain thresholds or changes in water level, discharge or current that could trigger migration. Based on fishers' experience, approximately 11 fish species make use of the first rainfall of the wet season (sometimes in combination with the lunar cycle) to start their migration. Furthermore, some nine species react to turbidity or water color while five species use the appearance of insects as a trigger for migration (Baran, 2006). Nevertheless, spawning and migration triggers can act independently. Spawning triggers also act on species that do not migrate, and migration can occur for purposes not related to reproduction (Baran, 2006).

Design of fish passes

An important factor to be considered in the planning of fish passes is the swimming capability of fish species (Williams *et al*., 2012), as their swimming speed is not consistent but rather depends on influencing factors such as body shape, size, muscular system, oxygen saturation, water temperature, and behavior. Effective fish passes in large dams in the Mekong River require consideration of diverse species with different sizes and swimming capabilities. Consequently, fish pass facilities also not only the small-sized species, those with weak swimming capabilities, but also large fishes. Among the Mekong fish species, the swimming capabilities of "weak" species and age classes are estimated based on the experience from temperate rivers.

Tropical rivers are characterized by large variation of water flow. Thus, in large dams in tropical rivers, turbulent flows may occur across vast areas below turbines and spillways, which could lead to impairment of the orientation among fishes. Most of the existing fish passes have been built for small- or medium-sized dams (up to 15 m high). For large dams, many challenges remain, including those constructed in multi-species tropical rivers. The efficiency of upstream fish pass depends on fish finding the entrance to the passage (perceptibility) and the passability of the fish pass.

There are multiple challenges in designing effective fish passes, especially with regard to the large-scale fish passes, migration of large species, migration peaks with high biomass, and the high diversity of species, all constituting different requirements. Nonetheless, fish pass solutions should provide multiple migration corridors along the riverbed, in mid-channel sections, along the shore line, within the mid-water column, and at the surface.

Figure 9. Lower fishway channel in Pak Peung Wetland Mekong Basin
*(**Source:** Baumgartner, 2016)*

In large dams, the areas where fishes are attracted by high-flow velocities (below turbines and spillway) must be relatively close to the entrance of fish passes to prevent the fish from spending much time and energy searching for entrance. A comprehensive evaluation of the applicability of the available fish passes requires assessment of the current biological monitoring of the fish assemblages of concern to determine the type, number and biological characteristics of fish that are to pass the fishways. The potential efficiency of a fish pass in the context of Mekong River could be estimated by comparing the characteristics of the Mekong migratory fishes with those fishes passing the fishways in water infrastructures in other countries and regions. Different species will have different requirements for fish pass and different responses to upstream and downstream conditions (**Figure 9**). For large multi-species rivers, vertical-slot fish passes and nature-like bypass channels are likely to provide the best solutions but still further research is necessary for these types of fish passes.

Invasive alien species in Mekong River

Dams, urbanization, expansion of agriculture, trans-boundary road development, and other rapid development activities also exacerbate the spread of invasive alien species (IAS). Once an invasive alien is established in a system like in the Mekong River, such introduction is essentially irreversible.

Among the faunal species, tilapia (*Oreochromis* spp.), common carp (*Cyprinus carpio*), pacu (*Colossoma macropomum*), and the sucker mouth catfish (*Hypostomus* spp.) are spreading in parts of the Lower Mekong Basin. Another serious concern is the golden apple snail (*Pomacea canaliculata*), which was believed to have been introduced to Taiwan and the Philippines as means of supplementing the protein needs of the rural poor. These snails soon escaped into waterways, quickly spreading not only through waterways but also in irrigation canals. They rapidly developed into serious pests in many areas of cultivated rice land in Asia, and as a result, over half of rice fields in the Philippines are infested with the golden apple snail (Miththapala, 2007).

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Understanding Climate Change Mitigation Measures Adopted by Women Aquafarmers: the tilapia culture in Cambodia

Chin Leakhena, Pattareeya Ponza, Thay Somony, Hav Viseth, Khum Sros, and *Hou Virakbot*

As the population of Cambodia reached almost 16 million in 2017 with an estimated growth rate of 1.6 % per annum, this necessitated improved food and nutrition security for the growing populace while economic development is being sustained. Rice and fish play important role in the diet of the people of Cambodia particularly those in the rural communities, providing them with the crucial elements in nutrition. Recent reports have indicated that the average annual per capita fish consumption of the people of Cambodia is 63 kg, and fish production comprises the important source of income for fishers and fish farmers of the whole country, and comes mainly from wild catch, the main source of which is the Great Lake, as well as the Mekong, Tonle Sap, and Bassac Rivers, with about 24 % coming from aquaculture in 2017. Nevertheless, the country's fisheries sector is faced with the challenge of providing sufficient supply to meet the demand while making sure that the supply would continue to be available for future generations notwithstanding the recent decline in fish production from the wild due to intensive fishing during the past years despite the government's efforts to regulate fishery catch. In order to mitigate such a situation, small-scale aquaculture of tilapia had been introduced throughout the country as an important means of improving food security and nutrition as well as generating employment and income opportunities. This has also given rise to the involvement of women in aquaculture ventures, and significantly contributing to the economy of the country.

As with the other farming activities, aquaculture relies heavily on the use of water and appropriate area or space for fish production (Jamu *et al*., 2003). Women household members have been actively engaged in on-farm and off-farm aquaculture operations while men household members are involved in productive endeavors outside their communities. In Cambodia, women have been practically participating in each step of aquaculture operations from planning, decision making, preparing the ponds to stocking of fingerlings, fertilizing the ponds, preparing feeds, feeding, pond maintenance, harvesting, and sale and marketing, generally helping significantly in increasing household incomes (FiA, 2016).

Recently however, variations in the climate had affected the country's aquaculture endeavors, as water supply becomes insufficient and water temperature had been rising, while frequent incidences of flooding occur during fish culture periods. In addressing such concern, the Government of Cambodia advocated the development of human capacity to improve the understanding of stakeholders on the status of the resources, and promote sustainable fish culture management (FiA, 2014). Nonetheless, water shortage has remained a great challenge confronting the fish farmers, because of long drought that continues to take place until the present time. There had been instances when some of the country's fish farmers were forced to harvest their fish stocks earlier than the scheduled harvest, producing fish that were below table sizes—around 0.1 kg per head, earning for them less income and low return of their investments. A study was therefore carried out to be able to understand the issues confronting the tilapia aquaculture industry in Cambodia, especially the impacts of climate change and the adaptation measures to mitigate such impacts, on the income-generating activities of its women populace. With support from the Department of Aquaculture Development (DAD) of Cambodia and the International Foundation for Science (IFS) of Sweden, two aquaculture producing Provinces in Cambodia (Kampong Thom and Siem Reap) were considered as pilot sites for the study (**Figure 1**) which was pursued through survey and interviews of sampled fish farmers, who were involved later in the fish culture trials.

Cambodia is located in the Indochina Peninsula, sharing international borders with Lao PDR, Viet Nam, and Thailand, and lies entirely within the tropics with its southernmost point slightly more than 10° above the equator. Cambodia has a total land area of 181,035 km^2 and is surrounded by low mountains and lowlands where the Mekong River runs across from the northeastern border with Lao PDR to the southern border with Viet Nam. Bounded on the southwest by the Gulf of Thailand, Cambodia embraces a coastline with extensive

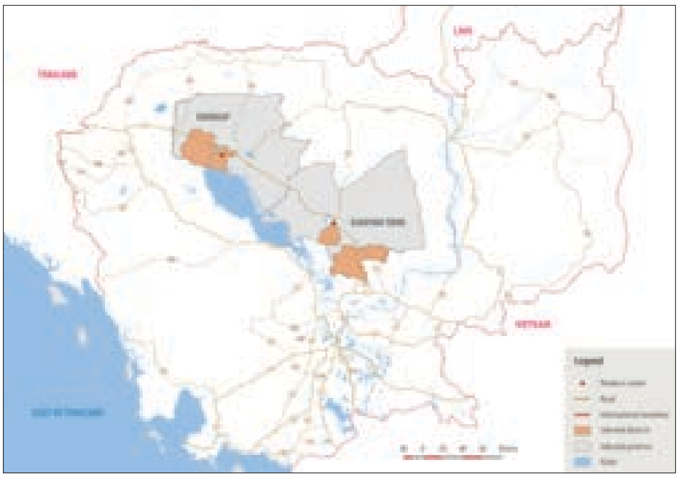

Figure 1. Map of Cambodia showing the pilot sites of the study: Siem Reap and Kampong Thom

mangrove forest of about 440 km. About 86 % of the country (including Kampong Thom and Siem Reap) lies within the Mekong catchment area. The Tonle Sap Great Lake, which is situated in the central western part of the country, and the largest and the most productive lake in Southeast Asia, serves as a natural reservoir of the Mekong River system, expanding from 2,500-4,000 km^2 in dry season to 10,000-15,000 km^2 in wet season, and has 4,800 km of flooded forest coverage (So & Buoy, 2005).

The climate of Cambodia is the same of the rest of Southeast Asia, being dominated by monsoon, and recognized as tropical dry and wet. It also specifically marks seasonal difference, the south-western and north-eastern monsoons, separated by a short transition period. The south-western monsoon or the wet season normally from May to October, dominates when atmospheric pressures are comparatively low over Asia, while the north-eastern monsoon or dry season from November to April, dominates when atmospheric pressure is high.

Aquaculture in Cambodia

The fisheries sector of Cambodia has for many years contributed significantly to the employment and livelihoods of the rural communities, food security, as well as to the country's GDP and foreign exchange balance. While offering employment (full-time, part-time, and seasonal) to more than 6 million of the 16 million people, the country's fisheries sector (capture fisheries and aquaculture) significantly provides the animal protein in the Cambodian diet, especially that fish forms part of their cultural heritage (FiA, 2010). The country's aquaculture has recently showed signs of rapid growth (**Table 1**), although still at a critical stage of development, it has the potential to meet the likely future shortfall in supply of fish, and generate employment for rural communities in the country. Nevertheless, there is a need to facilitate the development of more profitable and sustainable aquaculture, while at the same time conserve valuable fishery resources, and maximize its contribution to nutrition and poverty alleviation. Specifically, small-scale aquaculture in inland domain has potential benefits to the rural communities, and freshwater aquaculture is simple to operate and require less operations costs (TGAC, 2016). Although small-scale fish farmers have been encouraged to culture indigenous fishes, exotic fish species like tilapia has been preferred as its culture offers better returns of investment, especially that tilapia has recently become a more popular fish for domestic consumption, contributing significantly to improved food nutrition and income generation of local people especially the women's groups in Cambodia (Dr. Hav Viseth, personal communication, 2016).

In Cambodia, women comprise the major stakeholders in the fisheries sector, where their involvement is about 50 %, not only in fish farming but also in fish processing and trade. The Fisheries Administration (FiA) recognizes and promotes the role of women in fisheries, as reflected in the gender policy of Ministry of Agriculture, Forestry and Fisheries (MAFF). Under the umbrella statement of the MAFF, the gender mainstreaming strategy of FiA aims to enhance gender equality in the fisheries sector by recognizing the active role of both women and men in the sustainable development of fisheries and aquaculture (Chin, 2016).

Issues Confronting Tilapia Aquafarmers of Cambodia

In order to assess the adaptation measures that local tilapia fish farmers (or aquafarmers) advocate to mitigate the impacts of climate change and variations, a survey was carried out in two tilapia-producing provinces in Cambodia: Siem Reap and Kampong Thom. These provinces were chosen for the study due to the following reasons: 1) the provinces support a number of small-scale aquaculture ventures resulting from the projects implemented by FiA and some non-governmental organizations (NGOs); 2) most of fish farmers in these provinces are women; 3) the provinces' experiences in severe drought and flooding; 4) tilapia seeds are locally produced in Siem Reap; and 5) aquaculture ventures in these provinces have received strong support from the government as well as from NGOs (Chin, 2014; FiA, 2014).

Study sites

Kampong Thom Province (**Figure 2**) is located in the center of Cambodia on the floodplain of Tonle Sap Great Lake, covering a land area of 13,814 km^2. It is bordered by Preah Vihear to the north and Siem Reap to the west, Kampong Chhnang to the south, and Stung Treng and Kratie to the east. With a total population of 677,260 (327,013 men and 350,247 women) in 2019 and density of 45 people per km^2 (NIS, 2019), the Province consists of eight districts, 81 communes, and 766 villages. The daily maximum temperature has been increasing by 2–4 °C throughout the year, and typically daily maximum

Table 1. Fishery production of Cambodia (2014–2018) by quantity (t)

	2014	2015	2016	2017	2018
Total fishery production	**745,310**	**731,889**	**808,550**	**857,018**	**943,205**
Production from marine capture	120,250	100,984	126,700	121,025	153,600
Production from inland capture	505,005	487,905	509,350	528,493	535,555
Production from aquaculture	120,055	143,000	172,500	207,500	254,050

Source: *Southeast Asian Fisheries Development Center (2020)*

Figure 2. Location of Kampong Thom Province in Cambodia

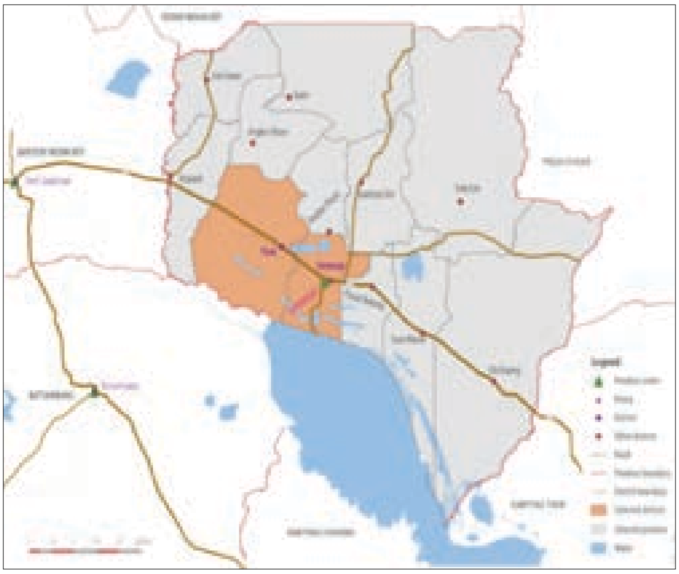

Figure 3. Location of Siem Reap Province in Cambodia

temperature of 33 °C usually occurs in March. Precipitation during the rainy season had also increased by 40 mm per month in September or by 18 %.

Siem Reap is located in northwestern part of Cambodia (**Figure 3**) and covers an area of 10,299 km^2 and comprises 12 districts, 100 communes, and 875 villages. It is one of the five (5) provinces around Tonle Sap Great Lake, and bordered by Oddor Meanchey to the north, Preah Vihear to the east, and Kampong Thom and Banteay Meanchey to the west. In 2019, the Province's total population was 1,006,512 (491,568 men and 514,944 women), and with an average household size of 4.6, its population density was 98 people per km^2 (NIS, 2019). Its climate is dominated by seasonal winds/monsoons, where the wet season starts in May and finishes at the end of October. The dry season is from November until April.

The Survey

From the list of fish farmers in Kampong Thom and Siem Reap Provinces, the respondent-fish farmers for the survey 2017 were selected through systematic random sampling and since women have been taking part in the country's aquaculture operations, the women fish farmers were targeted as respondents of the survey. The criteria for the respondents included: 1) at least two years experience in tilapia fish culture; 2) a household head; 3) having fishpond with an area of not more than 250 m^2; and 4) high responsibility in the aquaculture operations. Eight women fish farmers (four women fish farmers from each province) who met the criteria were considered for the survey. The respondent-fish farmers had experiences in fish culture at varying periods between 2 and 12 years, and received technical advice from both government extension officers and local NGO officers. From this group, 32 respondents were selected from the two provinces, *i.e.* 16 respondents for Kampong Thom and 16 for Siem Reap.

The Results

Generally, most of the fish farmers in Cambodia are women because women are always at home while the men go out from their communities to earn a living. So from the 16 respondents from Kampong Thom Province, three were men, while from the 16 respondents from Siem Reap Province only one was male (**Table 2**). High proportion of women involvement in fish farming is observed in Cambodia, especially in the grow-out stages. Increased participation of women family heads in fish production had been observed since 2012 due to the productive work of the male household members outside of their villages (Chin, 2013). Moreover, in the Cambodian tradition of land donation, there exists a key rural push factor where in order to address the lack of land, close relatives such as parents, uncles/aunts or siblings donate land to their daughters, nieces or women siblings, especially when they are establishing new households and are unable to obtain or access land in their village of origin (Maltoni, 2007).

The high proportion of female aquafarmers in the fish grow-out farms is probably due to important role of women in the pond maintenance and management which is already embedded in rural households of Cambodia (FiA, 2016). Although all family members (women and men) carry out the activities in the aquaculture sub-sector, the women put in an equal share of effort as with the men even in pond construction. Women are actively engaged in on-farm and off-farm tasks, participating in each step of the fish culture operations. It should also be noted that in Cambodia, high percentage of women are taking care of their families as part of their daily chores, but this does not interfere with their aquaculture endeavors as means of increasing their household income (Chin, 2015).

Table 2. Gender, ages, and educational attainment of the respondent-fish farmers

Gender	Respondent-fish farmers			Age (years)		Educational level		
	Kampong Thom	Siem Reap	Total (n)	Max (n)	Min (n)	None	Primary	Secondary
Female	13	15	28	68	24	3	25	0
Male	03	01	04	52	30	0	04	0
Total	**16**	**16**	**32**			**3**	**29**	**0**

The ages of the respondent-fish farmers ranged from 24 to 68 years old (**Table 2**). Age is important for pond management considering the need for experienced and matured fish farmers in fish culture operations. The ages of women involved in aquaculture vary from 24 to 68 years while those of men age vary from 30 to 52 years, while the high proportion of the respondents' ages falls in the range between 42 to 50 years old.

In terms of education, the respondent-fish farmers from Kampong Thom and Siem Reap Provinces attended the primary level only (**Table 2**). Of the 28 women respondents, 25 attended primary school and three did not have the chance to attend school. It should be noted however that the ages of women fish farmers that range from 40 years and 50 years, suggest that they were born during the civil war and Pol Pot Regime, and thus, must have not been able to pursue further education. Meanwhile, only four men respondents availed of primary school education. Educational background of fish grow-out farmers is an essential factor in absorbing new knowledge, technology, adaptive occupations, and in improving fish farm management. Furthermore, the limited educational background of the women respondents must have been a reflection of Cambodia's traditional culture that women do not necessarily have to go to school–they are bound inside the house to do household chores. Nonetheless, lack of information materials had been one of the constraints that women and men fish farmers encountered, limiting their capacity in decision making on fish farms and in obtaining additional knowledge on improved and advanced ways for culturing fish. In spite of the limited educational background of the respondents, FiA through the DAD and development partners supported the target women and men to undergo special training on aquaculture planning, farm management, and marketing. With enhanced knowledge and skills, they were able to practice on-farm and out-farm activities that include planning, seeking for customers, extending aquaculture techniques to new fish seed producers and grow-out farmers.

Almost all respondent-fish farmers have been working as rice farmers (90.6 %) and have not been involved with any other secondary occupations (**Table 3**). However, one of the fish farmers in Siem Reap gets her main income from bamboo basket making and two out of 16 fish farmers rely on fish culture. The majority of household head in Kampong Thom and Siem Reap provinces reported that rice farming is their main occupation, and had been doing rain-fed cropping each year. This figure is lower than the findings of Chin (2013) which indicated an average involvement of 99.0 % of fish farmers in rice farming but higher than that indicated in the report of Cramb *et al*. (2020) which was almost 80.0 %.

Climate variations affecting tilapia culture in Cambodia

One of the main objectives of the survey was to determine how the fish farmers were coping with the impacts of climate variations on their aquaculture endeavors. The respondents indicated that they have been confronted with incidences of flooding and drought (**Table 3**).

They reported that longer drought period is usually experienced from February to June, and flooding from September to October. Ten of the 16 respondents from Kampong Thom and 12 of the 16 respondents from Siem Reap had suffered losses from their fish culture ventures because of floods while six out of 16 respondents from Kampong Thom and three of the 16 respondents from Siem Reap have lost revenues due to long incidence of drought. There was however, one (1) fish grow-out farmer from Siem Reap who had never experienced losses caused by natural disasters (drought or flood) since she started culturing fish in 2012, because her fishpond is located on higher grounds and she adopts a shorter culture period (3–4 months), and her produce is mainly for household consumption.

During the dry season in Cambodia, fishponds usually receive limited water supply from natural water bodies for fish culture forcing fish farmers to harvest smaller size fish to avoid losses from drought. Nonetheless, to cope with the impacts of drought, fish farmers plant aquatic weeds near fishpond dikes and install green sheds in fishponds. In September when

Table 3. Main occupations of respondents and types of disasters that confront their tilapia culture endeavors

	Main occupations			Disasters affecting tilapia culture		
	Rice farming	Fish culture	Basket weaving	Flooding	Drought	None
Kampong Thom	16	0	0	10	6	0
Siem Reap	13	2	1	12	3	1
Total	**29**	**2**	**1**	**22**	**9**	**1**

heavy rains continually occur for three days to one week, fish farmers put nets around fishpond (burying the net at least 20 cm in fishpond bottom), install traps in front of water gates, and set cages in fishponds to avoid the escape of fish stocks.

Measures adopted by fish farmers to mitigate impacts of climate variations on tilapia culture

Majority of the respondents (29 out of 32) have never attended disaster prevention training although two respondents from Kampong Thom and another one from Siem Reap had undergone training from the FiA and FAO on flood prevention measures for aquaculture ventures, *e.g.* installing cages in fishponds and transferring the fish stocks from the pond to the cages, which was practiced by the three respondents (**Table 4**). However, in order to limit the cages installed in ponds as installation is costly by reducing the number of fish to fit into the cages, fish farmers usually size the fish stocks and sell the almost marketable sizes by end of August or early September. Such measures however are meant to address only the problems caused by flooding as they have not yet established measures that could mitigate the impacts of long drought on their fish culture operations, although they also learned that having a reservoir pond could help but this would entail using a reserved pond which could be used to culture more fish, besides this is sometimes not possible in rural areas where pond area is costly and space is limited.

Vulnerability of respondents to disasters caused by climate variations

Most of the respondents have experienced floods and/or droughts that led to revenue losses. For example, an average loss of KHR 230,800 or USD 57.70 per household could be incurred per year or maximum loss of KHR 735,500 or USD 183.90 per household per year, due to disasters caused by climate change. Such losses are high, especially for those in the remote areas, so that they would rather rely on more reliable source of livelihood such as rice farming. The impact of such losses is suffered mostly by women/wives more than men/husbands from Siem Reap as shown in **Table 4**, with minimal effect on women/wives and men/husbands altogether. The contrast happened in Kampong Thom where nine out of 16 respondents replied that women/wives and men/husbands altogether worry about income losses while seven out of 16 respondents said that women/wives took more responsibility than the men/husbands. Interestingly, the wife is concerned with the situation of fish farms, even during rains and at night time, in addition to her main duty of looking after everything inside the households, a recognized culture of traditional Cambodians.

As a result, income losses could put more mental pressure on women/wives than on men/husbands because in the Cambodian culture the caretaker of the household revenues is the wife. Therefore, any losses in income could have an impact on the household living expenses, affecting the financial stability of families.

Institutional support after disasters

Almost all respondents did not receive support from the government nor from any NGOs to enable them to recover their losses from fish culture due to floods or drought. Only one respondent received support from a project sponsored by FAO and FiA for the recovery of the losses incurred because of flooding in 2014, but after the project ended there was no further support. Any external support from relevant agencies is welcome especially by small-scale or family-scale fish culture ventures in Cambodia, considering that the limited budget of the government does not include allocation of funds for such purpose.

Adopting Tilapia Culture Techniques that Address the Impacts of Climate Change

From the respondent-fish farmers, eight qualified respondents were chosen as partners in the follow-up project that would adopt tilapia culture techniques that could address the impacts of climate change and variations. Four fish farmers from Kampong Thom and another four from Siem Reap were provided technical support and cost of operation for two-year tilapia fish culture, from pond preparation until post-harvest (**Box 1**). As project partners, the fish farmers were responsible for the management of the fishponds following the measures recommended through the previous survey for mitigating the impacts of climate change on tilapia culture, *i.e.* deepening of ponds and shortening of the culture period. The project partners were divided into two groups, where each group comprised two fish farming households per province. The first group worked on deepened ponds (from 1.0 m to 1.5 m water depth) and shortened period of fish culture from seven months to four months, while the second group raised tilapia following the usual method, *i.e.* 7-month culture period and

Table 4. Experience gained by respondents on disaster prevention and vulnerability of respondents to such disasters

	Attendance in training on disaster prevention		Persons most affected by disasters			Support after disasters	
	Yes	No	None	Women	Women + Men	Received support	No support
Kampong Thom	2	14	0	7	9	0	16
Siem Reap	1	15	1	13	2	1	15
Total	**3**	**29**	**1**	**20**	**11**	**1**	**31**

Box 1. General information on the project partners					
Name of project partner	Age (years)	Location of ponds	Pond size (m²)	Pond depth (m)	Culture period (months)
Ms. Say Rathana	47	Pouk Thmey Village, Pouk Commune, Pouk District, Siem Reap Province	200 (10 m × 20 m)	1.5	4
Ms. Yi Sinoun	66	Pouk Thmey Village, Pouk Commune, Pouk District, Siem Reap Province	225 (15 m × 15 m)	1.5	4
Ms. Noun Ei	43	Chrey Village, Sambour Commune, Siem Reap District, Siem Reap Province	238 (14 m × 17 m)	1.0	7
Ms. Noun Art	40	Chrey Village, Sambour Commune, Siem Reap District, Siem Reap Province	240 (15 m × 16 m)	1.0	7
Ms. Met Chenghor	42	Tros Village, Balang Commune, Baray District, Kampong Thom Province	150 (10 m × 15 m)	1.5	4
Ms. Tith Ros	38	Kampong Sdach Village, Krovar Commune, Baray District, Kampong Thom Province	144 (12 m × 12 m)	1.5	4
Ms. Long Meth	58	Kampong Sdach Village, Krovar Commune, Baray District, Kampong Thom Province	208 (16 m × 13 m)	1.0	7
Ms. Yin Mom	54	Achar Leak Village, Achar Leak Commune, Stung Sen District, Kampong Thom Province	234 (13 m × 18 m)	1.0	7

using the traditional depth of ponds (1.0 m water depth). The parameters to be measured during the culture period by the two groups include water temperature, pH, amonia, nitrite, and oxygen.

Pond management

Proper pond preparation should be practiced by draining their ponds using water pump, but mud may not be removed after draining the pond. Agriculture lime should be applied at 100g/m³ before stocking the fingerlings to reduce acidity of the pond water. Lime is spread on the pond bottom if it is already dry or mixed with water and sprayed if the pond has already been watered. After applying lime, the pH (using pH paper) should be checked to 11, otherwise additional lime should be applied until the pH reaches 11. Secchi Disk (**Figure 4**) is used to monitor the water quality and control the level of water. The five colors on the pole (*i.e.* red, yellow, green, light green, and blue) reveal the information indicated in **Box 2**.

Figure 4. Secchi disk

Box 2. Information on water quality using Secchi disk

- **blue (> 60 cm):** clear water, inadequate fertilizer, plankton just growing, fish may get stress due to low oxygen, must add more fertilizer
- **light green (45-60 cm):** not enough plankton in the water, should add appropriate amount of fertilizer
- **green (30-45 cm):** enough plankton in the water, good condition to grow fish (normal)
- **yellow (20-30 cm):** plankton increased and water quality decreased, should monitor the water quality and if possible, do not need to add more feed and fertilizer
- **red (0-20 cm):** excess plankton in the pond, bad condition to grow fish, insufficient oxygen in the morning, does not need to add more/reduce feed, fertilizer until water quality turns to normal (green color)

Green pond water indicates enough plankton production, but when visibility is up to light green, it means insufficiency in plankton and requires increased fertilization. The quality of water in fishponds should be observed two times per day because when pond water is yellow, there is excessive plankton production reducing the oxygen in the pond water particularly at night and on cloudy days, and can lead to fish mortality. When this happens, feeding and fertilization should be stopped until the color of the pond water becomes lighter.

Net could be installed around the fishpond before stocking to avoid the fish from escaping, especially during low flood and prevent predators from jumping into the pond to devour the stocked fish. The fishponds should be cleared of floating or submerged weeds as these would tend to block the penetration of sunlight into the water. Wild fish and other wild aquatic animals such as water snakes, crabs, and frogs should be removed as these wild animals could harm the newly stocked fingerlings, resulting in high mortality/losses of stocks in the ponds.

Five parameters should be checked for water quality, *i.e.* water temperature, pH, ammonia, nitrite, and oxygen, and monitored two times per day (morning at 7 a.m. and evening at 6 p.m.). Results of water quality monitoring in 2017–2018 and 2018–2019 in the pilot sites, illustrated that the temperature between the 1.0-meter depth pond and 1.5-meter depth pond had no significant difference (**Table 5**). The average pH was also not significantly different and was found to be suitable for tilapia culture.

Stocking

At the start, each project partner received 500 red tilapia fingerlings per year (one cropping). The stocking period depended on the availability of water supply from the nature

Table 5. Results of water quality monitoring in project partners' ponds (average for Kampong Thom and Siem Reap)

	Average temperature (°C)	Highest temperature (°C)	Lowest temperature (°C)	Average pH	Ammonia/ nitrite (mg/l)	Oxygen (mg/l)
2017-2018						
1.5-meter depth pond	29.20	31.06 (Nov)	27.44 (Dec)	7.33	0.0	5.00
1.0-meter depth pond	28.63	31.06 (Aug)	26.35 (Feb)	7.38	0.0	4.29
2018-2019						
1.5-meter depth pond	30.07	31.05 (Nov)	29.52 (Aug)	7.33	0.0	5.00
1.0-meter depth pond	28.92	31.02 (Nov)	26.32 (Jan)	7.31	0.0	4.29

(rainwater). Availability of water is an important factor for tilapia culture in the target areas, where rainwater could come in May to November. During the first year of project trial in 2017, stocking took place in July and August, and for the second trial in 2018, stocking was made in July. The weight of fingerlings varied from 20.00 g/head to 20.15 g/head and length from 10.40 cm/head to 10.43 cm/head, and bought at KHR 1,200 or USD 0.30/head. The size of fish seed is higher than the FiA recommended size at 5–7 cm or 3–5 g fingerlings as fish could reach table size earlier, particularly in cases where water in the ponds could be available only for 5–6 months (FiA, 2010). The fish seeds should be released gently and gradually to avoid stress while letting the seeds adapt to the temperature of the pond water.

The fish seeds for this project came from a local producer, the Ratha Da Fish Seed Producer in Siem Reap Province. Ratha Da Fish Seed Producer was selected to supply the fish seeds for the project because it is recognized by FiA as a good tilapia fish seed supplier in Cambodia; its fish seeds are of good quality and reasonably priced; owner of farm had been trained by FiA and USAID/HARVEST; and promoted by the Government of Cambodia as an aquaculture-related enterprise in the country. Furthermore, the fish seeds supplied by Ratha Da Fish Seed Producer were of good quality, in bright color, good shape, uniform in size and age, disease resistant, fast growing, healthy, high survival rate, and no environmental effects.

Feeding

In this project, pellet feeds containing 30 % protein was fed to the fish as it could increase fish growth and production. In order to attain good production, feeding was given twice per day in 1.0-meter depth fishpond and four times per day in 1.5-meter depth pond. In the 1.0-meter depth pond, fish was fed at 8:00 in the morning and 16:00 in the afternoon. For the 1.5-meter pond depth, feeding was done in the morning at 7:00 and 10:00, and in the afternoon at 13:00 and 16:00. The daily feeding ratio is shown in **Table 6**.

Monitoring of cultured fish

In the project sites, growth rate, mortality rate, and survival rate were monitored every 15 days (**Figure 5**), and generally, mortality rate of the tilapia cultured was lower in Kampong Thom than in Siem Reap (**Table 7**). For example, during the first year (2017–2018) of fish culture trial in the 1.0-meter depth pond in Siem Reap, 20 fish were found dead in one night because of the sudden change in temperature brought about by cloudy skies and non-stop rain in more than two days. In cases such as this and during critical situations, the pond water should be aerated using aerators and feeding should be stopped the following day. The dead fish from the Siem Reap ponds were found to have air in their stomach with bubbles, as well as some of parts of pellet feeds. Nonetheless, disease diagnosis could not be performed in the fishponds due to insufficiency of any disease diagnostic equipment.

In the first year of trial (2017–2018), the average feed conversion ratio (FCR) for 4-month grow-out period was 1.44 and 1.47 for the 7-month culture period. There was no significant difference between the FCR of tilapia cultured in 1.5-meter depth fishpond and 1.0-meter depth fishpond. The lowest FCR was 1.4 and the highest was 1.5.

As with the first-year trial (2017–2018), the parameters during the second-year trial (2018–2019) such as growth rate,

Table 6. Daily feeding ratio

Fish body weight (g)	1.0-meter depth pond		1.5-meter depth pond		Feed size (mm)	Feed protein content (%)
	Feed (% fish body weight)	No. of feeding per day	Feed (% fish body weight)	No. of feeding per day		
20 g	1.33 %	4	1.33 %	4	Powder	35
25 g	1.47 %	3	1.47 %	4	2	35
100 g	1.60 %	2	1.60 %	4	3	30
200 g	0.85 %	2	0.85 %	4	4	30
> 300 g	0.75 %	2	0.75 %	4	5	30

Table 7. Stock monitoring of cultured tilapia in 2017-2018 trial

	No. of culture days	Average growth (g/day)	Mortality rate (%)	Survival rate (%)	Average feed conversion ratio
Siem Reap Province					
• **1.5-meter depth pond**					
Ms. Say Rathana	124	2.34	4.00	96.0	1.5
Ms. Yi Sinoun	124	2.44	1.60	98.4	1.4
• **1.0-meter depth pond**					
Ms. Noun Ei	212	1.37	2.20	97.8	1.5
Ms. Noun Art	212	1.38	1.40	98.6	1.5
Kampong Thom Province					
• **1.5-meter depth pond**					
Ms. Met Chenghor	122	2.39	1.80	98.2	1.5
Ms. Tith Ros	122	2.47	0.40	99.6	1.4
• **1.0-meter depth pond**					
Ms. Long Meth	212	1.36	3.00	97.0	1.5
Ms. Yin Mom	212	1.35	2.00	98.0	1.5

Table 8. Stock monitoring of cultured tilapia in 2018-2019 trial

	No. of culture days	Average growth (g/day)	Mortality rate (%)	Survival rate (%)	Average feed conversion ratio
Siem Reap Province					
• **1.5-meter depth pond**					
Ms. Say Rathana	128	2.08	0.40	99.6	1.6
Ms. Yi Sinoun	128	2.25	0.80	99.2	1.5
• **1.0-meter depth pond**					
Ms. Noun Ei	247	1.19	1.60	98.4	1.5
Ms. Noun Art	248	1.19	0.80		1.4
Kampong Thom Province					
• **1.5-meter depth pond**					
Ms. Met Chenghor	126	2.33	1.20	98.8	1.5
Ms. Tith Ros	126	2.37	0.80	99.2	1.4
• **1.0-meter depth pond**					
Ms. Long Meth	243	1.20	2.00	98.0	1.5
Ms. Yin Mom	247	1.17	1.40	98.6	1.5

Figure 5. Growth rate measurement of tilapia stock

mortality rate, and survival rate were also monitored every 15 days. Results indicated that mortalities were low in both groups. The highest survival rate in the second-year trial was 99.6 %, while the lowest survival rate was 98.0 %. There was a significant difference between the average daily growth rate of the 1.5-meter depth pond (2.41 %) and 1.0-meter depth pond (1.37 %). The highest daily growth rate in the 1.5-meter depth pond was 2.47 % while in the 1.0-meter depth pond, the highest growth rate was 1.80 %, and the lowest daily growth rate in the 1.5-meter pond depth was 2.34 %, it was 1.36 % in the 1.0-meter depth pond (**Table 8**). There was significant difference between the average daily growth rate in the 1.5-meter depth pond (2.26 %) and 1.0-meter depth pond (1.19 %). The highest daily growth rate of 1.5-meter depth pond was 2.37 % while it was 1.20 % in the 1.0-meter depth pond, and the lowest daily growth rate in the1.5-meter depth pond was 2.08 % while in the 1.0-meter depth pond the lowest daily growth rate was 1.17 %.

The average FCR for the 4-month grow-out period was 1.49 while for the 7-month culture period FCR was 1.46. This average FCR could be considered normal compared to the FiA (2016) experience where the FCR of tilapia fish culture using pellet feed containing 30 % protein ranged from 1.20 to 1.80. There was no significant difference between FCR of tilapia fish culture in 1.5-meter depth pond and 1.0-meter depth pond. The lowest FCR was 1.40 and the highest FCR was 1.60.

Harvesting

In the first year trial (2017–2018), tilapia stocked in the 1.5-meter depth pond in Siem Reap Province was harvested in November 2017 and in Kampong Thom Province the stock was harvested in January 2018. For the stock in the 1.0-meter depth pond, the stock was harvested in March 2018 when the size of fish reached about 0.5–0.6 kg. There was no significant difference in the average fish yield in the study sites. The average fish yield in the 1.5-meter depth pond in the first-year trial was 299.0 kg, and 292.3 kg in the 1.0-meter depth pond (**Table 9**, **Figure 6**).

During the second year trial (2018–2019), the stock from the 1.5-meter depth tilapia pond was harvested in November 2018 and from the 1.0-meter fishpond depth in March 2019. The average tilapia yield from 1.5-meter pond depth was 289.0 kg and 294.4 kg from the 1.0-meter depth fishpond (**Table 9**). The fish farmers decided to put up their produce on farm sale, so that retailers come to the farm and collect the fish at the farms. This was, shipping cost for transferring tilapia cultured production to the market was not necessary.

Socioeconomic analysis

The tilapia stocks were harvested during the dry season, and sold directly to fish retailers. The fish farmers in Siem Reap were able to sell their fish at higher price (USD 2.50–3.0/kg) than those from Kampong Thom at USD 2.25/kg because Siem Reap is a popular tourist area and demand for fish is more than in Kampong Thom. Here, the project partners were not asked to return any money after completing the tilapia culture trial periods, as the income from the fish produced was considered as revenue of the respective fish farmers. The average income from the 1.5-meter depth pond in the first year trial was USD 747.63 which was higher than the average income from the 1.0-meter depth pond in the second trial year. This was followed by the average income from the 1.5-meter depth pond in the first trial year and the average income from the 1.0-meter depth pond in the second trial year at USD 736.10, USD 730.80, and USD 722.30, respectively.

From this project, it was found that the 1.5-meter depth pond and four months culture period provided significant result as the culture period was short but provided the appropriate market size of fish, sufficient amount of water for fish culture, and lower risk in terms of losses as flooding period could be avoided. Because of the remaining time (three months after culturing fish), the fish farmers adopting the 1.5 -meter depth pond and 4-month culture method could find alternative jobs,

Table 9. Production from study sites during 2017-2018 and 2018-2019 (kg)

	2017-2018 Production (kg)		2018-2019 Production (kg)	
	Siem Reap	Kampong Thom	Siem Reap	Kampong Thom
1.5-meter depth pond				
Ms. Say Rathana	292.8		268.8	
Ms. Yi Sinoun	305.5		290.3	
Ms. Meth Chenghor		294.6		295.8
Ms. Tith Ros		303.3		300.8
Average	**299.0**		**289.00**	
1.0-meter depth pond				
Ms. Noun Ei	293.4		295.2	
Ms. Noun Art	295.8		297.6	
Ms. Long Meth		291.0		294.0
Ms. Yin Mom		289.1		290.9
Average	**292.3**		**294.4**	

Table 10. Income incurred from study sites during 2017-2018 and 2018-2019 (USD)

	2017-2018 Income (USD)		2018-2019 Income (USD)	
	Siem Reap	Kampong Thom	Siem Reap	Kampong Thom
1.5-meter depth pond				
Ms. Say Rathana	732.00		672.00	
Ms. Yi Sinoun	763.75		725.75	
Ms. Meth Chenghor		736.50		739.50
Ms. Tith Ros		758.25		752.00
Average	**747.63**		**722.30**	
1.0-meter depth pond				
Ms. Noun Ei	733.50		738.00	
Ms. Noun Art	739.50		744.00	
Ms. Long Meth		727.50		735.00
Ms. Yin Mom		722.75		727.25
Average	**730.80**		**736.10**	

some worked as the dish-cleaners at restaurants in Siem Reap and/or produced handicrafts and souvenir items for sale.

It is recognized that women in Cambodia could give all out efforts to undertake aquaculture ventures as better source of livelihood and income. In this study, the women participated in every step of operating fish farms from planning, decision making, preparing the pond to stocking of the fingerlings, fertilizing pond, preparing feed, feeding, pond maintenance, harvesting, sale, and marketing. After the trials, the project partners from Kampong Thom and Siem Reap managed their incomes and decided to: save for the next tilapia culture; expand the pond size for fish culture; support some priority household expenses; and save for children's education at higher levels. It is important to note that one of the project partners could send her daughter to a university to study economics and finance, using the money she earned from the project study. This implies that with the adaptations that fish farmers had to undergo to mitigate the impacts of climate change on tilapia culture, the socioeconomic well-being of the rural populace could be improved, as the next generation could attend higher educational levels, improving the lives of families dependent on fish farming in the near future.

Conclusion

The socioeconomic indicators of the respondents from Kampong Thom and Siem Reap, particularly in terms of educational attainment were not very favorable, and most of the fish farmers rely on rice field farming as their main occupation. High proportion of women's involvement is found in the fish culture ventures in Cambodia considering that male farmers are involved in productive work outside their villages. The women participate in each step of the fish farm operations starting from planning, preparing the pond to stock fingerlings, fertilizing ponds, preparing feeds, feeding, pond maintenance, harvesting, sale, and marketing as well as in decision making. There was however a big challenge for small-scale fish farmers in Kampong Thom and Siem Reap Provinces, because of the long drought during February to June, and flooding from September to October. The existing system of setting cages in the ponds or netting the fishponds (for low flood) were adopted by few families only because of the high cost incurred.

Deepened fishponds and shortened period of fish culture were considered good method to adapt to the impacts of climate change although in the study, there was no significant difference between water quality, mortality rate, and FCR in 1.5-meter depth pond and 1.0-meter depth pond in Kampong Thom and Siem Reap Provinces. However, there was significant difference between daily growth rates of tilapia stocked in 1.5-meter depth pond and in the 1.0-meter depth pond until the fish to reach table size. Nevertheless, the use of 1.5-meter depth fishpond in culturing fish for four months provided significant result as the fish culture period is short, faster harvesting of the appropriate market size of fish, enough water supply for fish culture; and with low risk in losing fish during flooding period. Moreover, the fish farmers in the 1.5-meter depth pond could find alternative jobs such as working as the dish-cleaners at restaurants in Siem Reap and/or make handicraft products during their spare times (three months) after culturing the fish. Deepened fishpond and shortened period of fish culture could help improve the socioeconomic status of the rural poor as it could provide them with better income and allow them to send their children to attain higher education bringing welfare to improve their lives in the near future.

This research contributed to determining the suitable and adaptable methods to deal with the long drought period after dry season which often caused suffering to the poor groups of women. Help is needed by women fish farmers to be able to raise fish during the critical times of the year. At the moment, high percentage of rural households in Cambodia now relies on the aquaculture sub-sector as their main source of income.

The positive result of this trial will be expanded and utilized to be adaptable in the areas located close to study areas, and is expected to secure the livelihoods and nutrition of women's groups in the target provinces. This is one of the important approaches that aim to eliminate poverty in the rural areas of Cambodia.

Recommendations

Based on the results of this study, some recommended actions could be promoted in order to improve the aquaculture situation of Cambodia. These are indicated in **Box 3**.

Box 3. Recommended actions to improve the aquaculture situation in Cambodia

- Government and development partners should create awareness programs on prevention of flood and drought to mitigate their impacts on aquaculture in the whole country
- Government and development partners should establish special aid to help fish farmers to recover from natural disasters (flood and drought)
- The lessons learnt about 1.5-meter fishpond depth should be studied further to know the weaknesses and strengths to apply for other provinces.
- In order to test the qualification of 1.5-meter fishpond depth method applicable to use in the whole country, government and development partners should expand trial program in different provinces.

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Impact of Auction System for Swamps on Sustainability of Fishery Resources: a case in South Sumatra, Indonesia

Bayu V. I. Yanti and *Dina Muthmainnah*

Management of swamps in several parts of Indonesia is carried out using an auction system, which is also known as "lelang lebak lebung" in South Sumatra, and has been practiced for generations. A study was carried out through literature analysis of data and information established from previous research efforts, to identify and assess the impact of the auction system on the biological resources and their sustainability. Results of the analysis indicated that such an auction system harms the sustainability of fishery biological resources. Negative impacts could be seen through the decline in populations of several fish species and the increasing scarcity of several species of economically-important fishes. In addition, drastic decline in fish production and productivity had also been observed from year to year since the 1990s. Efforts to support the sustainability of living resources should take into consideration the concept of sustainable development with a view to promoting eco-social rationality with economic, social, and environmental dimensions. Several policy implications have economic dimension, *i.e.* the need to strike a balance between the fisheries communities' economic interests (especially fishers and fish traders) and those of the Government (Regional Original Income). In the case of social dimension, the fishery communities need social engineering to participate in auctions and understand how to utilize the fishery resources sustainably. Determining the conservation areas or refuges and controlling of fishing efforts are some of the necessary aspects in the environmental dimension.

From Article 1 Point 31 of Environmental Protection and Management Law No. 32/2009 of Indonesia dated 3 October 2009 concerning Protection and Management of the Living Environment, Customary Law Communities or traditional communities are "groups of people who have been living in certain geographic areas from generation to generation because of their ancestral ties, having strong relationships with the environment, and heeding the existence of a value system that determines the economic, political, social and legal structures." One of the environmental protection and management systems being adopted in Indonesia could be noted in the management system of inland water resources including those of deep pools in swamps.

Swamps have different characteristics from the other inland waters (*e.g.* lakes and reservoirs), as there is high difference in their water level between the dry and the rainy seasons (Arifin & Ondara, 1982; Muthmainnah & Gaffar, 2010). Swamp biodiversity is very rich in flora (plants including aquatic plants) as well as in fauna (animals including fish), having unique functions according to species. For example, there are plants that function as source of fish food or as nursery area, as well as spawning area. Fishing activities in swamps usually start at the beginning of the rainy season when fish migrate from main rivers for feeding or for spawning, and end during the middle of dry season when fish swim back to main rivers (Muthmainnah *et al.*, 2017).

Map of Indonesia showing South Sumatra Province
*(**Source:** Google)*

Figure 1. Example of swamp area for auction

Figure 2. Temporary house and fishing boat in an auctioned area

In several parts of Indonesia, the management applied for fishery activities in swamps **(Figures 1 and 2)** is carried out through an auction system. The most well-known auction system is the "lelang lebak lebung" or deep pool auction which is practiced in South Sumatra Province, especially in swamps with deep pools which are areas that never get dry, and serve as nursery grounds of various fish species during the dry season (Muthmainnah, 2020). Fishing in deep pools in swamp areas could be conducted by the winner of the auction, usually for a period of one year starting from January until December.

The winner of the auction has the right only for the fishing activities, because the ownership of auctioned area including the plants therein remain with the original landowner. There are three main stakeholders as beneficiaries of the auction system: the district government, fishing communities, and the capital owners, *e.g.* fish traders or fish processors needing supply of fish or raw materials for processing. The district government can turn the proceeds from the annual auction into a significant source of regional revenue for funding the Regional Development and Expenditure Budget.

The fish caught from the auctioned area are generally priced high because of the quality of the fish. Nonetheless, the fisher's income is still considerably low. The prices of fish caught are determined by the winner of the auctioned swamps, but since the fishers usually receive the money prior to the fishing activity, to be used in acquiring some fishing gear, they had to repay the auction winner the advanced amount by sending the fish catch. This condition has raised the question about the impact of the auction system on fish sustainability in the auctioned swamps areas.

Fishing Business Rights

Principally aimed at managing the fishery resources, the auction system is also meant to ensure that the natural resources are well utilized (Nasution, 1990). Nevertheless, it has been noted that the traditional community's fishing effort in a particular auction area is usually being put to several disadvantages, especially that non-fishers are allowed to participate in the auction process and allowed to obtain the fishing rights (Zain, 1982). This has resulted in the right to fish as a business venture in South Sumatra's swamp, especially in Ogan Komering Ilir Regency, as the right is obtained by traders/owners with capital but who do not work as fishers (Nasution *et al*., 1992).

In such a situation therefore, the fishers obtain the fishing rights not directly from the government through the auction process but instead secure water lease from the auctioned winner/trader at a price higher than that from the auction process. This phenomenon has motivated the desire of fishers to catch more fish irrespective of the species and sizes of the fish in the auctioned area. Certainly, this has directly or indirectly harmed the fishery resources and the environment. Herewith are presented the several indicators of the negative impacts based on results of a study carried out to determine the sustainability of the auction system with respect to the state of the fishery resources.

Fish Population and its Production in Auctioned Areas

Results of the study on the activities of the auction system indicated decreasing populations of several fishes in the auctioned swamp areas (**Table 1**). Although catfish, a dominant fish in the swamp areas is still abundant, according to the traditional fishing community, this fish is less attractive to consumers and comes with lower prices compared to other fishes. This certain species of catfish is a hybrid of the African catfish with local catfish (Nasution, 2012).

Moreover, as shown in **Table 2**, the sizes of fish in the auctioned area had been changing. Before the 1990s the fish size was bigger than those after the 1990s, also implying that changes in the environment have been taking place. Moreover, the average weight of fish in 1996 and 2001 also changed (**Table 3**). The decreasing sizes occurred in seven economically-important fishes. According to the fishers, it has also become difficult to catch these fishes.

Table 1. Opinion by fishers regarding the condition of fish populations

Common and scientific names of fishes in auction area	Ratio of fish quantity	
	Period	Period
Snakeskin gourami (*Trichopodus pectoralis*)	XXXX	X
Climbing perch (*Anabas testudineus*)	XXXX	X
Striped snakehead (*Channa striatus*)	XXXX	X
Three spot gourami (*Trichopodus trichopterus*)	XXXX	XXXX
Glass catfish (*Kryptopterus bicirrhis*)	XX	---
Bronze featherback (*Notopterus notopterus*)	XXXX	---
Tinfoil barb (*Barbonymus schwanenfeldii*)	XXXX	---
Giant freshwater prawn (*Macrobrachium rosenbergii*)	XXXX	---
Philippine catfish (*Clarias batrachus*)	XX	XXXX

Source: *Nasution (2012)*
Where: *XXXX = overflow; XXX = lots; XX = moderate; X = a little; --- = rare*

Table 2. Average amount of fish catch before and after 1990s in kg

Common and scientific names of fishes in auction area	Number of tails per kg	
	Before 1990s	After 1990s
Snakeskin gourami (*Trichopodus pectoralis*)	20-25	30-45
Climbing perch (*Anabas testudineus*)	8-10	15-18
Philippine catfish (*Clarias batrachus*)	10	20
Three spot gourami (*Trichopodus trichopterus*)	30	60
Striped snakehead (*Channa striatus*)	2-3	4-10

Source: *Nasution (2012)*

Table 3. Average weight of individual fishes caught in 1996 and 2001

Common and scientific names of fishes in auction area	Average weight (g/indv)	
	1996	2001
Indonesian snakehead (*Channa micropeltes*)	2,000-3,000	1,000-1,500
Striped snakehead (*Channa striatus*)	1,000-2,000	600-1,000
Channa melanopterus	1,500-2,000	350-500
Channa pleurophthalma	500-1,000	300-400
Kissing gourami (*Helostoma temminckii*)	80-100	50-60
Snakeskin gourami (*Trichopodus pectoralis*)	80-100	40-50
Philippine catfish (*Clarias batrachus*)	300-400	100-200

Source: *Modified from Nasution* et al. *(2002)*

The total fish production of fishers in an auction area before and after the 1990s in a day and whole week is shown in **Table 4**. These facts illustrate that the total fish production had decreased drastically, for during the period before the 1990s, fishers could catch 80 kg/day of fish, but after the 1990s the fishers could only come up with 25 kg/day (Nasution, 2012).

Therefore, from the information gathered through this study, it could be said that the auction system harmed the fishery resources and aquatic plants, rather than maintaining the sustainability of the fishery resources which appeared difficult to achieve. While fish productivity of the auctioned area based on the catch of fishers decline as well as the diversity of fishery resources, and the areas that support the sustainability of economically-important economic fishes had also decreased.

Table 4. Total fish capture production before and after 1990s

Period	Total fish production (kg)	
	Before 1990s	After 1990s
In a week	250	90
In a day	80	25

Source: *Nasution (2012)*

Advocating Eco-social Rationality

The utilization of natural resources should provide benefits to all users, either directly or indirectly. In terms of the use of natural resources, this is known as the utilization in natural harmony. Utilization in harmony with nature means the use of natural resources that must consider the carrying capacity of nature in producing the products from the resources.

For the of maximum benefit that users could obtain from the fish and plant resources in a swamp ecosystem, the exploitation should consider the various dimensions associated with their utilization. This dimension is seen in natural resource (fish and plant resources) utilization and natural resource users (humans, fishers). Such harmonious use of nature has implications on sustainable development, because basically, the meaning of sustainable development is "to meet current needs without sacrificing future generations' ability to satisfy their needs" (WCED, 1987).

The concept of sustainable development also involves combining the preservation of natural resources, environment, and construction which in this case, refers to the responsible utilization of the fishery resources in the auctioned swamp areas. Therefore, utilizing and managing natural resources and the environment including in auctioned areas, need the concern and attention of all members of the society on the conditions of the resources in the future. However, sustainable development does not mean no constructions or land changes at all.

Sustainable development approach needs to have the same assumptions, and the basic principles that guide users to achieve a truly sustainable development. The principle of sustainable development is also consistent with the emergence of eco-social rationalism, pioneered by John Dryzek, Ulrich Beck, and Andre Gorz, which later became the basis of rationality thinking that is more suitable for contemporary political economy. The eco-social rationality approach is believed to be capable of addressing environmental problems that are rooted in social issues, where social problems are institutional, ideological, psychological, and cultural in nature (Little, 2000).

In the eco-social rationalism, the environment is seen as a whole and has an end goal for all creatures. The emergence of environmental problems is a result of works of humans who want to control the universe. The notion of economic rationality put forward does not merely maximize material benefits and utility but also considers social and environmental rationality. Dryzek realizes that environmental problems usually arise from social structures and institutions and the aggregation of various human activities. Meanwhile, the eco-social rationalism approach is known to involve all social movements and social organization of an economic system as well as the government, which regulates it in the form of rules and regulations, which are politically outlined in policy documents. Thus, the primary basis used to frame the overall analysis to support the sustainability of biological resources in the swamp areas is the concept of sustainable fisheries development with the perspective of eco-social rationality.

Way to Support the Sustainability of Fishery Resources

Efforts to support sustainability of the biological resources in the auctioned swamp areas within sustainable development concept with simple eco-social rationality should focus on the utilization and management of these natural resources by people who are concerned with the economic, social, and environmental dimensions. The following recommendations are therefore put forward.

Economic Dimensions

The economic dimension must balance the economic interests of the traditional fishery community, especially the fishers and fish traders, and the government as a form Regional Original Income. In this case, to avoid the significant role of non-fishers in the auction system, only the natural members of traditional community should be the only ones who have the voice to bid in the auction, who are fishers regardless of the origin of the fishers' capital. Fishers in this position can make prior agreements with traders regarding the amount of loan with capital interest and determine the price of fish before the auction. In addition, fishers should also have bargaining position against traders or owners of the capital.

On the other hand, the district government as the auctioneer can set the standard price at the start of the auction, not to increase the prices yearly. Thus, fishers can estimate whether they still could get some profit if they obtain fishing business rights in the waters that are the object of the auction, *e.g.*, swamp areas. The district government should also allocate funds for fostering the management of the swamp areas which could be not less than 10 % of the value of the proceeds from the auction. This guidance is intended to benefit the traditional fisher communities, fishery resources, and the environment, and provides the fisheries technical guidance to officers, including the fisheries extension workers.

Social Dimensions

Under the social dimension, there is a need for social engineering of the fishery communities participating in the auction. They should be made to understand how to utilize fish resources in order to achieve sustainability. Relevant information should be disseminated, which could include the recruitment process of fish resources, the role of plants in the life of fishes, the need for location and services of fish resource conservation, friendly fishing activities, fostering the role of women fishers (wives), and the importance of fishers institutions in achieving the sustainability of fishery resources, and the environment, including the plants.

Environmental Dimensions

Environmental dimension is crucial in the auctioned area as under the auction system, part of the auctioned area should be determined to serve as a conservation or reserve area, especially for the auction of areas with fishes that are of high economic value and also the location of such conservation area. Then, restrictions are placed, *e.g.* on plants' use in the auctioned ecosystem, especially for plants that are sources of food for fish, and considering that the fish, spawning areas, and nursery areas for fish have significant economic values.

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Exploring the Aquaculture Potential of *Ayungin*, an Endemic Freshwater Fish in the Philippines

Frolan A. Aya

In the early 1960s, silver therapon (*Leiopotherapon plumbeus*), locally known as *ayungin*, is regarded as one of the most abundant freshwater fishery resources in the largest lake in the Philippines, Laguna de Bay. Small-scale fishing communities around the lake are reliant on this fishery resource for subsistence consumption and livelihood. Recently, *ayungin* is touted as the most exploited commercial freshwater fish species in most regions of the country. The decline of this important food fish has led to a growing interest in its domestication for culture production and for possible replenishment of depleted stocks in the wild. Therefore, efforts to domesticate, manage, and conserve this native aquatic species have been given a high priority. Due to its readiness to spawn in captivity and successful hatchery production in outdoor tanks, *ayungin* is considered an emerging species with potential for inland freshwater aquaculture.

In the Philippines, fish is the chief source of dietary protein of rural households. According to the Bureau of Fisheries and Aquatic Resources (2021), Filipinos consume as much as 37 kg of fish per capita in 2015. Fish are mainly caught from the country's vast marine and inland waters.

In freshwater habitats, there are more than 180 native aquatic species widely distributed in the country (Froese & Pauly, 2021). For instance, a diversity of native food fish species are inhabitants of the three major lakes in south Luzon, Philippines, namely Laguna de Bay, Taal Lake, and Naujan Lake (**Figure 1**).

Figure 1. Location of three major lakes in south Luzon, Philippines

Indigenous fish species play an important role in ensuring food security especially among poor households in rural areas.

One of the Philippine native food fish species is the silver therapon, locally known as *ayungin* (**Figure 2**), which is targeted by the small-scale and commercial fisheries in lakeshore communities (Palma *et al*., 2002). *Ayungin* is a popular traditional fish to eat among the locals because of its tasty flesh. Eating *ayungin* is considered as part of the tradition of the consuming public, particularly for those who are 60 years old and above (Salayo *et al*., 2015). There is something in *ayungin* that it is a more sought-after fish than any other freshwater fishes such as tilapia or milkfish. Small-scale fishers catch this fish using gillnet (**Figure 3**), hook and line, and motorized push net for household consumption as well as livelihood.

Figure 2. Silver therapon (*Leiopotherapon plumbeus*), locally known in the Philippines as *ayungin*

Declining stock of *ayungin*

About six decades ago, the production of *ayungin* was enormously abundant in the 90,000-hectare Laguna de Bay. Together with goby (*Glossogobius giurus*) and Manila sea catfish (*Arius manilensis*), this fish constituted 95 % (about 83,000 t) of the annual fish harvest (Manalang & Diaz, 2017). However, there are no regulations in catching this fish in the lake where everyone can catch anytime and anywhere. Intense fishing pressure (Palma *et al*., 2002) and more recently, the proliferation of the invasive alien species in Laguna de Bay (Guerrero III, 2014) contributed to the decline in the production of *ayungin*. There was a significant downward production trend of *ayungin* by as much as 75 % from 4,675 t in 2002 to 1,182 t in 2020 (Philippine Statistics Authority, 2021b), and this corresponds to more than 50 % decrease in value from USD 5,396 in 2002 to USD 2,387 in 2020 (Philippine Statistics Authority, 2021a) (**Figure 4**).

Figure 3. Small-scale fishers use gillnet to catch *ayungin* in Laguna de Bay, Philippines
*(**Source:** C. Fernando-Aya)*

Figure 4. Production of *ayungin* in the Philippines in 2002-2020 by quantity (t) and value (USD)
*(**Source:** Philippine Statistics Authority, 2021b, 2021a)*

A closer analysis of the rate in the volume of production showed fluctuation across years (**Figure 5**). There were four periods of positive growth (+4.62 % in 2003–2004, +1.30 % in 2006–2007, + 2.88 % in 2010–2011, and +5.47 % in 2012–2013) that were observed within the 18-year period. However, the periods of decline were noted for the years 2005–2006, 2007–2008, 2008–2009, and 2016–2017 at -21.42 %, -23.20 %, -21.45 %, and -23.82 %, respectively. Consequently, using this 18-year dataset, the average production rate of *ayungin* is estimated at -6.96 % per year. Using this value to make future prediction, the

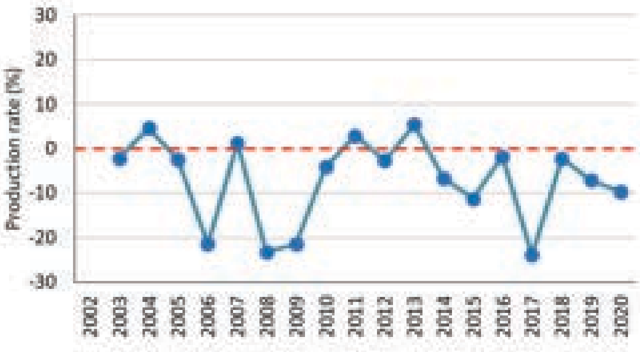

Figure 5. Production rate of *ayungin* in the Philippines in 2002-2020
*(**Source:** Philippine Statistics Authority, 2021b)*

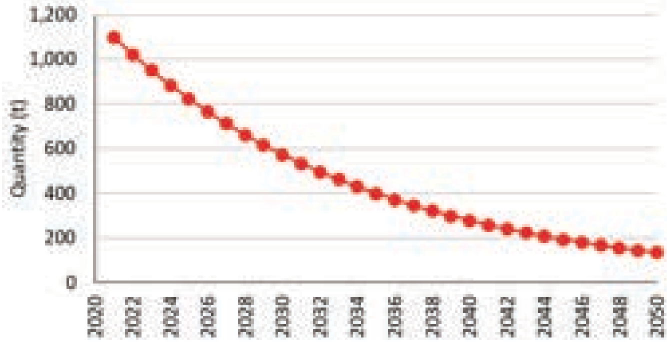

Figure 6. Predicted production of *ayungin* in the Philippines from 2021 to 2050 by quantity (t)

projected production is estimated at 575 t, 279 t, and 136 t in 2030, 2040, and 2050, respectively (**Figure 6**).

It is alarming to note that indeed, *ayungin* has been reported to have the highest decline rate among the freshwater fish species in the country (Guerrero III, 2021). The declining production of *ayungin* has severely affected the livelihood of approximately more than 24,000 fishers (Israel, 2007) around Laguna de Bay, particularly the small-scale fishing communities who depend on *ayungin* fishery as main source of food and income. Fishers now earn lesser income as compared before (Gervacio, 2012). However, despite the declining wild populations of *ayungin* in most regions of the country, the demand for this fish remained high. The market price of this fish ranges from USD 6.2 to as high as USD 16.5, which is about 2–5 times more expensive than the selling prices of tilapia and milkfish (Tacio, 2013).

Aquaculture potential of *ayungin*

The popularity of *ayungin* as food fish and its importance in the lake's subsistence fishery have, therefore, led the Binangonan Freshwater Station of SEAFDEC Aquaculture Department, in partnership with the University of the Philippines Diliman, to develop hatchery rearing techniques for domesticating this Philippine native fish species. In 2010, hormone-induced spawning of captive broodstock has been developed (L. M. B. Garcia, personal communication, 2010) using human chorionic gonadotropin (hCG) hormone. Spawning of *ayungin* was also induced through the application of salmon gonadotropin releasing hormone (sGnRH) (Javier *et al*., 2015). More recently, Aya and Garcia (2020) induced spawning in *ayungin* using the combination of hCG and ovaprim®.

Larval rearing techniques for *ayungin* in outdoor tanks have been established in 2015 but still require further refinements. Larvae of *ayungin* feed on natural food organisms such as copepod nauplii, rotifers, copepods, insect larvae, and ostracods during its early feeding stages (Aya *et al*., 2015, 2019). A stocking density of 0.4 larvae per liter in 4 m^3 outdoor tank is recommended (Aya & Garcia, 2016), with survival rates as high as 48 % (Aya *et al*., 2019).

Early-stage juveniles that weigh 0.17–0.18 g were harvested from outdoor concrete tanks after 30–40 days, followed by another four weeks in indoor plastic tanks before stocking in nursery cages (F.A. Aya, unpublished data) (**Figure 7**). In addition, Aya *et al*., (2021) evaluated different feeding regimes and stocking densities for rearing early-stage *ayungin* larvae under laboratory conditions. It was found that the larvae survived very well with the 69–81 % survival rate, demonstrating that *Artemia* nauplii were more suitable than the combined rotifers and formulated microdiet, and that larvae should be stocked at densities of 5–15 larvae per liter.

Recently, the aquaculture extension manual on the biology and hatchery rearing of *ayungin* (Aya & Garcia, 2020) has been published and is now available for download at the SEAFDEC/AQD Institutional Repository (https://repository.seafdec.org.ph/handle/10862/5898). The manual contains the detailed information on the patented hatchery rearing technology of *ayungin*.

Way Forward

The domestication, management, and conservation of native aquatic species would likely have positive socioeconomic and ecological consequences. Unfortunately, research efforts on the culture production of *ayungin* in the country are limited. Therefore, further refinements on the technology for seed production and rearing of *ayungin* are still being continued. Meanwhile, nursery and grow-out rearing techniques, including the development of artificial diets for this species, are currently in progress. It is hoped that through these interventions, the production of sufficient number of viable seeds of this native fish species may help secure food fish supply and provide the small-scale fishers with sustainable livelihood.

Figure 7. Early-stage *ayungin* juveniles reared in polyethylene tanks *(above)* before stocking in hapa net cages for nursery culture *(below)* at the Binangonan Freshwater Station of SEAFDEC/AQD in Binangonan, Rizal, Philippines

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Towards the Management of Marine Litter and Microplastics in the Southeast Asian Region

Pontipa Luadnakrob and *Sukchai Arnupapboon*

Management of aquatic pollution that include marine litter, *e.g.* marine debris, microplastics, and abandoned, lost or otherwise discarded fishing gear, is one of the most challenging issues that need to be addressed through global cooperative efforts. In the Southeast Asian region, the severity of the issue on marine litter requires strong collaboration for the development of preventive approaches to mitigate their impediments to sustainable economic growth. Innovation, research, and development of technologies to reduce marine litter are necessary for the well-being and sustainable management of biodiversity and natural resources. Recently, SEAFDEC has made some efforts to assess the condition of marine litter in the Southeast Asian region through several projects supported by the Japanese Trust Fund. This article highlights the initiatives as well as the ongoing and planned activities of SEAFDEC in collaboration with the ASEAN Member States (AMSs) and academic institutions to understand the impacts of marine debris and microplastics on the environment.

The ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 (Southeast Asian Fisheries Development Center, 2020) supports the United Nations Sustainable Development Goal (SDG) 14: "Conserve and sustainably use the oceans, seas, and marine resources for sustainable development" and its Target 14.1: "*By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution*." Guided by Resolution No. 11: "*Increase awareness and support the reduction of impacts of aquatic pollution and marine debris, including abandoned, lost or otherwise discarded fishing gear (ALDFG), and microplastics/ microbeads on fisheries and aquaculture*;" and Plan of Action No. 26: "*Assess and manage the impacts of aquatic pollution and marine debris, including abandoned, lost, or otherwise discarded fishing gear (ALDFG) and microplastics/ microbeads, on fisheries and aquaculture*," SEAFDEC has been undertaking activities that aim to address the issues on marine debris and microplastics in the Southeast Asian region. Along the lines of such efforts, the ASEAN Member States (AMSs) endorsed the "ASEAN+3 Marine Plastics Debris Cooperation Action Initiative" at the 21st ASEAN Plus Three Summit in Singapore in November 2018, supported the "ASEAN Framework of Action on Marine Debris" at the Special ASEAN Ministerial Meeting on Marine Debris in Bangkok, Thailand in March 2019, and adopted "Bangkok Declaration on Combating Marine Debris in the ASEAN Region" at the 34th ASEAN Summit in Bangkok, Thailand in June 2019.

Marine litter is defined by the United Nations Environment Programme as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (United Nations Environment Programme, 2021). Generally originating from people's activities in rivers, coastal areas, and seas, marine litter threatens the environment and organisms. The most common type of marine litter are plastics which are categorized as megaplastic (> 100 mm), macroplastic (> 20 mm), mesoplastic (5–20 mm), microplastics (< 5 mm), and nanoplastics (< 100 nm) (Barnes *et al*., 2009). In fact, about 60–80 percent of the world's litter is composed of plastics (Avio *et al*., 2017), contributing to the main concerns in marine pollution because of their durability and ability to resist degradation.

An estimated 90 percent of marine plastic wastes had been blamed to 10 rivers in Asia and Africa, one of which is the Mekong River which is about 4,300 km long and flows through six countries in Indochina and splits into several smaller rivers before flowing to the South China Sea (Hatta & Nishiwaki, 2018). Plastics are highly in demand in the daily lives of humans for comfort, and come in forms of plastic bags, plastic bottles, food packaging, among others. Nowadays, numerous tonnes of plastic litters are not properly managed, recycled, or disposed of (Jambeck *et al*., 2015). In 2010, five AMSs, namely: Indonesia, Philippines, Viet Nam, Thailand, and Malaysia, were among the largest sources of mismanaged plastic wastes entering the oceans (**Figure 1**).

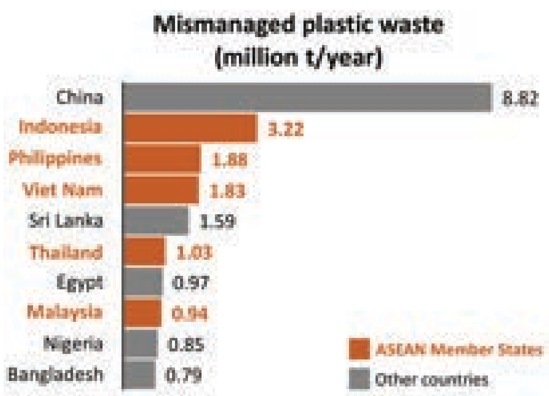


Figure 1. Top 10 countries with mismanaged plastic waste ranked by volume (million t/year) in 2010
(***Source:*** *Jambeck* et al.*, 2015)*

Harmful impacts of marine litter on marine animals

During the 2013 International Coastal Cleanup, the top ten debris items recorded were, in descending order: cigarette butts, plastic food wrappers, plastic beverage bottles, plastic bottle caps, straws and stirrers, plastic grocery bags, glass beverage bottles, other plastic bags, paper bags, and beverage cans; and seven of these items are made of plastic (Secretariat of the Convention on Biological Diversity, 2016). Reports have indicated that many marine organisms (*e.g.* invertebrates, fishes, turtles, whales) ingest plastic litter in their search for food that generally led to their deaths. For example, a dead sperm whale that was washed ashore near Kapota Island in Indonesia in 2018, was found to have ingested plastic litter that comprised 115 pieces of drinking cups, 25 plastic bags, plastic bottles, two flip-flop slippers, and a bag containing more than a thousand pieces of strings, all in all weighing about 6 kg (BBC News, 2018). In Kuala Penyu, Malaysia, a whale shark washed ashore in 2019 was found to have starved to death after ingesting a large plastic bag that caused physical obstruction in its gastrointestinal tract that led to its death (Chan, 2019). In Thailand, the number of deaths among marine animals in 2016 due to marine litter was 355 that included 11 dugongs, 180 sea turtles, and 164 dolphins and whales (Thaitrakulpanich, 2016). Moreover, a pilot whale was found dead at a canal in Songkhla Province, Thailand in 2018 and upon examination, its stomach was found to contain plastic bags and other plastic items weighing around 8 kg (Sriring, 2018).

Studies on microplastics in Southeast Asia

In the oceans, most plastics are broken up into smaller particles by the pressure from waves, water current, and wind, and these small plastic bits are called microplastics or nanoplastics. Several studies have demonstrated that marine organisms could take up microplastics and nanoplastics, which could be accumulated in their tissues as toxic pollutants (Avio *et al*., 2017). In the South Pole, which is supposed to be the least marine polluted area, it was found that there were plenty of plastic pieces in the water, snow, and ice with sizes smaller than 5 mm (Isobe *et al*., 2017). However, studies on marine litter and microplastics are still insufficient, particularly in the Southeast Asian region, although a few studies carried out in the region included a study in Malaysia by Mobilik *et al*. (2014) who assessed the amount and distribution of marine debris during different monsoon seasons in public beaches and found more than 7,000 items during the southwest monsoon, around 6,000 items during northeast monsoon, and around 3,000 items during intermediate monsoon. The total weight of all items collected was around 863 kg including 87 % plastic and the rest were timber, rubber, metal, glass, and cloth. The study on contamination of microplastics in bivalves, namely: *Danax* sp. and *Paphia* sp. by Tharamon *et al*. (2016) indicated that for both species, the most prevalent type of microplastics was fiber both in Chaolao Beach (82 %) and Kungwiman Beach (79 %) in Chanthaburi Province, Thailand. Sediment cores collected from Japan, Malaysia, Thailand, and South Africa indicated that the amount of extracted microplastics increased toward the surface. From the core samples at the surface sediment, the amount of microplastics varied from 100 pcs/kg in the Gulf of Thailand to 1,900 pcs/kg in Tokyo Bay (Matsuguma *et al*., 2017). In Sumba, Indonesia, the microplastics found in the water column (5 m, 50 m, 100 m, 300 m, and near the sea bottom) consisted of fibers, granules, and other plastic forms; and around 82 % of microplastics were found at the thermocline area which is less than 100 m water depth (Cordova & Hernawan, 2018).

Initiatives of SEAFDEC related to management of marine debris

In an effort toward addressing the issues on marine debris and microplastics in the Southeast Asian region, SEAFDEC collaborated with relevant organizations and agencies to implement several projects in improving research techniques and provided technical support to AMSs in building the capacity of their human resources in conducting sampling survey and data analysis on the impacts of marine litter on the environment. Specifically, the SEAFDEC Training Department (SEAFDEC/TD) conducted a preliminary assessment of marine litter on the seafloor of Sri Racha in Chon Buri, Thailand (**Figure 2**) in January 2015 (Yasook *et al*., 2015). About 1.9 km^2 area was swiped using otter board

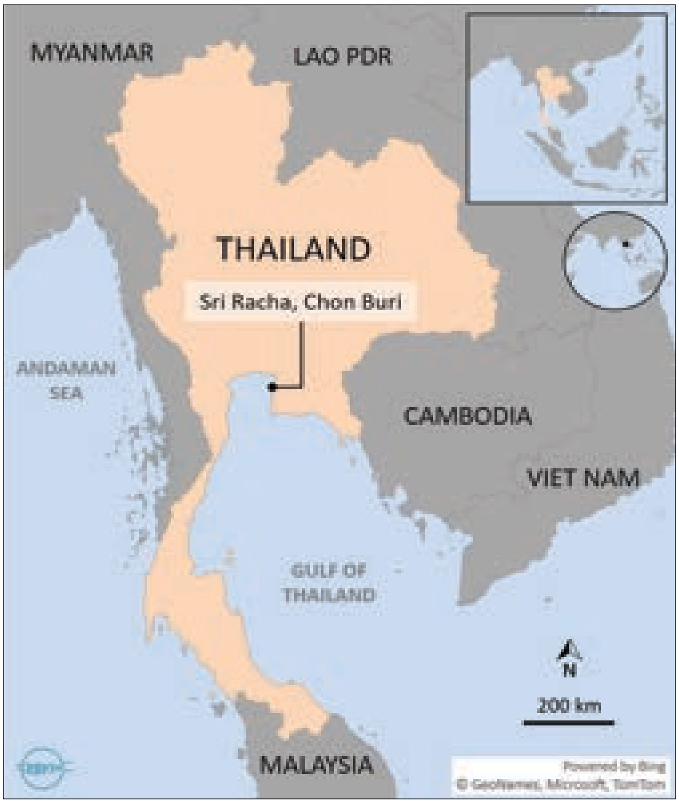


Figure 2. Survey area: Sri Racha, Chon Buri, Thailand in 2015

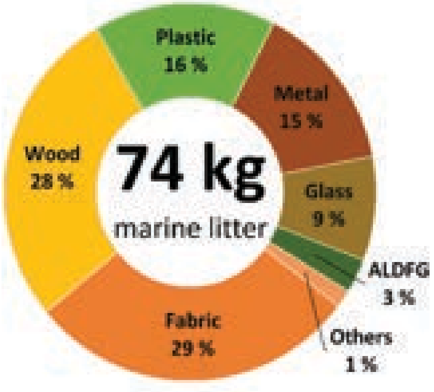


Figure 3. Composition of marine litter at the seafloor of Sri Racha, Chon Buri, Thailand, collected during the 2015 survey

bottom trawl, collecting about 74 kg of marine litter items that composed of fabric, wood, plastics, metal, glass, ALDFG, and other items (paper, rubber, and coal) (**Figure 3**). However, further study is necessary to compare the marine litter in other locations and seasons of the country.

During the Collaborative Research Survey in August–October 2018, SEAFDEC/TD collaborated with the Burapha University in Chantaburi Campus, Thailand, to carry out the study on the distribution of marine litter at the seafloor of the Gulf of Thailand using the M.V. SEAFDEC 2 (Arnupapboon *et al*., 2019). This resulted in the collection of more than 700 pieces of items during the otter board trawl operations. **Figure 4** shows the preliminary analysis of the marine debris hotspots in the Gulf of Thailand. Moreover, studies on the accumulation of microplastics in fish, sea bottom, and seawater were also carried out. Once the reports of the surveys and studies are completed, the overall results of the collaborative survey would be shared among the AMSs through trainings and workshops to enhance the capacity of researchers in the region.

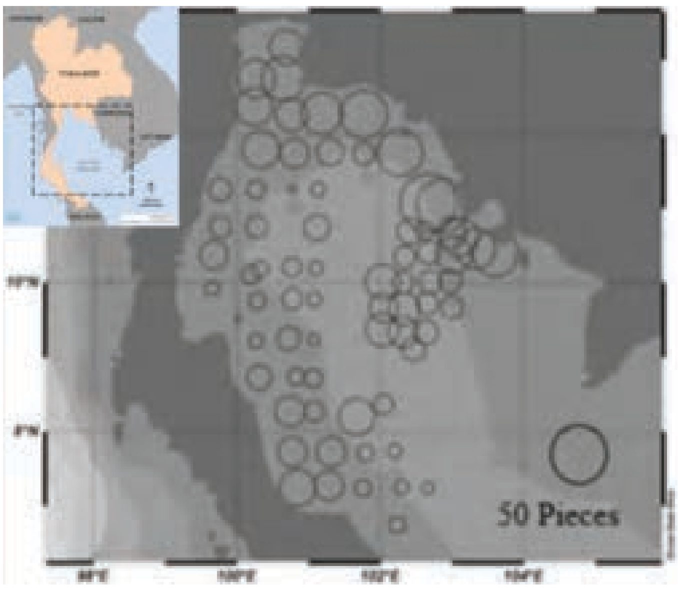


Figure 4. Marine debris distribution and density at sea bottom in the Gulf of Thailand during the 2018 survey

From November to early December 2019, SEAFDEC/TD organized the shipboard training for researchers from various research agencies on marine debris observation utilizing the M.V. SEAFDEC 2 while it was on a survey cruise in the inner part of the Gulf of Thailand. Back-to-back with the shipboard training, SEAFDEC/TD also conducted the Collaborative Research Survey on Marine Debris in the Gulf of Thailand using the M.V. SEAFDEC 2. The shipboard training and collaborative research were facilitated under the Japanese Trust Fund Project on Offshore Fisheries Resources Exploration in Southeast Asia. Moreover, while conducting regular surveys onboard the research vessels of SEAFDEC, SEAFDEC/TD also initiated the development of appropriate method of visual observation of floating marine litter. Subsequently, the method would be shared with the researchers from the AMSs to enhance their knowledge and capacity to study marine debris in the waters of their respective countries.

In 2020, SEAFDEC/TD organized the "Technical Ad Hoc Meeting on Marine Debris in Thailand" in Samut Prakan, Thailand with participants from Japan, Thailand, and SEAFDEC/TD. The Meeting was aimed at establishing a collaborative research between SEAFDEC and the Science and Technology Research Partnership for Sustainable Development (SATREPS) Programme of the Government

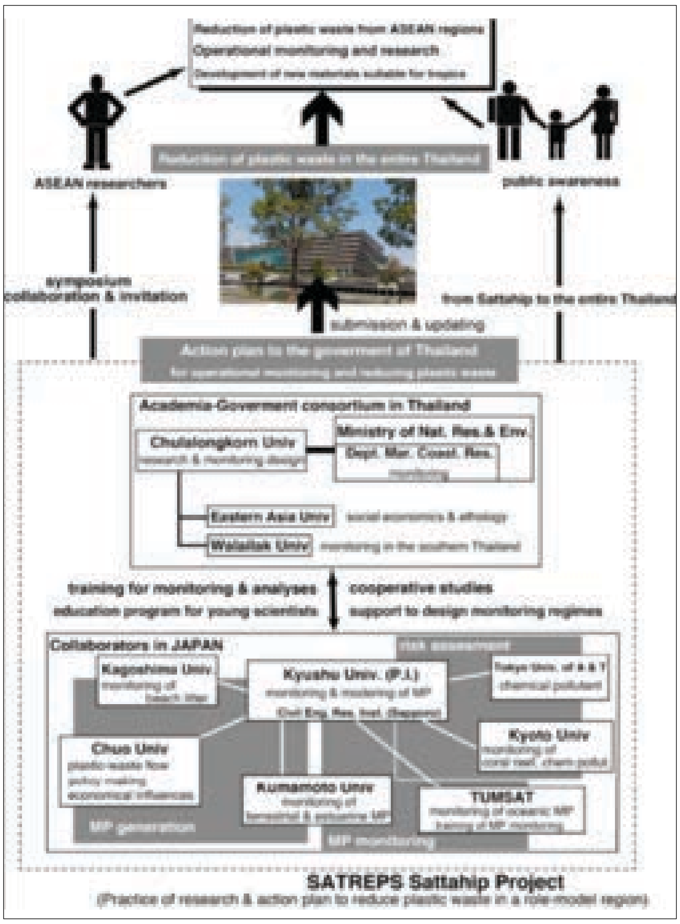


Figure 5. Conceptual framework of the Marine Debris in Thailand Project

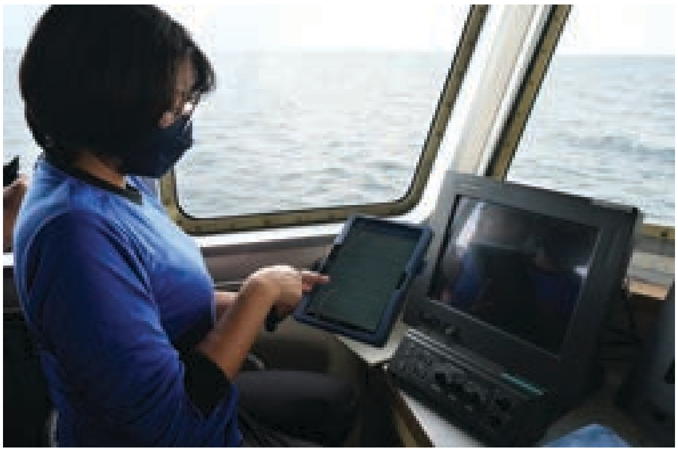
of Japan that promotes international joint research. Under SATREPS, the proposed "Project on Marine Debris in Thailand" was presented through a conceptual framework shown in **Figure 5**. The proposed collaborative research is aimed at 1) establishing a center of excellence regarding marine plastic pollution research in Southeast Asia; and 2) supporting, justifying, and updating the action plan issued by the Southeast Asian countries on the management of marine litter.

Moreover, SEAFDEC Inland Fishery Resources Development and Management Department (SEAFDEC/IFRDMD) is assessing the uptake of microplastics by freshwater fishes to determine the presence of microplastics in commercially exploited freshwater fishes considering that consuming these microplastic-contaminated fishes could pose potential risk to humans (Kaban *et al*., 2021). This Project is being supported by Japan-ASEAN Integrated Fund (JAIF).

Sampling of microplastics from seawater

Way Forward

Currently, several projects are being implemented by SEAFDEC that aim to address the issues on marine debris and microplastics in the Southeast Asian region. Under the SEAFDEC/TD project "Responsible Fishing Technology and Practice" in 2020–2024, one of the activities is aimed at developing environment-friendly fishing gear and practices to prevent and significantly reduce marine debris. Through the project "Sustainable Utilization of Fisheries Resources and Resources Enhancement in Southeast Asia" in 2020–2024, the second leg of the Collaborative Research Survey in the Gulf of Thailand would be pursued to collect baseline data on marine debris, develop standard procedures on marine debris observation, enhance the capacity of researchers on marine debris and microplastics research, and strengthen the network of Southeast Asian researchers engaged in research on marine debris and microplastics. Regional training courses on microplastics and marine debris would also be organized to support the marine debris and microplastic research program, by strengthening the capacity of researchers from the AMSs on marine debris and microplastic surveys, and analysis as well as development of strategies for the management of marine debris and microplastics.



Trial on visual observation and recording of floating marine litter onboard the M.V. SEAFDEC 2

Furthermore, several activities would be undertaken under the project "Regional Collaborative Research and Capacity Building for Monitoring and Reduction of Marine Debris from Fisheries in Southeast Asia" during 2021–2022. Short descriptions of such activities are shown in the **Box**.

Box. Activities lined up for 2021–2022 under the project "Regional Collaborative Research and Capacity Building for Monitoring and Reduction of Marine Debris from Fisheries in Southeast Asia"

- Gathering of information to estimate the amount of ALDFG in pilot sites
- Conduct of workshop on information exchange and development of technical guide to mitigate incidence of ALDFG
- Conduct of survey in the Gulf of Thailand to evaluate the impacts of microplastics on fishery resources
- Evaluation of the amount of marine debris collected by different types of fishing gears during fishing activities at sea
- Assessment of the microplastics in marine and freshwater fish
- Capacity building of officers and researchers from the AMSs on the study methods for management of marine debris and microplastics
- Establishment of the Project website and communication materials
- Development of a technical manual for marking of fishing gears

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Highlighting the Importance of Studying Microplastics in Freshwater Fishes

Siswanta Kaban, Dina Muthmainnah, Arif Wibowo, Toshiya Suzuki, Aroef H. Rais, and *Virgilia T. Sulit*

Plastic pollution has recently been considered one of the major pressing concerns in the world, as the demand for plastic continues to increase, especially over the last decade and during the COVID-19 pandemic. Nowadays, most of people's daily practices tend to move toward the use of more plastic materials that could not be rapidly recycled, not only for wrapping various things including food products, but also for the manufacture of plastic-wear gears such as hand gloves, face shields, and personal protective equipment (PPE) used by health workers in their work areas during this period of the pandemic, *e.g.* in hospitals, health centers, and health check-points among others. Amidst these developments, increase in production of plastic materials is not usually followed by advocacy on the adoption of plastic waste management, a phenomenon that remains a global challenge.

Plastic debris or plastic particles that enter the environment come in a wide range of sizes. Arthur *et al*. (2009) defined microplastics as any plastic particles or polymers that are smaller than 5.0 mm, originating from manufactured plastics that come in particular sizes and/or shapes with varying purposes. Microplastics could be primary or secondary microplastics, where primary microplastics come from materials specifically produced for industrial use, while secondary mircoplastics are those particles that result from the physical, biological, or chemical degradation of larger particles (Andrady, 2011) and constitute the main source of microparticles released into the environment. In general, larger plastic particles of various sizes could be detected visually, which means that their relevant physical information could be extracted using the naked eye and such inspection process is generally used in monitoring their presence in the environment. **Figure 1** shows some types of microplastics that come in various shapes.

However, some plastic microparticles, such as small microplastics (< 1.0 mm = 1000 µm) and nanoplastics (< 100 nm) can only be detected through the use of light microscopy. These particles are relatively difficult to detect, especially in terms of their chemical composition except through the use of infrared spectroscopy or any microscopic technology. This is true for food products including freshwater fishes since the small microparticles usually pass through the gut wall, as in the case of fishes.

Microplastics could be found in marine waters, riverbeds, natural fertilizers, and soils, even contaminating drinking water, and recently these particles had also been traced in the human food chain. The omnipresence of microplastics in almost all things around makes it an enormous challenge to protect the health and well-being of humans and the environment. The threat of microplastics to marine life has been extensively studied, like the ingestion of microplastics by several marine species has already been examined and analyzed, but little is known of the presence of microplastics in freshwater fishes so that information regarding the impacts of microplastics ingested by freshwater fishes are still very scarce. Considering that the uptake of microplastics by fishes is known to contaminate the human food chain, it has also become urgent to assess the presence of microplastics especially in freshwater fishes since consuming microplastic-contaminated freshwater fish could pose potential risk to humans.

Plastic pollution has recently become one of the key environmental issues of the world in general and of the ASEAN Member States (AMSs) in particular, not only coming from the plastic particles in the form of marine debris but

Figure 1. Microplastics *(top)* and their shapes *(bottom)*: A - sheet; B - film; C - line/fiber; D - fragment; E - pellet/granule; and F - foam
Source: *Wu* et al. *(2017)*

also from those particles found in freshwater environments. Against this backdrop, the SEAFDEC Inland Fishery Resources Development and Management Department (SEAFDEC/IFRDMD) based in Palembang, Indonesia has embarked on a one-year preliminary investigation of microplastics in freshwater fishes in Southeast Asia starting in 2021, with financial support from Japan-ASEAN Integration Fund (JAIF).

This study is part of the SEAFDEC project "Regional Collaborative Research and Capacity Building for Monitoring and Reduction of Marine Debris from Fisheries in Southeast Asia" which is being supported by JAIF and coordinated by the SEAFDEC Secretariat. Under this Project is a study that focuses on the impacts of microplastic contaminants in freshwater fishes which is being carried out by SEAFDEC/IFRDMD with pilot site at the Musi River, South Sumatra, Indonesia. This study is in parallel with the investigation of mircoplastics in marine fishes which has the Gulf of Thailand as its pilot site, and carried out by SEAFDEC/TD. Results of these studies could provide a clear understanding of the characteristics of microplastics in freshwater and marine fishes and the risks from consuming microplastic contaminated fish and fishery products. Generally aimed at securing food safety in the Southeast Asian region, these studies are being undertaken through monitoring surveys on the effects of microplastics in freshwater and marine fishes at the targeted pilot research sites in Indonesia and Thailand, respectively, and risk assessments of the hazards on humans and the environment caused by the microplastics as contaminants. The results would be disseminated to the AMSs to provide valuable lessons on the impacts of microplastics on the socioeconomic development of the AMSs.

Microplastic pollution in inland waters

Southeast Asia is endowed with natural inland waters that include vast river systems and lakes, floodplains, and wetlands, as well as man-made and enhanced natural waters such as reservoirs and dams (Pongsri *et al*., 2015). A rich diversity of aquatic species inhabits these inland waters, including a variety of freshwater fishes that contribute to food security, generate livelihood and recreational opportunities, and serve as sources not only of nutrients for the rural populace but also income for millions of people living along these water bodies.

Inland fishery activities give a vital component of the economy in sustaining and alleviating the economies of rural communities whose subsistence depends on inland fishery products. These inland water resources could be sustainably utilized to promote responsible inland fisheries. However, most of the region's inland water resources are being degraded, and many are almost lost, mainly due to destructive human activities that lead to pollution. It is in this regard that the awareness of residents living around the inland water bodies should be enhanced, especially on the use of plastic materials in their day-to-day activities, as well as on the proper and responsible disposal of solid wastes.

Being a natural recipient and receptacle of solid wastes, inland water resources are at risk of being polluted and contaminated by microplastics, a situation similar to the issues of plastic debris in marine environments, making the inland waters known to be important source of plastic pollution. In the study of Bessa *et al*. (2018) carried out in the Mondego Estuary, Portugal, the results indicated that ingestion of microplastics in sea bream populations, where the dominant polymers were polyester, polypropylene, and rayon (semi-synthetic fiber). The presence of these pollutants in commercial fish populations from Mondego Estuary which was reported for the first time had raised concerns on the potential negative effects of microplastics in the human food chain.

The extensive use of plastic materials has resulted in the presence of microplastics in the food chain and exposure of consumers to such contaminants. There have also been studies that confirmed the presence of microplastics in freshwater fishes. The review conducted by van Raamsdonk *et al*. (2020) which focused on recently published data on concentrations of microplastics in food, possible effects, and monitoring methods, some studies on zebrafish, a freshwater fish, indicated diverse results related to the type and extent of the effects of microplastic ingestion, although exposure of the fish to microplastics led to changes in their gut microbiota, lipid metabolism, and oxidative stress.

Preliminary assessment of microplastics in freshwater fishes in Southeast Asia: a challenge

The investigation on microplastics in freshwater fishes in Southeast Asia which is being carried out by SEAFDEC/IFRDMD, is aimed at characterizing the composition of microplastics in commercially important freshwater fishes at Musi River in South Sumatra Province, Indonesia (**Figure 2**). The study also intends to come up with a risk assessment of the microplastics present in freshwater fishes on human health and the environment.

The Musi River is a type of inland water ecosystem located on the Sumatra Island in Indonesia. The river roughly flows from Barisan Mountains in Kepahiang, Bengkulu to the Bangka Strait that drains to the South China Sea, stretching a total length of about 750 km. Also flowing through Palembang, the provincial capital of South Sumatra, Musi River has nine tributaries, namely: Batang Hari Sembilan which includes the Komering River, Ogan River, Lematang River, Batangharileko River, Rawas River, Lakitan River, Semangus River, Kelingi River, and Kikim River. The area of the Musi River Basin is around 2.5 million ha or about 20 % of the total

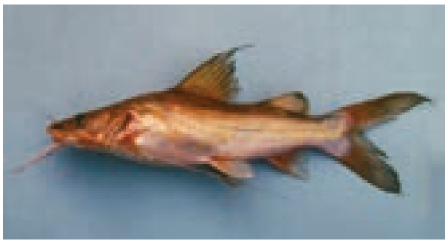
Figure 2. Map of Sumatra, Indonesia showing Musi River, the pilot site for the study on microplastics in freshwater fishes, with the sampling stations 1-9 identified

area of the Sumatra's rivers and swamps of 12.5 million ha (Manggabarani, 2015; Sukadi, 2005). The Musi River has a strategic role in supporting the economic development of the people in South Sumatra.

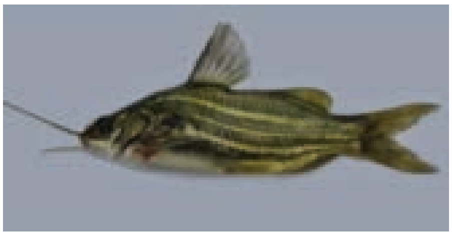
The important role of the Musi River has been recorded historically since the days of the Srivijaya Empire. At that time, the Musi River was widely used as the transportation route for ships carrying agricultural produce to trade centers both in the South Sumatra region and outside the region to all of Sumatra and the islands outside Sumatra. Until now, the Musi River is still used by various sectors such as fisheries and transportation, while its bank is used by other sectors, such as agriculture, industrial, and forestry, as well as for palm plantations, and settlements, all of which contribute one way or another, to the status of the river's aquatic ecosystem. The Musi River has high biodiversity, such as fish, crustaceans, mollusks, and reptiles that have economic value and functions to maintain environmental balance.

For this SEAFDEC/IFRDMD study, the presence of microplastics in three economically important freshwater fishes, namely: catfish (*Mystus* sp.), bagrid catfish (*Hemibagrus nemurus*), and *Pangasius* sp. (**Figure 3**) would be monitored and analyzed. The fishes would be caught using gillnet and long line from three river zones. The fishes to be monitored in the upstream zone are *Mystus* sp. and *Pangasius* sp.; in the middle zone, *Hemibagrus nemurus* and *Pangasius* sp.; and in the downstream zone, *Hemibagrus nemurus* and *Pangasius* sp.

Pangasius sp.



Hemibagrus nemurus



Mystus sp.

Figure 3. Three commercially-important freshwater fish species to be monitored in the IFRDMD study on microplastics
(*Source:* www.fishbase.org)

Way Forward

The results of the investigation by SEAFDEC/IFRDMD would be discussed during a regional workshop to be participated by representatives from the AMSs that is aimed at disseminating the results of the investigation, especially the presence of microplastic contaminants in freshwater fishes. From the recommendations of the workshop, SEAFDEC/IFRDMD would formulate the appropriate workplan for monitoring and analyzing the presence and risks of microplastic contaminants in freshwater fishes to humans and the environment, taking into consideration the other inland waters of the AMSs. Furthermore, the said workplan would also include identification and reduction or elimination of the sources of microplastics in freshwater ecosystem. It is also envisioned that the results of this pilot study would provide the methodology and information necessary in establishing standardized sampling programs and more comprehensive understanding of the absorption of microplastics in freshwater fishes. Ultimately, the results would lead to the identification of the scientific evidence on the microplastic contaminants in the food supply chain and the risks of such contaminants to humans and the environment.

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CALENDAR OF EVENTS

Date	Venue	Event	Organizer(s)
		2021	
28 January	Webinar	Webinar on Inland Fisheries Connectivity, Irrigation and Water Management	APFIC
1-5 February	Rome, Italy	34th Session of FAO Committee on Fisheries	FAO
10 February	Webinar	Webinar on Review of Illegal Fishing in the APFIC Region	APFIC
11 February	Webinar	Webinar on Impacts of COVID-19 on Seafood Supply Chains	Worldfish
15 February	Webinar	Webinar on Global Panel Policy Brief Launch: Harnessing Aquaculture for Healthy Diets	Worldfish
18-19 February	Krabi Province, Thailand	Onsite Training on Promotion of Fish Handling Technique and Labor-saving Equipment for Fisheries, Krabi Province, Thailand	SEAFDEC/TD
23-24 February	Virtual Meeting	3rd ASEAN Meeting on Combating IUU Fishing in Partnership with the EU	ASEAN
24 February	Teleworkshop	Regional Workshop on the Study on Impacts of COVID-2019 Pandemic on the Fisheries Sector of the ASEAN-SEAFDEC Member Countries	SEAFDEC Secretariat
24 February	Webinar	Webinar on Antimicrobial Resistance (AMR) and Antimicrobial Use (AMU) in Aquaculture in Asia	APFIC
24-25 February	Online Training	Online Training on Utilization and Improvement of eACDS Application Version 2 for Fisheries Officers of Malaysia	SEAFDEC/TD
10 March	Webinar	Webinar on Multispecies Stock Assessment for Management	APFIC
25 March	Webinar	Webinar on Aquaculture Innovation in the APFIC Region	APFIC
31 March	Webinar	Webinar on Subsidies, WTO and Fisheries	APFIC
30 Mar – 1 Apr	Online Workshop	Online Practical Workshop on the Use of eACDS Application Version 2 for Fisheries Officers of Brunei Darussalam	SEAFDEC/TD
6 April	Webinar	Webinar on Information Technology for Small-scale Fisheries	APFIC
7-9 April	Online Workshop	Online Practical Workshop on the Use of eACDS Application Version 2 for Fisheries Officers of Viet Nam	SEAFDEC/TD
8 April	Webinar	Webinar on Co-management of Small-scale Fisheries	APFIC
8 April	Webinar	Webinar on Guidelines for Microfinance and Credit Services in Support of Small-Scale Fisheries	CAFI-SSF Network
21 April	Virtual Event	Webinars on Technological Innovation: e-dialogue on Seaweed 'Diversity and Technology: Towards a Sustainable Seaweed Industry'	INFOFISH
27-28 April and 11 May	Virtual Meeting	53rd Meeting of the SEAFDEC Council	SEAFDEC
5-7 May	Virtual Meeting	36th Session of the Asia-Pacific Fishery Commission (APFIC)	APFIC
19-21 May	Virtual Conference and Exhibition	TUNA 2021 World Tuna Conference & Exhibition "The Global Tuna Industry: Trailblazing through tough times"	INFOFISH
24-28 May	Virtual Meeting	8th General Session of the World Assembly of National Delegates of the OIE	OIE
27 May	Video Conference	16th Meeting of the ASEAN Working Group on the Convention on International Trade in Endangered Species of Wild Fauna and Flora and Wildlife Enforcement (16th AWG-CITES and WE)	ASEAN
31 May-4 Jun	Virtual Meeting	3rd Meeting to the Parties to the 2009 FAO Agreement on Port State Measures	FAO
May (Tentative)	TBD	Regional Training Course on EAFM Management Tools	SEAFDEC/TD
10 and 17 June	Webinar	Webinar on WTO Fisheries Subsidies Draft Consolidated Chair Text	SEAFDEC Secretariat
14-29 June	Online	Training Course on Marine Fish Hatchery	SEAFDEC/AQD
8 August	Webinar	Webinar on Gender in SSF/SSA fisheries aquaculture	APFIC
19-20 August	Virtual Conference	8th International Conference on Fisheries and Aquaculture 2021	Indonesia & Thailand
August (Tentative)	TBD	Regional Training Course on the Utilization Techniques of FGIS and RS to Improve Fishing Ground Exploration and Fisheries Management in Southeast Asia	SEAFDEC/TD
October (tentative)	Online Training	Training Course on Fish Health Management	SEAFDEC/AQD
November (tentative)	Online Training	Training Course on Community-based Freshwater Aquaculture for Remote Rural Areas of Southeast Asia	SEAFDEC/AQD
November (tentative)	Online Training	Training Course on Feeds and Feeding Management	SEAFDEC/AQD

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, *Thidar Tun*, from the national drawing contest in Myanmar

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.