FISH for the PEOPLE

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Positioning Regional Aquaculture and Inland Capture Fisheries to Fill the Global Fish Supply-Demand Gap

Southeast Asian Fisheries Development Center

Editor in Chief (Fish for the People)

SEAFDEC Secretariat
Kasetsart University Campus
P.O. Box 1046, Kasetsart Post Office,
Bangkok 10903, THAILAND
E-mail: fish@seafdec.org

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Editorial

Before 1960s or so, fishing in Southeast Asian waters was simple and mostly confined in nearshore areas using non-mechanized fishing boats, and where the territorial seas lay only 12 nautical miles from shore. As the region's population continued to rise, beefing up the respective countries' national economies became necessary to meet the needs of the growing number of people. Development planners therefore looked at fisheries as an area for development viewing the fishery resource as inexhaustible. Gigantic fisheries plans were developed and the fishing capacities of the countries were enhanced unmindful of the sustainability of the natural resources. As a result, overfishing became prominent as landings declined, with the fishers feeling the brunt of the diminishing catch both in quantity and in size.

When the Southeast Asian Fisheries Development Center (SEAFDEC) was established in 1967, it was given the specific mandate of promoting sustainable fisheries development in Southeast Asia as means of improving its food situation taking into consideration the region's burgeoning population. As SEAFDEC continues to pursue such herculean task, it had to establish a department that could bridge the gap between sustainable fisheries and global fish demand, which had been exacerbated by the extension of the Exclusive Economic Zone (EEZ) to 200 nautical miles from shore during the 1982 United Nation's Convention on the Law of the Sea, although such a situation had also encouraged national planners to cooperate in finding the ways and means of developing the region's fisheries in a sustainable manner.

As the global population continues to follow a logarithmic trend, the gargantuan responsibility of aquaculture to bridge the fish supply-demand gap became a serious concern, but this also led to the rapid growth of the region's aquaculture sub-sector in the midst of problems and constraints. Addressing the concerns expressed towards the sustainability of aquaculture has been the tall order of the SEAFDEC Aquaculture Department.

The marine and inland capture fisheries sub-sectors are inherent in the region's economic scenario. While marine capture fisheries had been undergoing resource recovery, the development of inland capture fisheries became very apparent. Although comprising only part-time job workers in agricultural households in rural areas, inland fisheries has been contributing, in a way, to food security in rural economies, a role which has been scarcely recorded and reported. To enable this sub-sector to enhance its development, there is a need for the countries to assess their legal fisheries frameworks to make sure that the sustainable development of inland capture fisheries is embedded in fisheries plans and programs, including improvement of inland fisheries data compilation in order that the real status and value of the region's inland fisheries become very clear. This task has been granted to the Inland Fishery Resources Development and Management Department of SEAFDEC.

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Call for Articles

FISH for the PEOPLE is a policy-oriented special publication of SEAFDEC. Now on its 16th 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 layman'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.

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.

Reviving the Aquaculture of Black Tiger Shrimp in Southeast Asia: Perspectives and Future Direction

Siri Ekmaharaj

The intensive culture of black tiger shrimp (*Penaeus monodon*) was first developed in the late 1985s, during which time, Thailand was the first country to export cultured shrimps (both tiger shrimp and other marine shrimp species) to the world market from 1991 to 2014. The country's total production of black tiger shrimp at its peak was about 420,000 metric tons (MT)/yr in 1998 and 1999. Then, the shrimp aquaculture industry encountered many problems that were mainly related to water pollution in the culture areas followed by disease outbreaks caused by the White Spot Syndrome Virus (WSSV) impacting on the sustainability of the tiger shrimp culture. As recovery in terms of production was quite slow, the Specific Pathogen Free (SPF) white shrimp (*Litopenaeus vannamei*) was introduced to the country in 2002. Since then until early 2011, Thailand's production of white shrimp had increased to an average of 620,000 MT/yr while the production of tiger shrimp was only about 1-2 % of the country's total shrimp production. Later, when the shrimp culture industry of the ASEAN Member States suffered another major blow due to the incidence of early mortality syndrome (EMS) in cultured marine shrimps during 2010-2011, production of the white shrimp dropped rapidly in most countries including Thailand. Many shrimp farmers in Thailand are now going back to the culture of black tiger shrimp (*P. monodon*) using disease-free broodstock produced by private companies in Thailand. This paper, which summarizes some innovative culture techniques that have been improved and re-introduced recently in the country's shrimp farms, is based on the Keynote Lecture delivered by the author during the **Dean Domiciano K. Villaluz Memorial Lecture**, one of the major activities during the Celebration of the 45th Founding Anniversary of SEAFDEC Aquaculture Department (AQD) in Iloilo, Philippines on 12 July 2018.

The Government of Thailand through its Department of Fisheries (DOF) has mapped out plans to support the shrimp farmers in coping with the current situation of the shrimp culture industry and in looking for markets for their produce. Currently, tiger shrimps are being transported live to Mainland China directly from accredited shrimp farms and commanding good prices. Japan is also looking for prospective suppliers of tiger shrimp for consumption in the country. Recently, the new demand for boiled shrimps (both tiger and big size white shrimps) has also been expressed by China. These prospective markets encouraged the shrimp famers to improve their production of the black tiger shrimp which has already been increasing by 10,000 MT/yr in 2016-2017.

It is expected that China would need up to 80,000 MT of fresh shrimps per year which could be provided by the Southeast Asian countries. Moreover, the main market for boiled marine shrimps is still China which requires about 100,000 MT/yr, and currently being supplied by some South American countries. In order to tap this new market for marine shrimps, there is a need to increase the farm production of tiger shrimp which is an indigenous marine shrimp species in Southeast Asia, to cater to the demand of the new markets in China and Japan.

Former SEAFDEC Secretary-General *Dr. Siri Ekmaharaj* at SEAFDEC/AQD on 12 July 2018

World Aquaculture Production

Based on the statistics provided by FAO on fisheries production of the world, aquaculture production has dramatically increased from 1995 up to 2014, about 167,200,000 MT in 2014 (FAO, 2016). Meanwhile, production from capture fisheries has relatively been steady at about 93,400,000 MT (**Figure 1**) since the late 1980s, in view of the many problems encountered such as overfishing in some areas, and water pollution that destroys some spawning grounds and nursing areas. Therefore, increased aquaculture production has been considered as an option to supply the increasing demand of the peoples of the world for food fish, and a solution to food security.

In terms of aquaculture production by country, China has been the leader, sharing about 58.2 % of the global production and

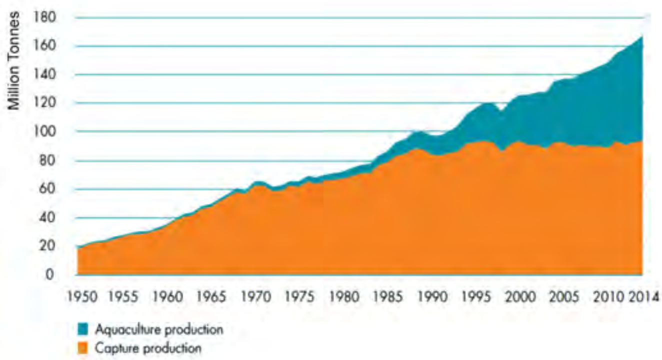

Figure 1. World's fisheries production from capture fisheries and aquaculture (FAO, 2016)

Table 1. Top ten aquaculture producers in 2014, by quantity and value

Country	Production (million tons)	% of global production	Value (billion US$)	% of global value
China	58.8	58.18	141.97	61.06
Indonesia	14.4	14.25	10.56	4.54
India	4.9	4.85	10.81	4.65
Viet Nam	3.3	3.26	7.90	3.40
Philippines	2.3	2.28	2.14	0.92
Bangladesh	2.0	1.98	4.83	2.08
Republic of Korea	1.6	1.58	2.15	0.92
Norway	1.3	1.29	7.03	3.02
Chile	1.2	1.19	10.31	4.43
Egypt	1.1	1.09	2.02	0.87
Global	**101.07**	**100**	**232.50**	**100**

Source: FAO Fisheries and Aquaculture Information and Statistics Service

61.1 % of the global value (**Table 1**). The fisheries production of China and India comprises mainly freshwater fishes, while Philippines and Indonesia are the main producers of seaweeds from aquaculture.

Aquaculture Production of Thailand

In Thailand, production from capture fisheries has also dramatically decreased (**Figure 2**), since some of the production during 1995-2007 came from offshore capture fisheries through joint ventures between Thailand and some countries, which had been considerably phased out by most of the countries. Meanwhile, aquaculture development of Thailand has been growing consistently for the past 30 years. From a total aquaculture production of 260,400 MT in 1989, this had increased 6 times in 2009 to about 1,416,000 MT (*www.fisheries.go.th/stat/*).

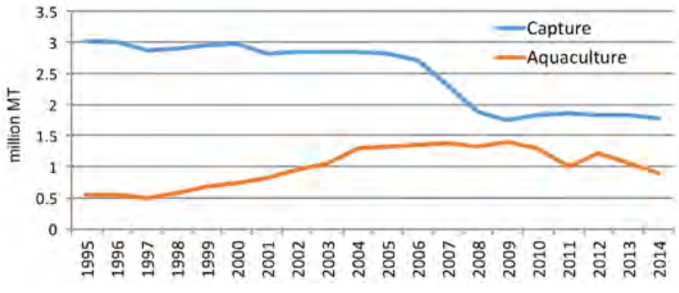

Figure 2. Production from aquaculture and capture fisheries of Thailand during 1995-2014 (SEAFDEC, 1998-2014)

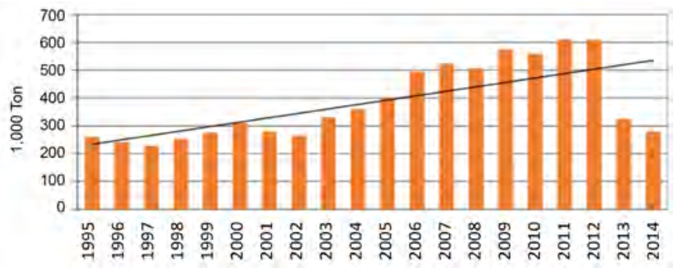

Figure 3. Aquaculture shrimp production of Thailand in 1995-2014 (Information and Communication Technology Center, 2016)

In terms of aquaculture species, Thailand has also been a leading exporter of cultured marine shrimps since 1992 (Ekmaharaj, 2006), when the production was still increasing steadily, reaching 609,700 MT in 2012 with a market value of US$ 3,047.4 million. After that, the production dramatically decreased (**Figure 3**) due to serious disease outbreaks in culture areas. As reported, most of Thailand's shrimp production is destined for export, with only 15 % consumed domestically (Ekmaharaj, 2005).

Impacts of Marine Shrimp Culture on the Environment

The development of marine shrimp farms, not only in Thailand but also in other countries have been blamed for its impacts on the coastal environment. Ekmaharaj (2005) identified the impacts of shrimp culture on the environment that need to be addressed. These include: loss of mangrove areas, salinity intrusion into ground water aquifer, degradation of coastal environment and resources, and unsustainability of pond nutrients due to excessive use of chemicals and drugs.

Loss of mangrove areas

At the start of the intensive shrimp aquaculture period, mangroves in coastal areas had been slashed for the development of shrimp culture farms. Recognizing the negative effects of such development on the coastal and fishery resources, the Government of Thailand launched several projects to stop mangrove destruction, and rehabilitate the mangrove and coastal environments.

Such projects which are aimed at minimizing mangrove destruction included the promotion of coastal zone management, and construction of sea water irrigation system for shrimp farms which had been piloted in Chanthaburi Province under Kung Krabaen Bay Royal Project. Through the latter project, the mangroves have been preserved while shrimp farms could still be constructed behind the mangrove areas.

Figure 4. Mangrove conservation and responsible shrimp farm operation at the Kung Krabaen Bay Royal Project: **(A)** shrimp farms constructed behind mangrove area; **(B)** zoned shrimp culture area for supplying clean sea water through the Project's Sea Water Irrigation System; **(C)** the Kung Krabaen Bay Royal Project showing the Bay, where waste water is discharged after being filtered by mangroves

In the Sea Water Irrigation System, clean sea water is pumped to supply every shrimp farm under the Project (Tookwinas (Ekmaharaj) and Yingchareon, 1999). When the shrimp stock is harvested, the effluents would be kept in sedimentation ponds before these are discharged to Kung Krabaen Bay through the mangroves that serve as filter for the waste water (**Figure 4**).

Salinity intrusion into ground water aquifer

Some operators of shrimp farms near rice fields could have unintentionally discharged pond sea water near the rice fields impacting on the cultured rice and the environment including the ground water aquifer. In addressing this concern, the Government of Thailand enforced a regulation that aim to protect the rice fields and the environment, by not allowing the discharge of mangrove filtered waste water from shrimp farms into rice fields and their nearby areas.

Degradation of coastal environment and resources

After harvesting the shrimp stock, shrimp farmers are required to remove the mud sediments out of the culture ponds, put these into a mud disposal pond, and the pond bottom is sprayed (**Figure 5**) to eliminate predators (Tookwinas (Ekmaharaj) and Songsangjinda, 1999). Every shrimp farm in Thailand has therefore been required to have a mud disposal pond and water discharge treatment pond to conserve and protect the coastal environment.

Figure 5. Pond bottom being sprayed after shrimp stock is harvested to eliminate predators, prior to drying and preparing the pond for another culture cycle

Moreover, as means of minimizing the loading of nutrients into coastal environment, the use of auto-feeding system is being recommended for intensive shrimp farming (**Figure 6**). This would minimize the waste materials from excess feeds as the cultured shrimps would be able to eat all the feeds, improving the food conversion ratio (FCR) from an average of 1.5 (without auto-feeding) to 1.2 (with auto-feeding). In this system, the concentration of effluents is less compared to ponds that do not use auto-feeder. These practices are actually in accordance with the Hazard Analysis and Critical Control Point (HACCP) in shrimp aquaculture (Tookwinas (Ekmaharaj) and Suwannarangsi, 1996).

Figure 6. Auto-feeding system in operation in intensive shrimp farm in Thailand

Unsustainability of pond nutrients due to excessive use of chemicals and drugs

Nowadays, the use of many chemicals and drugs in shrimp farms had been found to cause negative impacts. In Thailand, a law has been enforced controlling the use of some chemicals

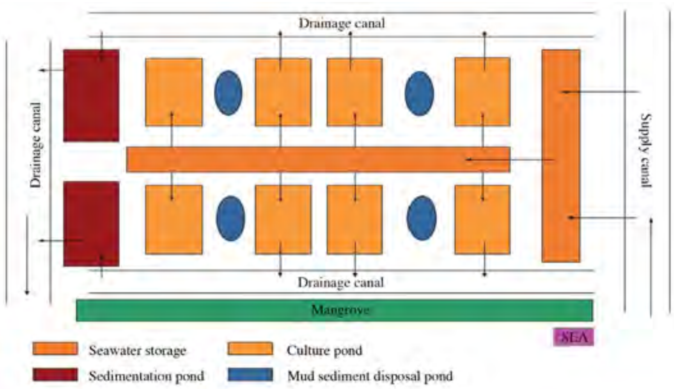

Figure 7. Recommended layout of a responsible intensive shrimp farm (Ekmaharaj, 2005)

and drugs in aquaculture. In addition, a concept farm layout had been promoted to minimize the impacts of shrimp farms on the coastal environment and resources. The concept diagram (**Figure 7**) shows and guides the shrimp farmers on how to layout and construct their farms, and the shrimp farmers in Thailand are encouraged to adopt this concept diagram in constructing their farms (Ekmaharaj, 2005).

History of Marine Shrimp Culture in Thailand

Before 1973, there was only traditional culture for marine shrimps using the fry of banana shrimp (*Penaeus* spp.) collected from the wide. When hatchery production of banana shrimps was successful in 1973, the Department of Fisheries of Thailand (DOF) promoted the stocking of banana fry in traditional farms. Farm size during that time was about 2-3 ha/pond and partial feeding of the stock was adopted. Starting in 1985, when shrimp farmers in Thailand and Taiwan practiced the intensive culture technique for tiger shrimp that was introduced from Taiwan, the culture area had increased and the technique was adopted immediately by many farmers. However, since chemicals were widely used, diseases outbreak subsequently occurred. This encouraged the farmers to adopt biological culture techniques starting in 1994. Then, white shrimp was introduced to replace the tiger shrimp. After that, a few farmers started to follow the organic farming of shrimps that make use of more environmental management techniques (Ekmaharaj, 2005). The trend of marine shrimp aquaculture in Thailand is summarized in **Figure 8.**

		Use of Chemicals and Drugs	Biological +Chemical Management	Biological+ Environmental Management
			→	→
Traditional Farms	Semi-intensive Farms	Intensive Farms		Organic Farms
→	→	→		→
1973	1985	1994	2007	Present

Figure 8. Development of marine shrimp aquaculture in Thailand (Adapted from Ekmaharaj, 2005)

Figure9. Shrimp culture in Thailand: intensive large-scale marine shrimp farm *(top)*; top view of large-scale intensive shrimp farm *(middle)*; and typical small-scale intensive shrimp farm *(above)*

Figure 10. Typical 4-wheel aerator

Figure 11. Ten 4-wheel aerators

Intensive marine shrimp culture in Thailand

Intensive marine shrimp culture could be conducted in small-scale or large-scale farms (**Figure 9**), and the techniques used are not different. The stocking density of shrimp fry at PL 10-13 should be from 40 to 100 PL/m^2, in order to attain a survival rate of 60-80 %, and FCR of about 1.4. Through this scheme, the yield could be from 6,000 to 9,500 kg/ha.

Farm equipment (aerator)

Many types of aerators are used in shrimp culture ponds. The most typical type is four-wheel (**Figure 10**) which had been in operation in Thailand from the early stages of intensive shrimp farming. This aerator could be set in a 5-6 ha pond. Later, this had been redesigned by adding more wheels to the aerator to increase speed and supply more air (oxygen) in the ponds (**Figure 11**). This was followed by the spiral aerator (**Figure 12**), which can supply more oxygen and save on electricity.

Some farms in Thailand designed their own types of aerators believing that their newly-designed aerators would supply more oxygen in every level of sea water in the ponds and down to the pond bottom. One such innovation is shown in **Figure 13**, where water in-jet is installed under water in shrimp ponds. However, this type is not very much widely used.

Figure 12. Spiral aerator

Figure 13. New type of aerator with in-jet system installed under water in ponds

Tiger Shrimp Aquaculture of Thailand

Tiger shrimp was the original cultured species in intensive shrimp farms in Thailand, when shrimp farming was first developed in 1985. The country's production from marine shrimp aquaculture dramatically increased because of the tiger shrimp, of which about 90 % of the production was exported. However, many constraints impede the sustainability of tiger shrimp culture leading to the country's decreasing production from shrimp aquaculture. These constraints were mainly related to water pollution in culture areas followed by disease outbreaks caused by the White Spot Syndrome Virus (WSSV). Since recovery of the shrimp production was quite difficult to achieve, the SPF white shrimp (*Litopenaeus vannamei*) was introduced to the country in 2002 (Ekmaharaj, 2005). When the shrimp culture industry of ASEAN Member States suffered another major blow due to the incidence of early mortality syndrome (EMS) in cultured marine shrimps during 2010-2011, production of the white shrimp dropped rapidly in most countries including Thailand.

Since it was found that tiger shrimp could tolerate EMS, some Thai farmers are now going back to the culture of tiger shrimp using disease-free broodstocks produced by private companies in Thailand. Their decision has been triggered by the increasing market demand for big size tiger shrimp in China, and also because the supply for white shrimp in the world market is believed to be already over the demand. This is also an opportune time to look back at the culture of the tiger shrimp which is an indigenous species in the Southeast Asian region.

Present Culture Techniques for Tiger Shrimp

The present culture techniques for tiger shrimp that is now widely used among Thai farmers involve three key factors: (1) clean pond water, (2) clean pond bottom, and (3) clean shrimp fry or disease-free shrimp fry (Surasak, 2018; Hemarak, 2018). Disease-free tiger shrimp fry (**Figure 14**) is now widely stocked in ponds to prevent diseases that might be carried by wild-caught fry into the culture ponds. These disease-free tiger shrimp fry come from disease-free broodstocks (**Figure 15**) produced in controlled broodstock farms (3-5 pc/kg) since most broodstock from the wild could also be carriers of diseases.

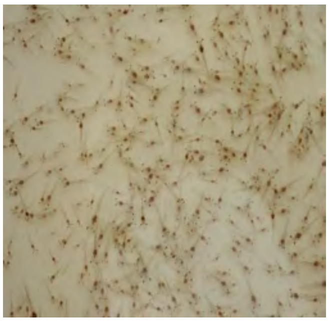

Figure 14. Healthy tiger shrimp fry at PL 15-20 ready for stocking in ponds

Figure 15. Disease-free tiger shrimp broodstocks are now produced by private companies in Thailand

Pond preparation

Pond bottom should be prepared very well. All polluted materials from the previous cropping should be removed and taken to the mud disposal pond. The pond bottom should be dredged (**Figure 16**) to get rid of waste materials, which should be pumped out from the ponds (Tookwinas (Ekamaharaj) and Songsangjinda, 1999). By making use of a machine (**Figure 17**), the pond dike should be packed to prevent the pond water from leaking.

Figure 16. Dredging pond bottom to remove waste materials

Figure 17. Packing dikes properly to prevent pond water from leaking

Natural live food organisms (planktons)

Natural live food organisms (planktons) should be cultured before fry is stocked in ponds in order that the stocked fry could immediately have live food. During pond preparation, fertilizers, either dry manure or chemical fertilizers, should be put in culture ponds to produce live food organisms or planktons, before clean sea water is pumped into the ponds. If necessary, aerators could be used. It is only after a month or when plankton bloom is observed, that shrimp fry could already be stocked.

Recommended stocking density

Stocking big size tiger shrimp fry about PL15-PL20 is recommended, at stocking density of 30 PL/m^2. The tiger shrimp fry should come from hatcheries that are standard code certified as shown in **Figure 18** (in the case of Thailand: ISO/IEC 17065:2012 of the Department of Fisheries of Thailand). The shrimp fry should be transported from hatcheries for stocking in ponds (**Figure 19**) within the shortest time possible of about 2-3 hrs.

Figure 18. Typical certified (ISO/IEC 17065:2012) tiger shrimp hatchery in Thailand

Figure 19. Stocking of shrimp fry in a culture pond

Sea water storage

Sea water storage pond (**Figure 20**) should have enough capacity to supply clean sea water to culture ponds. The sea water is usually stocked for some period of time, using the techniques of purifying or cleaning the sea water. It is necessary that the sea water is stocked in ponds for a few months to settle down all detritus materials and excess nutrients, especially in cases where the water is pumped from newly harvested shrimp ponds. Some chemicals such as chlorine could be applied to kill the bacteria that settle down in the water although it is always the best to promote non-use of chemicals.

Figure 20. Sea water storage in a Thai farm

Feeding

Auto-feeding machine should be used in order to minimize nutrient wastes (**Figure 21**), as it has been found out that excess feeds are less in auto-fed ponds than in manually-fed ponds, and the FCR could also be improved from 1.5 to 1.2 or even less. Feeding rate should be checked daily and adjusted accordingly using a dip net as shown in **Figure 22**.

Figure 21. Use of auto-feeding machine

Figure 22. Feed checking

Predators

Some predators such as mud crab, snake and others that prey on the shrimps stocked in ponds especially at night, should be prevented. One of the easiest and cheapest methods of preventing the entry of predators in ponds is by installing nets on pond dikes as shown in **Figure 23**.

Figure 23. Installing nets on dikes would prevent entry of predators into the pond

Monitoring shrimp health and water quality

Shrimp health is the key success in shrimp farming. Good health of the stocks means better growth rate, high survival rate and high yield. Therefore, the health of shrimp stock should be routinely monitored and examined (**Figure 24**), and if any incidence of infection or any pathogen is observed, treatment should be applied immediately.

Water quality in ponds should also be monitored and analyzed (**Figure 25**), as water quality is another factor that could

Figure 24. Regular monitoring of health of shrimp stock in laboratory

Figure 25. Monitoring water quality on site

affect the shrimp's health. Some water parameters that must be monitored daily are pH, dissolved oxygen and water temperature, although some parameters could be analyzed weekly or monthly.

Harvesting and marketing

The harvested shrimps should first undergo size selection near the culture ponds (**Figure 26** and **Figure 27**). The shrimps for processing should be transported to processing plants within a few hours after harvest in order to keep its quality. Tiger shrimps produced in Thailand are now being transported live to Mainland China directly from accredited shrimp farms in Thailand commanding good prices (**Figure 28** and **Figure 29**). Japan is also looking for prospective suppliers of tiger shrimps for consumption in the country. Then the packed shrimps could be loaded into a cold storage truck (**Figure 30**).

Figure 26. Size selection of harvested shrimps for export

Figure 27. Sorted shrimps by size prior to loading in containers

Figure 28. Packing of live shrimps for export

Figure 29. Live shrimps loaded in containers for export

Figure 30. Cold storage truck for transporting shrimps for export

Recently, new demand for boiled shrimps (tiger and big size white shrimps) has been expressed by China. These prospective markets encouraged the Thai shrimp famers to improve production of the tiger shrimp which has already been increasing from 9,000 to 10,000 MT/yr in 2016-2017 (**Figure 31**). It is believed that China would need up to 80,000 MT of fresh shrimps per year which could be provided by the Southeast Asian countries. The main market for boiled marine shrimp is still China, which requires about 100,000 MT/year and is currently being served by South American countries. To tap this new market for shrimps, farm production of the tiger shrimp which is an indigenous marine shrimp species in Southeast Asia, should be increased to cater to the demand of the new markets in China and Japan.

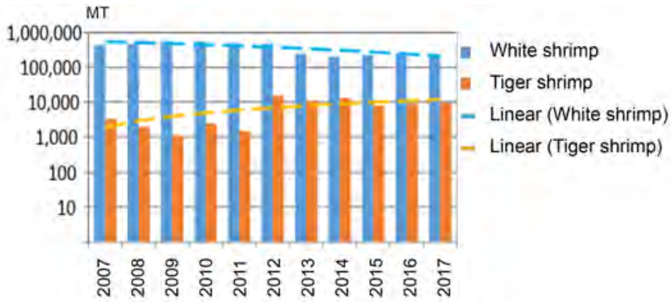

Figure 31. Thailand's production of white and tiger shrimps in 2007-2017 (DOF, 2018)

Potentials of Marine Shrimp Culture in Southeast Asian Countries

FAO (2016) reported that Indonesia is the top producer of marine shrimps in 2014 at about 620,000 MT, followed by Viet Nam at 510,000 MT. Thailand comes next with production of about 300,000 MT (**Figure 32**).

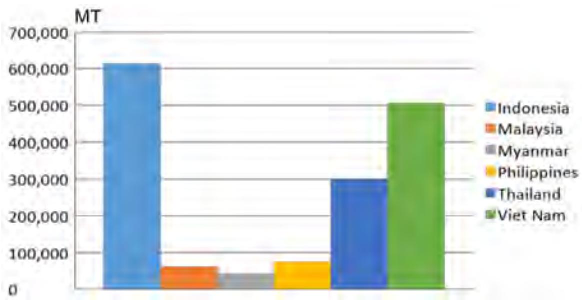

Figure 32. Production of marine shrimps of selected Southeast Asian countries in 2014 (FAO, 2016)

Reviving the Tiger Shrimp Aquaculture Industry of Southeast Asia

The prospects of reviving the tiger shrimp aquaculture of Southeast Asia are high. As shown in **Box 1**, the strengths outweigh the weaknesses, and the opportunities are prevalent in Southeast Asia (Ekmaharaj, 2006). Therefore, reviving the culture of the tiger shrimp which is indigenous in Southeast Asia should be considered provided the HACCP for shrimp aquaculture and GAP Shrimp are observed and practiced.

Future Direction

The future direction for marine shrimp aquaculture in Southeast Asia should be focused on minimizing the environmental impacts and should be aimed at attaining sustainability of the industry (**Box 2**).

Box 1. On the revival of the tiger shrimp aquaculture in Southeast Asia

Strengths
- Availability of labor in many countries, except Thailand and Malaysia as well as Singapore and Brunei Darussalam
- Tiger shrimp is an indigenous species in Southeast Asia
- Tiger shrimp can tolerate early mortality syndrome (EMS)
- Suitable culture areas: Viet Nam has very long coastline (3600 km); Indonesia and the Philippines have large numbers of islands; although there are no more new areas for expansion in Thailand and Malaysia
- ASEAN has very long experience in aquaculture and shares very high portion of aquaculture production

Weaknesses
- Diseases outbreak remains a very complicated problem, and there is still no effective solution to eradicate viral diseases and bacterial infection such as EMS
- Natural disasters such as typhoon and tsunami can occur in many countries (Viet Nam, Philippines and Indonesia) bringing very serious damages to shrimp culture areas
- Culture techniques need to be improved along with culture period progression or from time to time (crop to crop), since some problems such as disease outbreaks can easily occur, resulting in very high mortality

Opportunities
- With the long history of aquaculture in the ASEAN, there are still opportunities for the development of tiger shrimp culture in the region

Box 2. Future direction for the marine shrimp aquaculture in Southeast Asia

- Expansion of culture areas should no longer be allowed due to land limitations while there are still activities such as tourism and other industries that are also suitable to be located in coastal areas
- Ensuring that the impacts of marine shrimp culture on the environment is minimized if not avoided
- Continuing research is still necessary to generate much better culture techniques and higher yields per unit area
- Culture of the tiger shrimp should be pursued rather than another alternative species, as the cultured tiger shrimp has already secured a niche in the global market
- Farmers should form themselves into clusters to be able to avail of better access to: information on the advances of culture techniques, the privileges during auctions of raw materials to be used in farms, and the facilities such as cold storage among others for big volumes of harvested shrimps during marketing

Acknowledgement

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About the Author

Dr. Siri Ekmaharaj served as Secretary-General of SEAFDEC from 2005 to 2009. He is now the Director of the Inspection and Certification Division, Asia Medical and Agricultural Laboratory and Research Center in Bangkok, Thailand (E-mail: *ekmaharajsiri733@gmail.com*).

Capacities for Managing the Development of ASEAN Aquaculture

Pedro B. Bueno

Two core capacities are necessary to manage the development of any economic sector, *e.g.* fisheries. These are **governance**, in order that development is geared to the goals of society, directed towards those goals, and growth is orderly; and **innovativeness**, so that the resources are utilized with utmost effectiveness and efficiency, and producers have the ability to supply products in the quantity, reliability and form that meet market requirements, anticipate demand, and better yet, create demand. These two are linked: **good governance** provides a favorable environment as well as encouragement for science and technology -- and the brains that produce them -- to flourish; while **innovations** not only enhance the progress and welfare with new products, systems and processes but also support and facilitate better governance. In December 2015, full economic integration came into reality in the ASEAN with the establishment of the ASEAN Economic Community (AEC) which aspires to be a single market and production base, a highly competitive economic region, a region of equitable economic development, and a region fully integrated into the global economy (ASEAN, 2015). The aquaculture development strategies of the ASEAN Member States (AMSs) are aligned with such regional aspirations, but the question is whether the sector has the capacity to address the concerns over, meet the challenges of, and realize the aspirations for aquaculture development. Based on a review made by the author for an ASEAN-EU Project, this article provides positive indications of the region's capabilities in sector management, and science and technology.

In 2014, the AMSs produced more than 25 million metric tons of aquaculture products including plants, accounting for about 21 % of the total global output, and 53 % of the total fishery production of the ASEAN region, up from 21 % in 2000. The average yearly growth of ASEAN aquaculture production over the 15-year period from 2000 to 2014 was 14 %. This reflects an increase on average of 1,326 thousand metric tons a year (SEASOFIA, 2017).

Development of the sector in general has become orderly, with fewer conflicts and a greater ability to comply with legally prescribed and voluntary standards. The ASEAN-EU Project - Sustainable Ethical Aquaculture Trade (SEAT), for instance found no major health hazard related to pathogens from seafood farmed in Thailand and Viet Nam that are supplied to EU citizens. A significant reduction in the use of antimicrobials for shrimp in Thailand was noted, when not too long ago, shipments from both countries were returned or burned. This indicates two things: the sector has become more environmentally and socially responsible, and the management mechanisms — command and control, market-based, and voluntary or self-management — have become more effective.

The Southeast Asian region has had a long history of capacity development in aquaculture and allied sciences through various arrangements, among which had been scientific collaboration in inter-regional projects. This has provided a firm foundation for further cooperation in Science and Technology (S&T) between the ASEAN and other regions, and among the AMSs. The source of much of the research manpower is mainly the universities followed by government R&D institutes and in some countries, the industry, *e.g.* Thailand's CP Foods, Indonesia's CP Prima.

Linkages of the three main players, *i.e.* academic/scientific-industry-government, have strengthened the industry and provided a mechanism for collaborative action in the diagnosis of industry problems and search for, management of the development, and promotion of the solutions to industry problems. This tripartite cooperation at the national level has been enriched and bolstered by: (i) collaborative assistance — through multilateral and bilateral cooperation — of centers of excellence in other regions that have included the EU, USA, Oceania, as well as Japan and other Asian countries; (ii) technical assistance from regional indigenous organizations and international development assistance agencies; and (iii) intra-ASEAN cooperation under various technical cooperation frameworks.

Aquaculture Resources in the ASEAN

The physical resources available for aquaculture have been slowly and steadily declining from numerous pressures, *i.e.* conversion to other uses, domestic, agricultural and industrial demand on freshwater supply, and degradation of the water and soils. But there remains a significant coastal resource that could be tapped for mariculture with such systems as cage culture and the integrated multi-trophic aquaculture or IMTA (Sorgeloos, 2014).

Land and Water Resources

Among the AMSs, Indonesia has the longest aggregate coastline in the world and 55 % of the ASEAN coastal resources, followed by Philippines with 20 % and Myanmar with 8 %. Coastal length can indicate the potential resource available for aquaculture production. In terms of inland area, Indonesia has likewise large resources with 42 % of the ASEAN resources followed by Myanmar with 15 % and Thailand with 12 %. But a better indicator of potential than available land is the availability of renewable freshwater resources per square kilometer per year. On this, Indonesia has 32 % of the ASEAN's followed by Myanmar at 18 %, Viet Nam 14 %, and Malaysia 9 %. Against the current levels of exploitation, Indonesia also has a very large potential for further freshwater aquaculture development.

Species and Systems

WorldFish (2011) had noted that the region has a diverse mix of aquaculture systems and species. After seaweeds (mainly grown in Indonesia and the Philippines), catfish constitutes the largest species group making up about 15 % of the total production, much of it by Viet Nam. Marine shrimps and freshwater prawns, carps, and other finfish also made up a large proportion with 13 %, 12 % and 11 % of the total production, respectively. Tilapia is the number one freshwater species cultured in Thailand and the Philippines. The other important freshwater species are the clarias catfish and snakehead (*Channa* sp.). Indonesia and Malaysia also have a significant production. Green mussels and oysters are important in Thailand and the Philippines, and blood cockle (*Anadara* sp.) in Malaysia. Myanmar has significant production of the Indian major carps, especially rohu (*Labeo rohita*). Cambodia has been growing snakehead (*Channa* sp.) in freshwater cages, and tilapia and some carps in earthen ponds. Marine culture species in Cambodia are the Asian sea bass (*Lates calcalifer*) and some grouper species. Other species in the ASEAN, which are seldom recorded include the spiny lobster, *Panulirus ornatus*, grown in shallow coastal water pens from wild seeds in Viet Nam and the Philippines, ornamental fishes and aquarium plants (a significant industry geared for export in Malaysia, Thailand, and Indonesia with Singapore usually as the assembler and shipper to destination markets), and amphibians (frogs and soft-shell turtles in Thailand and Indonesia). Trout has been introduced in Viet Nam as well as sturgeon, although trout production is yet minimal and sturgeon is concentrated in a single production site in northern Viet Nam (Le Thanh Luu, *pers.comm*.).

Ponds and off-bottom (cage) culture constitute the most common production systems with 44 % and 38 % of all systems, respectively. Nearshore cage culture of marine finfish is significant in Indonesia, Thailand and Viet Nam as well as in Malaysia and Philippines. Cage culture of milkfish, a staple species along with tilapia, is expanding in the Philippines. Cobia (*Rachycentron canadum*) was introduced and caught on rapidly in Viet Nam although there is a small production in southern Thailand much of it from demonstration cages of the Department of Fisheries.

Shrimp and reef fishes (mostly grouper) are the high-value species, where shrimp is internationally traded and reef fishes are mostly traded in the regional markets, the bulk going to China. Shrimp production in Thailand, Viet Nam and Malaysia suffered a setback starting 2011 with the outbreak of Acute Hepatopancreatic Necrosis Disease (AHPND). Thailand for instance saw its yearly production plummet from approximately 600,000 tons in 2010, before the widespread outbreaks of EMS/AHPND caused a drop, to 250,000 tons in 2013. Recovery, mostly aided by innovations in technology and practices, has been steady.

Structure

The ASEAN aquaculture is mostly market-oriented although pockets of subsistence type farming could be seen in some remote areas in Lao PDR, the northern and hilly regions of Viet Nam, Myanmar and Indonesia. Timor Leste, which lies in the Southeast Asian region, has mostly family-run subsistence culture of tilapia and carps but its seaweed culture is export-geared. While the sector features a few large vertically integrated, *i.e.* CP Foods/CP Aquaculture in Thailand and ALSONS Aquaculture in the Philippines, and horizontally integrated, *e.g.* CP Prima Indonesia, industrial operations, its most significant feature is the domination by small-holder producers and mostly small- to medium-scale enterprises handling the products after the farm gate. Feed and veterinary supplies come from large national, regional and multinational operations but seed supply is mostly from small- and medium-sized hatcheries. Integrators, processors and exporters are medium to fairly large operations. Indeed, livelihood opportunities along the aquaculture value chain are aplenty, and the demand for farmed aquatic products is increasing.

Prospects for Development

Among the top 15 aquaculture producers in the world, four are AMSs, *i.e.* Indonesia, Thailand, Viet Nam, and the Philippines (SOFIA, 2014). The region will experience continued growth in seafood production and demand. Forecasts based on current population trends, and maintaining annual per capita consumption of 30.1 kg/year, predict 2.4 million MT of additional demand by 2020 and 5.0 million MT by 2030. Aquaculture is expected to be a major supplier to meet this demand as the volume of wild catch continues to stagnate. Future demand depends partly on population growth, but primarily on the fact that wealth and urbanization will continue to increase. Helping meet higher demand is an increasingly efficient marketing mechanism. The growing middle class in the ASEAN is where the demand for fish will rise significantly. The ASEAN demand for meat will also increase, which will bring its own environmental demands. In this respect, fish have an important advantage over livestock because they are more efficient at converting feed into biomass. Aquaculture has clear benefits in this respect over meat production (WorldFish, 2011), and aquaculture systems emit much less greenhouse gas than livestock husbandry systems.

Issues and Concerns

This encouraging picture notwithstanding, the potential of aquaculture to contribute further to livelihoods, food security and income is increasingly at risk from various forces sweeping the sector. The rapid growth of aquaculture itself has raised concerns over the environmental sustainability of that growth. Central to these are the demands aquaculture places on biophysical resources (such as feed and seed) and on the environment from its discharges or wastes (WorldFish, 2011). Even if more resources are potentially available, expansion is not unlimited, markets and profitability cannot always be guaranteed, standard production models cannot be applied everywhere, and growth could move fast beyond the reach of the poor. On top of the concerns over resource sustainability are those that come under the broad ambit of environmental and social responsibility. These are reflected in the requirements for certification of aquaculture products, eco-labels, tighter food safety and environmental standards, and recently, fair labor and employment practices, and assurance of decent work along the value chain.

Conflicts and competition over common resources are old concerns. Competition with suppliers of other similar products or different product forms that satisfy the same consumer need is not new. Then, there is the occasional economic and financial crisis. All these are now exacerbated and amplified by the hazards from climate change and variability. Brought down to the practical level — from the standpoint of an aquafarmer — these concerns are essentially production and marketing risks. Amid such circumstances, the Thirty-fifth Session of the Asia-Pacific Fishery Commission in May 2018 in Cebu, Philippines identified two sets of challenges that confront fisheries and aquaculture governance (**Box 1**), and recommended a number of regional strategies and actions to address these concerns. The capability of the ASEAN to support these strategies and actions is also assessed in this article.

Box 1. Challenges in the development and use of planning management tools to aquaculture governance

I. On the development and use of planning and management tools

1. Lack of established laws and regulations or weak implementation of existing regulations in supporting the adoption of the tools
2. Lack of common recognition of the need to adopting the tools at different levels of government authorities
3. Insufficient financial support and human capacity
4. Difficulties in adapting the tools to different culture systems and environments, and to multi-species culture systems

II. On institutional support to the enforcement of laws and regulations

5. Lack of strong political will and institutional support to enforce established laws and regulations
6. Limited concerted efforts at regional, national and local levels to strengthen aquaculture regulations and governance
7. Inadequate institutional and financial support, and human capabilities at national and regional levels
8. Lack of good understanding to the importance aquaculture regulations, Ecosystem Approach to Aquaculture (EAA), and zonal development among policy makers and stakeholders.
9. Inadequate inter-sectoral collaboration in regulating and planning the aquaculture industry

The ASEAN aquaculture needs to be ever more economically efficient, and environmentally and socially responsible in production, management, processing, and marketing to stay economically viable, be socially relevant, and remain competitive. These are underpinned by innovation, and the relationships among these basic components of sustainable development as illustrated in **Box 2**, which also shows the linkages between the three pillars of development and the institutional support needed to foster social, economic and ecological responsibility.

Capacities

The capacities of the AMSs in terms of governance and pursuing innovations have also been assessed. **Governance** comprises a policy framework, a strategy and plan, laws, enabling regulations, implementing guidelines, and administrative machinery. This set of command and control mechanisms for governance is complemented and usually enhanced by three other instruments: the market, voluntary or self-management arrangements, and stakeholder participation. In assessing the capacity for **innovations**, some indications were used, *i.e.* from breeding and genetic improvement, health management, product safety and quality assurance, production systems improvement, and post harvest including product transformation.

Governance capacity in the ASEAN: a broad assessment

Two sources provide the basis of this assessment (**Box 3**): (1) "Commercialization of Aquaculture Development in Southeast Asia" conducted by the Food and Agriculture

Box 2. Relationship among the four basic components of sustainable development

SOCIAL	ECONOMIC	ECOLOGICAL
Social stability and equity are requisites of a conducive climate for investments in economic development and environmental management	Economically developed communities tend to pay more attention to and allocate resources for environmental improvement, where economic development in turn fosters social stability and could encourage equity	Healthy and resilient ecological systems can better support economic development and contribute to social resilience
INSTITUTIONAL		
Effective governance underpins and fosters social accountability, responsible and orderly economic growth, and environmental responsibility		

Organization of the United Nations (FAO) and the Network of Aquaculture Centres in Asia-Pacific (NACA) from 2003 to 2005 (Hishamunda *et al*., 2009); and (2) brief overview of the aquaculture development status of each AMS. Every country has a policy on aquaculture, a national strategy and plan as well as the administrative machinery for regulation, management and development. Even in some countries where aquaculture is still governed under a Fisheries Act, specific policy and programs have been drawn for aquaculture development. The fisheries development strategy and plan of Cambodia has a prominent emphasis on aquaculture development and its role in food security and poverty alleviation in rural communities.

Box 3. Broad assessment of governance capacity in the ASEAN
Legislative and regulatory framework. In Thailand, aquaculture is administered under a Fisheries Act. By recognizing aquaculture explicitly as a legitimate activity, Myanmar, with its 1998 Aquaculture Act, encouraged illegal operations to be registered, increasing the number of registered legal farms. Even without specific legislations all countries in the region regulate aquaculture. However, lack of capacity and cost of monitoring limit the effectiveness of such regulations. Preservation of mangroves is among the policy targets in all the countries (except Lao PDR). In Malaysia, there is no aquaculture law that controls aquaculture development, except for the 1990 Fisheries (Marine Culture System) regulations that relate to net cages and mollusk culture in the marine environment. Under the 1985 Fisheries Act, the Minister of Agriculture is responsible for aquaculture regulations, and since land and inland waters are under state jurisdictions, planned new regulations are proposed to state governments for adoption and enforcement, which include the requirement that all aquaculture farmers must obtain a license and a permit. In Thailand, farms already operating in mangrove areas can continue but no new leases are granted. Viet Nam gives no official leases for mangrove areas. Viet Nam has promulgated a Law on Investment (59/2005/QH11) regulating investment activities – in all sectors including aquaculture -- for business purposes; defining the rights and obligations of investors; providing guarantee of lawful rights and interests of investors; and encouraging investments with incentives.
a. ***Zoning.*** Indonesia and Malaysia impose zoning for aquaculture management. In Indonesia, for land use planning there are aquaculture integrated zones, where only in particular zones can certain species be farmed, and where technical knowledge is disseminated to fish farmers, all of whom are growing the same species. Zoning in Malaysia is under federal jurisdiction and applied only to marine areas. The Philippines has established more than 60 Mariculture Parks for small investors in cage culture since 2001. Viet Nam has adopted a safe aquaculture zone concept and designated several shrimp growing areas as safe aquaculture zones.
b. ***Aquaculture leases and permits.*** Property rights provide security to investors and reassurance to lenders. In the Philippines, property rights are well established, but, in Myanmar, there are conflicts due to scarce resources in the public domain such as marine waters or land. Changes in land use regulations in Myanmar permitted rice fields in the seasonally saline areas of the delta to be converted into shrimp farms, resulting in dramatic expansion of shrimp farming in the coastal areas. In Cambodia, there are few regulations controlling freshwater aquaculture, but operations beyond a (small) size require permits and licenses to operate in its coastal areas. Malaysia's aquaculture investment zones (AIZ) are the basis for large farms obtaining a Temporary Ownership of Land, which can be on a 30-year lease, and renewed annually. Here, no license is required to run a land-based farm but a permit is required for cage culture in marine waters, and the new regulations require a license to run all aquaculture farms and permission to construct a building. In Myanmar, leases can be for 30 years, renewable for land beyond a certain distance from the waterline. The Philippines has used leases as a policy to stimulate aquaculture, with mixed results. Viet Nam provides long leases for aquaculture and also guarantees a rapid response to license applications.
c. ***Water regulations.*** As a common resource its allocation among competing users can be critical to the development of aquaculture. When shrimp diseases struck the region in the early 90s, the late King Rama IX initiated the development of a marine irrigation project in Kung Krabaen Bay to protect the shrimp industry which was then concentrated along the Gulf of Thailand (eastern coasts). Here, centralized seawater supply drawn one kilometer from the shoreline, clean and not likely to be polluted by shrimp farm effluents, is provided. In Myanmar, aquaculture has been hampered by the government's priority towards agriculture so that in the allocation of water, agriculture has priority over aquaculture. In the Philippines, one cannot dam flowing water for exclusive private use without a permit or license from a national agency mandated to regulate water use. Full payment is required even if the irrigation water is merely diverted to a fishpond and returned to the irrigation canal. In Thailand and most other AMSs putting up any structure in open water areas, such as fish traps and fish cages, requires a permit from the local or regional unit of the national fisheries agency. In Indonesia, Philippines, and Thailand, local government units have full authority over coastal waters up to what is considered national waters, which in the Philippines is 15 km from the coastline.
d. ***Environmental policy and regulations.*** Government policies are often reactive rather than proactive in nature. A classic case is the government policy towards aquaculture development in mangrove areas. Early movers in shrimp farming, such as the Philippines and Thailand, allowed unrestricted development at considerable environmental cost. Both countries have since followed a more cautious approach to brackishwater farming, with an emphasis on environmental and social sustainability. Most countries have recognized the dangers of uncontrolled development, and restrict coastal access through zoning or through setting up of maximum limits. In Indonesia, an Environmental Impact Assessment (EIA) is required for farms of 50 ha or more in brackishwater areas, and for larger farms in lakes and in marine waters, and a Code of Conduct with producer organizations has been promoted. In Malaysia, there is also a voluntary code of conduct. The 1998 Law in Myanmar, not only promoted aquaculture by reducing land disputes, but also encouraged more sustainable practices, and another law conserves the oyster fishing grounds. The Philippine Government has imposed a total ban on any further development of the remaining mangroves, and mangrove reforestation is being encouraged. In Viet Nam, the government sets no ceiling as to the area of public land that can be applied for and developed, but the area granted is based on an approved business plan and presumably the financial capability of the applicant.

Box 3. Broad assessment of governance capacity in the ASEAN (Cont'd)
e. ***Policies and regulations on aquaculture products and contaminants.*** Standards of quality and hygiene, labor regulations, animal welfare and GMOs, can and have been used as non-tariff barriers. For exports, these regulations must be complied with, although domestic markets increasingly demand them as well. • In Indonesia, policies are based on the FAO Code of Conduct, where seed is inspected for quality according to ISO 9000 standards. All imported fish must have a health certificate and there are provisions planned for GMOs. The Fish Quality and Processing Development supervises the provincial laboratories for fish inspection and quality control, which are responsible for certifying the end product according to Hazard Analysis and Critical Control Point (HACCP) and the Integrated Quality Management Program of 2002. • The Malaysian Government has taken a number of steps to ensure that products sold domestically are safe and that fish exported meet with international standards. A Fish Inspection and Quality Control (FIQC) system has been implemented. Health Certificates are issued by the Health Ministry, and an Inspection Certificate by the FIQC in accordance with the Codex Alimentarius. • In Myanmar, there are some regulations for environmental issues but there are no regulations for farmed fish. • Thailand assures the quality and safety of its aquaculture products, and controls chemical use in aquaculture through a Chemical and Drug Quality Control Board with a traceability procedure, and a Fisheries Products Quality Control Board with registration, inspection, and enforcement. • Viet Nam's HACCP-based farm level Safe Quality Food Standards specifically for pangasius farming aims to develop full traceability of pangasius from "egg to export". Developed by the National Fisheries Quality Assurance and Veterinary Directorate in partnership with the Swiss auditing company Societe Generale de Surveillance (SGS), the system was built on SGS's Safe Quality Food Standards based on the HACCP system (Bush *et al*., 2009). • Viet Nam provides an example of a comprehensive regulatory framework for the responsible management of the animal feed (including fishfeed) industry with Decree No. 39/2017/ND-CP issued on April 4, 2017. The Philippines and Thailand have long had in place feed standards and regulations reinforced by better management practice guidelines that assure the production and sale of efficient, quality and safe feed products, at reasonable cost, and used effectively for better FCR and low environmental impacts.
f. ***Voluntary management mechanism.*** The past 18 years have seen a widening spread and adoption of self-regulatory mechanisms, foremost of which are Thailand's Code of Conduct and Good Aquaculture Practice, followed by better management practice guidelines for specific commodities and systems such as pangasius in Viet Nam, cage culture of grouper and other reef fishes in Indonesia, and a better management guidebook for local governments in the Philippines to manage environmental impacts of aquaculture. The primary driver of this surge was aquatic animal diseases, and was precipitated when scientists made clear to farmers the link between disease and the environment. Subsequent reinforcement came from consumer preferences transmitted through trade and advocacies from various entities (NGOs, mass media, governments) representing the interest of consumers.
g. ***"Green tax and polluter pays" schemes.*** Eco-labels are beginning to take hold, particularly in Thailand but tax on pollution or a green tax is not used, because it is often seen as a tough measure for most developing countries and usually politically unacceptable. A study on coastal zone management in Krabi, Thailand showed that a combination of incentive-based tools such as green taxation and non-incentive-based tools such as coastal land use zoning (based on the carrying capacity of receiving waters) optimally led to economically and environmentally responsible shrimp farming (Pongthanapanich, 2006). Under the Code of Conduct standard for shrimp farming in Thailand, which is based on the polluter pays principle, a farmer is required to set aside a certain area (around 10 % of the total production area) for sludge and waste water treatment before these are discharged into the environment. In a way, this is a cost to farmers as the area taken by the treatment pond is subtracted from the production area.

The role of government is more enabling than pro-active in the Philippines where aquaculture is largely left to (partially regulated) market forces, and where private entrepreneurship has been the main force behind aquaculture development. In Indonesia, Malaysia, Thailand, and particularly Viet Nam, the governments are actively promoting the sector through incentives and other policies. In Cambodia and Myanmar, aquaculture was viewed as a minor contributor to food self-sufficiency, thus, was subordinated to agriculture or to capture fisheries, but both countries have explicitly recognized the role of aquaculture, clarified land tenure to avoid conflicts, and reassured private investors. The result has been an expansion of registered farms and output.

Cambodia has formulated an Aquaculture Development Plan under its National Strategic Development Framework, which focuses on small holders, poverty alleviation and food security. In Brunei Darussalam, fisheries including aquaculture are seen to contribute to the diversification of the national economy from the oil and gas sector. In Singapore, the Agri-Food & Veterinary Authority as the national authority for aquaculture development and sector management, even as it manages aquaculture farms through the issuance of farm licenses, also carries out scientific studies in quality seed production for the local industry and shares the technology with other members.

Capacity for innovation: indicative assessment

Assessment of the capacity for innovation, especially for the whole region, will always be fraught and peppered with generalities and broad qualifications. **Table 1** provides some examples at the regional and national levels, and from public and private sector initiatives. A number of these have had or continue to have technical collaboration with and financial assistance from external organizations.

Table 1. Selected innovations in various segments of the aquaculture value chain

Area	Achievements	Participating Entities
Breeding and genetic improvement	Broodstock development and genetic improvement shrimp	Consortium of CP Aquaculture, Mahidol University (CENTEX Shrimp/BIOTEC), Department of Fisheries (DOF) Thailand, shrimp associations
	Artificial breeding and hatchery of marine shrimp *Penaeus monodon*	SEAFDEC Aquaculture Department (SEAFDEC/AQD), Philippines
	Freshwater prawn (*Macrobrachium* spp.) artificial spawning and breeding	National Inland Fisheries Institute (NIFI), DOF Thailand
	Artificial breeding, mass seed production of giant river prawn	DOF Malaysia and DOF Thailand
	All female production of giant freshwater prawn	Aquaculture Department, Faculty of Fisheries, Kasetsart University, Thailand
	Cross breeding of African catfish and indigenous catfish, mass seed production	A farmer in Thailand; Aquaculture Department, Faculty of Fisheries, Kasetsart University, Thailand
	Artificial breeding (breakthrough) of river catfish	NIFI, DOF, Thailand
	Milkfish broodstock development and induced breeding	SEAFDEC/AQD with assistance mainly from the International Development Research Centre (IDRC) Canada, and Japan International Cooperation Agency (JICA)
	GIFT Tilapia	WorldFish with collaboration from Philippine institutions
	All male tilapia	Asian Institute of Technology (AIT) Thailand, Freshwater Aquaculture Center (FAC), Philippines,
	Saline tolerant tilapia	National Inland Fisheries Technology Center (NIFTC), Philippine Bureau of Fisheries and Aqiatic Resources (BFAR) with French scientists' collaboration
	Improvement of seed stocks of *Eucheuma/ Kappaphycus* seaweeds	Marine Science Institute (MSI) of the University of the Philippines (UP) and SEAFDEC/AQD Philippines
	Development of Food Grade Carrageenan and manufacture of refined carageenan	Seaweed Industry Association of the Philippines; DOF, Thailand; Colloid manufacturers from US, France, Denmark clustered in Cebu City, Philippines
	Domestication and breeding of Mekong River fish species; hatchery development and seed production	Living Aquatic Resources Research Center (LARReC), Lao PDR in collaboration with Agricultural Research Centre for International Development (CIRAD), France and the Mekong River Commission
	Breeding of Arowana, culture and promotion in international aquarium trade	Department of Fisheries Malaysia (DOF Malaysia); private sector
	Artificial breeding and mass seed production of grouper Asian sea bass	Malaysia, Singapore, Indonesia, and Thailand
Aquatic animal health management	SPF (specific pathogen free) shrimps in Thailand	Science-Industry-Government consortium; Thailand
	EUS (epizootic ulcerative syndrome in fish) identification of causal organism, control	Aquatic Animal Health Research Institute of DOF, Thailand, with assistance from Department for International Development (DFID) of UK
	Fish disease diagnostic kits	Universiti Pertanian Malaysia (patented)
	Identification of organism causing early mortality syndrome (EMS) in shrimp, development of PCR-based detection protocol	CENTEX Shrimp, Mahidol University in association with National Chen Kung University, Taiwan; DOF, Thailand in association with Tokyo University of Marine Science and Technology, Japan
Product safety and quality assurance	Traceability system and requirements (*e.g.* Good Aquaculture Practice Program, Movement Document) for traded aquatic products, biotoxin monitoring, food safety control management (*e.g.* GMP, HACCP) and cold chain management requirements for seafood products to ensure freshness and safety	SEAFDEC Marine Fisheries Research Department (SEAFDEC/ MFRD) Singapore; Agri-Food & Veterinary Authority (AVA) of Singapore, DOF of Thailand
Environmental management	The development of TROPOMOD model, adapted from DEPOMOD/MERAMOD, to predict environmental impacts from aquaculture in the tropics, which has been validated for milkfish and tilapia, and marine brackish and freshwaters.	Philippines under the project Mitigating Aquaculture Impact in the Philippines (PHILMINAQ) funded by EU. Partners were two European institutions, MSI of UP, and BFAR

Table 1. Selected innovations in various segments of the aquaculture value chain (Cont'd)

Area	Achievements	Participating Entities
	Development and adoption of a better management practice for managing aquaculture and its impacts by Local Governments	This is probably the first case of a BMP guide adopted and used by local government's area management, in ASEAN.
Farming systems and production facilities	VAC system (in Vietnamese refers to *vuon, ao, chuong* which means garden/pond/livestock pen) for crops, fish and livestock	Viet Nam
	Floating cage culture – mechanized and using Norwegian-type cages for grouper and other finfish; Manufacture of circular floating cages using local materials	DOF Malaysia Private entrepreneurs (Philippines)
Post harvest, processing and product transformation	Comminuted products, product development from fish by-products, training and advisory to food industry	SEAFDEC Marine Fisheries Research Department, (SEAFDEC/MFRD) Singapore INFOFISH, Malaysia; Agri-Food & Veterinary Authority (AVA) of Singapore
	Value addition: enhancing nutritional value of fish products Waste utilization for pharmaceuticals	AIT Thailand
	Ready-to-eat products (esp. sushi products for the Japanese market)	Private fishery product processing industry, Thailand; National Food Institute, Thailand;
	Smoked and deboned milkfish, canned products from milkfish (for local and export markets)	BFAR, UP College of Fisheries, and the private sector (ALSONS Aquaculture), Philippines
	MUZE - Multi Stream Zero Effluent process of extracting seaweed based compounds	On pilot scale, Indonesia (Dr. Ian C. Neish, *pers.comm.*)

Major Players in Aquaculture Research including Main Clusters and Research-Industry Links

The ASEAN region is endowed with academic, research and development, and technical institutions with expertise in various areas of aquaculture education and research. Many of the national institutions have established problem-based or more durable institutionalized collaborative working arrangements with several regional indigenous organizations (NACA, INFOFISH, Mekong River Commission, SEAFDEC) and international organizations like WorldFish, FAO, UNEP and IUCN, various donor and technical assistance agencies from Australia, Canada, EU, Japan and North America, and global industry, and professional associations such as the World Aquaculture Society, Asian Fisheries and Aquaculture Forum, and Global Aquaculture Alliance, among others. In addition, there are national institutions especially the universities that have been strengthened through various means of cooperation through graduate study and research fellowships in European, Australian, New Zealand, American, Japanese, and other Asian universities; exchange of faculty and scientific staff; special attachments by senior scientists from other universities (in Europe, Australia, America, Japan and other Asian countries); and collaboration between scientists in various projects. These modes of capacity building for scientific personnel — in many cases along with facility upgrade — have built up a strong S&T capability in the ASEAN. Universities forge linkages with industry even as some of their highly trained researchers and technologists find jobs in the industry.

Linkages for R&D in Aquaculture: Examples

A number of alliances and linkages in S&T have facilitated the search and design of solutions to the aquaculture industry problems, bannered by capacity building. A review of 12 ASEAN-EU Collaborative Projects (just ended or ongoing in 2014, which therefore does not include the recently initiated Myanmar Sustainable Aquaculture Project or MYSAP of EU and Germany's GIZ) identified 12 areas of capacity building.

These are: (1) Governance of the Sector; (2) Resource and Environmental Management; (3) Health Management; (4) Certification against Trade-related Standards (safety/quality, environmental and social); (5) Post-harvest and Processing; (6) Market Access and Trade; (7) Value Chain Management; (8) Climate Change Adaptation and Resilience; (9) Higher Productivity and Income; (10) Sustainable Intensification; (11) Livelihood Improvement of Small Farmers; and (12) Social Responsibility, which includes gender equity, food and nutrition security, and poverty alleviation. Some of these categories, such as Market Access (as the outcome of health management, certification and post-harvest) and Social Responsibility (as the end result of almost all the other areas), can be argued to be the outcomes of a number of related categories.

Opportunities for Research Excellence, Cooperation and Innovation

A national aquaculture innovation system would provide the opportunity for sustained cooperation in research and the utilization of research results for the management and development of the sector. It could comprise two sub-systems: (a) Consortium - industry players are organized into a consortium to enable a continuing (as opposed to *ad hoc*) diagnosis of industry problems and search for their solutions, whose membership includes S&T institutions, Policy and Regulatory bodies, and the industry, and features the credibility endowed by science-based evidence to the processes and products of the sector, thus considerably strengthening efforts to better inform buyers and consumers; and (b) Industry association or federation — professionalized, broadly representative of all stakeholders with close links to professional and scientific resources, *e.g.* the Federation of European Aquaculture Producers or FEAP at the regional level, ASEAN Seafood Federation and the ASEAN Seaweed Industry Club at the regional level, the Seaweed Industry Association of the Philippines and the Thailand Shrimp Association at the national level, and the Vietnamese Fisheries Association to represent a very broad national membership (government, industry, academia), are examples of the industry groups that could be strengthened and infused with scientific and professional programs. These two sub-systems are not mutually exclusive; the association or federation could be the organized industry partner in the consortium. Either model would effectively marshal science-industry-government cooperation for addressing a set of problems in an integrated manner.

Opportunities for Strengthening R&D Capacities, Sharing Results of Aquaculture S&T

There are several not mutually exclusive modes for strengthening R&D capacities and sharing of the results of research and technology development. These could be done through: farmer-researcher cooperation; technical cooperation among ASEAN countries, international institutions; National Agricultural Research Systems; public-private partnerships; industry, professional and scientific forums; aquaculture innovation cluster composed of academic/scientific institutions, regulatory and management agencies, private industry and farmers' associations, farmers' and producers' federations; and the ASEAN (Fisheries Working Group) for regional policy and program formulation, among others. Scientific collaboration from other regions in key areas of competence that complement those of the ASEAN in strengthening regional and national capacities for R&D and development of innovative products and systems should also be established. Basic research could be done in partner institutions, the result of which could then be brought to the ASEAN for applied, adaptive and farming systems research.

Policy Recommendations

The policy recommendations, shown in **Box 4**, are aimed at strengthening the S&T capacities in the ASEAN to support

Box 4. Policy recommendations for strengthening S&T capacities in the ASEAN

1. Encourage and facilitate the formation of aquaculture S&T innovation clusters to solve specific problems (such as diseases of shrimp) or address the industry's value-chain issues from the biological to the physical to the technical, and economic and social aspects;
2. Form S&T networks of excellence in inter-disciplinary research and development, with a key regional institution and national centers linked to it and to each other;
3. Assure start-up funding for S&T initiatives in aquaculture within the ASEAN by ASEAN participants which is predictable and sustainable, and set up an ASEAN Sustainable Aquaculture S&T Advancement Fund;
4. Formalize within the ASEAN Secretariat (working with the ASEAN Foundation) a mechanism akin to an investment center, that would identify, screen, and endorse for funding proposals of regional or sub-regional scope for investments in research and technology development; and
5. Promote an integrated approach to S&T that is multi-stakeholder, multi-disciplinary, and covering the entire range of application of scientific result from policy to implementation.

More details about this **article** could be found in the **review** *ASEAN Research Landscape in Aquaculture: Opportunities for Investments and Cooperation in Science and Technology* carried out by the author in June-August 2014 under the Regional EU-ASEAN Dialogue Instrument (READI), a four-year (2011-15) initiative that supported the ASEAN-EU policy areas including science and technology. The review was supervised by *Alex Degelsegger* of the Vienna-based Center for Social Innovation, then a senior consultant for the Science and Technology Component of READI. Altair Asesores of Madrid Spain, the lead firm of a consortium that implemented the project, facilitated the commissioning of the review, the result of which was uploaded on the READI website in 2015. Highlights were found in *http://readi.asean.org/readi-2011-2015/news/155-asean-research-landscape-in-aquaculture-opportunities-for-investments-and-cooperation-in-science-and-technology* although the page has been discontinued. However, copies of the review including its three Annexes could be sent to anyone interested and upon placing requests to: *pete.bueno@gmail.com*. Regional policies are suggested to support, institutionalize within the framework of regional integration – embodied by the ASEAN Economic Community -- and sustain the S&T initiatives in tackling complex and dynamic issues.

the management of aquaculture development in the ASEAN and institutionalizing a mechanism for cooperation in S&T among the AMSs.

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About the Author

Mr. Pedro B. Bueno was Director General of the Network of Aquaculture Centres in Asia-Pacific in 2001-2006. He had been the international consultant of FAO for various projects in the Pacific, Africa, Central Asia, Caribbean, South Asia, Southeast Asia, and of other international assistance organizations including the World Bank, Asian Development Bank, Australian Centre for International Agricultural Research, EU and UNDP. In 1978-1981, he was the Information Specialist of the SEAFDEC Aquaculture Department based in Iloilo, Philippines. Lately, he has been engaged by SEAFDEC to assist the Senior Fishery Adviser in the conduct of in-house training workshops on project cycle management for the SEAFDEC staff.

Addressing Gaps in the Culture of Pathogen-free Polychaetes as Feed in Shrimp Hatcheries

Mary Anne E. Mandario

One of the factors that contribute to the success of shrimp hatchery operations is the availability of good quality broodstock diets. Polychaetes have been regarded as the best maturation diet for shrimps as they contain essential nutrients requisite for the reproduction of shrimps. Consequently, the demand for polychaetes increased with the intensification of shrimp farming and as a result, the natural stocks are depleting gradually and thus, could no longer provide sustainable supply for shrimp hatcheries. In addition, the issue on biosecurity concerning wild polychaetes prompted the shrimp farmers to obtain polychaetes from reputable sources, thus, the culture of polychaetes under controlled condition has become a sustainable alternative. The SEAFDEC Aquaculture Department (SEAFDEC/AQD) therefore initiated the "Refinement of rearing and feeding techniques for sustainable mass production of the polychaete *Marphysa* sp." to address the gaps in polychaetes culture and ensure the sustainability of polychaetes production to supply the shrimp hatcheries at SEAFDEC/AQD, and where the potential mass production of the polychaetes (*Marphysa* sp.) in indoor tanks is being undertaken to ensure that these are pathogen-free.

Polychaetes are aquatic multi-segmented worms which are the most abundant and diverse group of Phylum Annelida, and are found around the world from abyssal depths to shallow estuaries, rocky shores, and even free swimming in open waters. Along with sediment-dwelling mollusks and crustaceans, they are mostly abundant in mud and sand habitats. Their pencil-like bodies are soft and usually only a few centimeters long and their slow movement is aided by the retractable grip of four dense clusters of bristles and hooks on each segment called chaetae, thus the name "polychaete." There are over 80 families existing to this day and each family has distinguishing body shapes and chaetal types (Read & Fauchald, 2018).

The ecological importance of polychaetes cannot be understated. In the natural environment, they feed on detritus and smaller benthos and some species prey on other small animals using their retractable pharynx, and are fed upon by higher order predators such as fish, crustaceans, larger invertebrates, and even birds. The significant role played by polychaetes in nutrient cycling sustains the benthic environment (Hutchings, 1998). Head-down deep polychaetes are deposit feeders known for having strong effects on bioturbation and nutrient mineralization both by sediment ingestion, reworking and burrowing (Papaspyrou, Kristensen, & Christensen, 2007), and enhance organic matter mineralization and recycling (Aller, 1994). The presence of polychaetes in the sediments of organically enriched fish farms hastens the decomposition of organic matter (Heilskov & Holmer, 2006), and the burrowing formation of polychaetes creates an oxidized layer in the sediment providing optimal environment for aerobic bacteria to proliferate (Kunihiro *et al*., 2005) and, in the process, increase bioremediation.

Polychaetes have been used as bait in recreational fishing industry for many years. In 2015, the five most expensive (retail price per kg) polychaete species sold in the global market were *Glycera dibranchiata* (US$ 237), *Diopatra aciculata* (US$ 150), *Nereis (Alitta) virens* (US$ 96), *Marphysa sanguinea* (US$ 85), and *Arenicola defodiens* (US$ 82) according to the three UK-based ragworm fisheries (Watson, Murray, Schaefer, & Bonner, 2017).

In aquaculture, polychaetes can be used as feed either in pure form, combined with other natural food, or used as one of the ingredients of formulated diet for shrimp broodstock. The use of polychaetes as an effective maturation diet to shrimp broodstock has long been recognized because they contain high levels of proteins, lipids, n-3 polyunsaturated fatty acids (PUFA), and hormonally-active compounds that are responsible for the ovarian maturation of penaeid shrimps and at the same time improve the quality and viability of offspring (Lytle, Lytle, & Ogle, 1990; Luis & Passos, 1995; Naessens *et al*., 1997; Coman, Arnold, Callaghan, & Preston, 2007; Meunpol, Iam-Pai, Suthikrai, & Piyatiratitivorakul, 2007). The polychaete species commonly used as feed to shrimps are *Perinereis hellerri* (Palmer, Wang, Houlihan, & Brock, 2014), *Palola* sp. (Pamungkas, 2015), *Nereis virens* (Brown, Eddy, & Plaud, 2011), *Perinereis nuntia* (Techaprempreecha *et al*., 2011), and *Marphysa* sp. (Meunpol, Meejing, & Piyatiratitivorakul, 2005).

In recent years, however, the collection of polychaetes from the wild for aquaculture purposes declined due to biosecurity reasons (Velvizhi *et al*., 2013), as polychaetes collected from the wild are possible carriers of pathogens as they accumulate the viral pathogen in their digestive tract by consuming virus particles in the sediment. When these polychaetes from the wild are used as aquaculture feed, pathogenic diseases could be transferred to healthy broodstock shrimps leading to possible viral infection in the shrimps (Vijayan *et al*., 2005).

The collection of polychaetes in the coastal areas is considered as a major livelihood for the Irular tribal fishing community in Pitchavaram Region in Tamil Nadu, India (Velvizhi, Gopalakrishnan, Murugesan, & Kannan, 2013). The Irular fishing community collects the polychaetes by digging the areas identified with the presence of burrows and as soon as polychaetes emerge, they are handpicked and washed with water (Velvizhi *et al*., 2013). The collected polychaetes are supplied to shrimp hatcheries all over the country and it is estimated that about 6-20 MT of polychaetes are utilized annually (Vijayan *et al*., 2005).

Harvesting of polychaetes from the wild destructs the sediment bottom and thus, disturbs other benthic organisms living in the sediments. Over-exploitation of polychaetes in the natural environments could adversely affect the nutrient cycling and other biochemical processes (Kristensen & Mikelsen, 2003; Laverock, Gilbert, Tait, Osborn, & Widdicombe, 2011). However, an estimated 121,000 MT (valued at US$9.15 billion) of polychaetes were collected from the wild globally in 2015 (Watson *et al*., 2017). The increasing demand for polychaetes from leisure and aquaculture has therefore resulted to over-exploitation of the natural resources of these organisms, while presently, polychaete aquaculture is still limited to compensate the high demand.

SEAFDEC/AQD's "*OPLAN Balik Sugpo*"

SEAFDEC/AQD is currently gearing towards reviving the tiger prawn (*Penaeus monodon*, locally known as *sugpo*) industry under the banner "*OPLAN Balik Sugpo*" which entails the development of a complete and detailed operational plan that aims to bring back the booming production of tiger prawn in the Philippines. The prawn industry was considered as a sunshine industry in the country in 1980s until the occurrence of diseases brought it down. SEAFDEC/AQD is now working towards effective breeding program which ensures Specific Pathogen Free (SPF) broodstock, healthy post-larvae, and at the same time, refining the grow-out technology of intensive and semi-intensive shrimp farming. Considering the significance of polychaetes in shrimp aquaculture, there is a need to produce pathogen-free polychaetes under controlled and biosecured conditions. Thus, this study aims to showcase the potential of *Marphysa* sp. for mass production in indoor tanks to supply the needs of the shrimp hatchery of SEAFDEC/AQD, considering that this polychaete species can spawn many times throughout its lifetime making it sustainable for culture.

Culture of *Marphysa* sp. in Indoor Tanks

In order to ensure the sustainable production of polychaetes, it is necessary to address the culture gaps in every life stage of *Marphysa* sp. by understanding its biology and culture requirements. *Marphysa* sp. is one of the polychaete species commonly used as feed to shrimps and it is abundant in mangrove wetlands and fishponds in northern Iloilo, Philippines. This species belongs to family Eunicidae which is known to be gonochoric (with separate sexes), exhibit no sexual dimorphism (no difference in male and female physical attributes), and capable of multiple reproductive cycles throughout their lifetime (Giangrande, 1997; Gambi & Cigliano, 2006).

The multiple reproductive strategies exhibited by *Marphysa* sp. is considered as a sustainable advantage over the polychaete species under the family Nereididae, in which death follows right after spawning (Fischer & Fischer, 1995). Based on actual observation at SEAFDEC/AQD, *Marphysa* sp. encloses its eggs inside a gelatinous egg mass or jelly cocoon where the early stage of larval development takes place during spawning. Two days after hatching, the jelly starts to disintegrate and the trochophore larvae (early stage polychaetes) start to settle in the sediment. *Marphysa* sp. can grow up to 30 cm or more after five to six months in captivity (**Figure 1**).

Figure 1. Late juvenile (3-5 cm long) and sexually mature (10 cm and longer) *Marphysa* sp. in captivity

Nursery phase

One jelly cocoon enclosing 6,653 ± 1,606 trochophore larvae or 33,267 ± 8,032 individual/m² was stocked in each of the three nursery tanks (4 L capacity) at SEAFDEC/AQD hatchery and grown for one month in biofloc (**Figure 2**), an

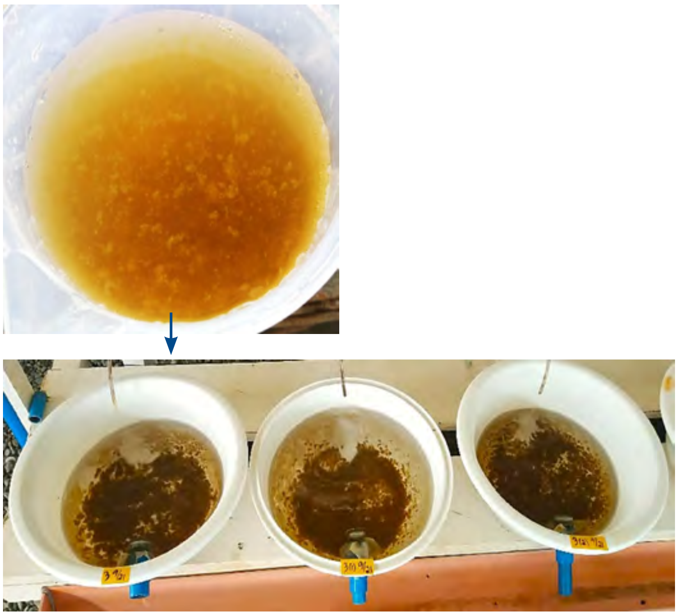

Figure 2. Biofloc as a substrate and feed in the nursery rearing of *Marphysa* sp.

aggregate of microorganisms, microalgae, zooplankton, and organic particles from uneaten feeds (Crab, Defoirdt, Bossier, & Verstraete, 2012; Ekasari *et al*., 2014) containing proteins and immunostimulants (Ju *et al*., 2008; Xu & Pan, 2013) and serves as a natural food source for shrimps (Kent, Browdy, & Leffler, 2011). Biofloc was used in this study to serve as substrate and first exogenous food source of polychaete larvae. The nutrients from the biofloc were consumed by the polychaete larvae for growth and development. For water management, a continuous flow-through seawater exchange was followed. Water temperature and salinity were monitored daily. In order to prevent the loss of polychaete larvae, a screen with a 90 µm mesh size was fitted to the drain pipe of each larval rearing tank.

Grow-out phase

After one month at the nursery, juvenile polychaetes from each of the three tanks were transferred to another tanks (0.20 m²) filled with mud and grown for another four months until harvest. Polychaetes were fed with feed mill waste (FMW) comprising feeds and feed ingredients that remained in the feed mill equipment after every operation. The water in each grow-out tank was changed every other day. Water salinity and mud temperature were measured daily.

To determine the body weight of polychaetes in each of the three grow-out tanks, the first sampling was done after two months from initial stocking and the second sampling was done after three months from the first sampling. The body weight was measured by weighing (blotted wet body weight) each of the twenty individuals from each replicate tank. Polychaetes at early stages of development were prone to damage and stress due to handling. Thus, polychaete survival was measured only at this period due to the difficulty in collecting juvenile polychaetes.

Survival and Growth of Cultured Polychaetes

At the end of the experiment, polychaete survival was computed based on the number of surviving polychaetes over the total number of trochophore larvae stocked in each replicate tank at initial stocking multiplied by 100. The biomass was computed as: biomass (g/m²) = mean body weight (g) × surviving polychaetes. The fragile nature of the polychaetes prevented the determination of survival prior to the five-month period. For the purposes of computing the biomass after three months, the survival rate after five months was used instead and it was presumed that the survival rates after three and five months would be similar. As shown in the **Table**, the average body weight after three months was 130 ± 60 mg and ranged from 70 to 250 mg. The biomass was 244 ± 70 g/m² and ranged from 163 g/m² to 384 g/m². After five months of culture, about 307-466 individuals/tank or 1,535-2,330 individuals/m² were collected. The survival rate was 8 ± 3 % which ranged from 3.47 % to 13.21 %. The mean body weight was 290 ± 30 mg with the range of 240-340 mg. The biomass was 593 ± 54 g/m² and ranged from 522 g/m² to 699 g/m².

Conclusion and Way Forward

Aquaculture of polychaetes in indoor tanks is feasible provided that optimal rearing conditions are met. The use of biofloc as a substrate and nursery feed for polychaete larvae and FMW as grow-out feed resulted to good survival and growth performances of *Marphysa* sp. Water salinity (29-32 ppt) and sediment temperature (29-30 °C) in all culture tanks were at optimum levels. The five-month culture period showed greater polychaete body weight and biomass than the three-month culture period. Extending the culture period for another month would have most likely resulted to greater body weight and biomass. With these results, fish farmers have the options on the schedule of harvesting their polychaete stocks

Table. The average survival rate (%), average body weight (mg), and biomass (g/m²) of cultured *Marphysa* sp.

	Culture period		
	Initial stocking	Three months	Five months
Number of individuals/tank	6,653 ± 1,606	-	413 ± 53
Range of individuals/tank	3,520-8,835	-	307-466
Number of individuals/m²	33,267 ± 8,032	-	2,063 ± 264
Range of individuals/m²	17,600-44,175	-	1,535-2,330
Survival rate (%)*	-	-	8 ± 3
Range of survival rate (%)	-	-	3.47-13.21
Average individual body weight (mg)*	-	130 ± 60	290 ± 30
Range of individual body weight (mg)	-	70-250	240-340
Biomass (g/m²)*	-	244 ± 70	593 ± 54
Range of biomass (g/m²)	-	163-384	522-699

** values are presented as mean ± Standard Error (n = 3)* based on the size that they need. Small size polychaete can be fed to juvenile shrimps while bigger ones can be fed to shrimp broodstock.

With regards to commercial production, the study provides knowledge on the aquaculture of mud polychaete which is an ecologically friendly feed material for shrimp production. Ultimately, this translates into a substantial improvement in the efficiency of shrimp aquaculture especially for SEAFDEC Member Countries with viable sources of *Marphysa* sp. broodstock. In addition, the development of best culture techniques for indoor mass production of polychaetes could impede the reliance on natural resources. The biosecurity issue could be addressed as well when shrimp broodstock are fed with cultured polychaetes and the transfer of diseases could be prevented. To ensure the sustainable supply of pathogen-free polychaetes, there is a need to conduct further studies on how to manipulate the spawning frequency. Increase in spawning frequency accompanied with good quality offspring will guarantee a sustainable production of *Marphysa* sp.

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About the Author

Ms. Mary Anne E. Mandario is an Associate Researcher working with the Breeding and Seed Production Section of SEAFDEC Aquaculture Department in Tigbauan, Iloilo, Philippines.

Establishing Adaptive Strategies towards a Climate-resilient Seaweed Farming: A Case in Panobolon Island, Guimaras, Philippines

Raisa Joy G. Castel

Seaweeds are ecologically important primary producers, competitors, and ecosystem engineers (Harley *et al.*, 2012), support complex food webs in coastal zones, and provide habitats and food for associated organisms, from apex predators to invertebrates (Reisewitz, Estes, & Simenstad, 2006). Seaweeds are intimately linked to human cultural and economic systems via the provision of ecosystem goods and services ranging from food, medicine, to cosmetics (Pickering, 2006) and storm protection (Rönnbäck, *et al.*, 2007). There is strong scientific consensus that coastal marine ecosystems, along with the goods and services they provide, are threatened by anthropogenic global climate change (IPCC, 2001). However, the impacts of ongoing and future anthropogenic climate change in seaweed-dominated ecosystems remain poorly understood (Harley *et al.*, 2012). It is therefore, timely and relevant to provide better understanding of the experiences of seaweed farmers and their capacity to anticipate, cope with, resist, and recover from the impact of natural hazards (Blaikie, Cannon, Davis, & Wisner, 1994). The Philippine-based SEAFDEC/AQD is currently conducting a three-year (2015-2018) study on the economic benefits and losses of seaweed farming due to climate change indicators. With pilot site in Panobolon Island, Nueva Valencia, Guimaras, Philippines, the study highlights the adaptive strategies and the effects of climatic change on the productivity of small-scale seaweed growers in a community.

Seaweed is one of the major exported commodities of the Philippines, and the country is one of the top farmed seaweed producers in the world (FAO, 2018) as shown in **Table 1**. Seaweed farming is being widely adopted and practiced in many coastal communities in the Philippines. As of 2014, the major producing areas (**Figure 1**) were in Region IVB (Southern Tagalog Region also known as MIMAROPA, comprising the Provinces of Mindoro, Marinduque, Romblon, Palawan); Region IX (Zamboanga Peninsula, comprising the Provinces of Zamboanga del Norte, Zamboanga Sibugay, and Zamboanga del Sur); and in the Autonomous Region in Muslim Mindanao or ARMM consisting of five predominantly Muslim provinces: Basilan, Lanao del Sur, Maguindanao, Sulu, and Tawi-Tawi (Philippine Statistics Authority, 2018).

BFAR (2014) also indicated that in 2014 (**Table 2**), the Philippine production of seaweeds was mainly contributed by ARMM (622,995.6 MT) contributing about 40 % to the total seaweeds production of the country; followed by MIMAROPA (361,352.59 MT) accounting for about 23 %, and Region IX (206,161.12 MT) about 13 %. In 2004, the data from the Seaweed Industry Association of the Philippines indicated that all over the country, more than 116,000 families consisting of more than one million individuals were utilizing more than 58,000 ha of the seas for seaweeds farming.

Figure 1. Major seaweed producing regions in the Philippines: *clockwise from top:* MIMAROPA, Zamboanga Peninsula; and ARMM

Seaweed Farming in Panobolon Island

Panobolon Island is an island barangay (village) located in the municipality of Nueva Valencia, Guimaras, in Western Visayas, Philippines (**Figure 2**). It has a total land area of 310.50 ha and comprises four sub-villages, namely: Aminhan, Bagatnan, Punta Sur, and Punta Norte. The main source of livelihood of the people is fishing. Small-scale seaweed farming (**Figure 3**) has become the secondary source of livelihood that led to the creation of an organization known as the Panobolon Unified Fisherfolk Association (PUFA).

In Region VI: Western Visayas Region, the Provinces of Antique and Guimaras are the main producers of seaweeds. Guimaras had its highest production in 2009 at 1,641 MT. From 189 MT production in 2000, it gradually decreased to 22 MT in 2004 and started to increase from 2005 (187

Table 1. Major farmed seaweed producers in the world, by country in 2005-2016 (in thousand MT, live weight)

Country	2005	2010	2011	2012	2013	2014	2015	2016
China	9,446	10,995	11,477	12,752	13,479	13,241	13,835	14,387
Indonesia	911	3,951	5,170	6,515	9,299	10,077	11,269	11,631
Philippines	1,339	1,801	1,841	1,751	1,558	1,550	1,566	1,405
Republic of Korea	621	902	992	1,022	1,131	1,087	1,197	1,351
Democratic People's Republic of Korea	444	444	444	444	444	489	489	489
Japan	508	433	350	441	418	374	400	391
Malaysia	40	208	240	332	269	245	261	206
Tanzania	77	132	137	157	117	140	179	119
Madagascar	1	4	2	1	4	7	15	17
Chile	16	12	15	4	13	13	12	15
Solomon Islands	3	7	7	7	12	12	12	11
Viet Nam	15	18	14	19	14	14	12	10
Papua New Guinea	0	0	0	1	3	3	4	4
Kiribati	5	5	4	8	2	4	4	4
India	1	4	5	5	5	3	3	3
Others	25	14	15	16	13	12	16	8

Source: FAO, 2018

Table 2. Seaweeds production of the Philippines in 2014, by region (in metric tons: MT)

Region/Provinces included	Production (MT)	% of country's total seaweeds production
National Capital Region (NCR): Metro Manila	-	-
Cordillera Administrative Region (CAR): Abra, Apayao, Bengeut, Ifugao, Kalinga, and Mountain Province	-	-
Region I (Ilocos Region): Ilocos Norte, Ilocos Sur, La Union, Pangasinan	34.97	0.0
Region II (Cagayan Valley): Batanes, Cagayan, Isabela, Nueva Vizcaya, Quirino	527.18	0.0
Region III (Central Luzon): Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, Zambales	2,368.53	0.2
Region IVA (CALABARZON): Cavite, Laguna, Batangas, Rizal, Quezon	32,617.7	2.1
Region IVB (MIMAROPA): Mindoro, Marinduque, Romblon, Palawan	361,352.59	23.3
Region V (Bicol Region): Albay, Camarines Norte, Camarines Sur, Sorsogon, Catanduanes, Masbate	59,863.75	3.9
Region VI (Western Visayas): Aklan, Antique, Negros Occidental, Capiz, Guimaras, Iloilo	77,466.93	5.0
Region VII (Central Visayas): Bohol, Cebu, Negros Oriental, Siquijor	104,943.47	6.7
Region VIII (Eastern Visayas): Biliran, Eastern Samar, Leyte, Northern Samar, Samar, Southern Leyte	17,925.84	1.2
Region IX (Zamboanga Peninsula): Zamboanga del Norte, Zamboanga Sibugay, Zamboanga del Sur	206,161.12	13.3
Region X (Northern Mindanao): Misamis Oriental, Misamis Occidental, Bukidnon, Camiguin, Lanao del Norte	40,784.83	2.6
Region XI (Davao Region): Compostela Valley, Davao del Norte, Davao Oriental, Davao del Sur	6,005.49	0.4
Region XII (SOCCSKSARGEN): South Cotabato, Cotabato, Sultan Kudarat, Sarangani, General Santos City	144.05	0.0
Region XIII (Caraga Region): Agusan del Norte, Agusan del Sur, Surigao del Norte, Surigao del Sur, Dinagat Islands	16,383.89	1.1
Autonomous Region in Muslim Mindanao (ARMM): Basilan, Lanao del Sur, Maguindanao, Sulu, Tawi-Tawi	622,995.60	40.2
TOTAL	**1,549,575.98**	**100.0**

Source: BFAR, 2014

Figure 2. Seaweeds study site in Panobolon Island, Nueva Valencia, Guimaras, Philippines

Figure 3. Small-scale seaweed farmers in Panobolon Island, Nueva Valencia, Guimaras, Philippines

MT) until 2009 (1,641 MT). However, abrupt declines in production were observed in 2010 as well as in 2014-2015 (**Figure 4**). Despite the gradual recovery of production of seaweeds farming in Guimaras in 2016-2017, production of the small-scale growers in Panobolon Island declined from 2016 to 2018 because of extreme weather conditions, lack of good quality seedling cultivars that can resist diseases and withstand erratic weather conditions, as well as low market selling price of dried produce.

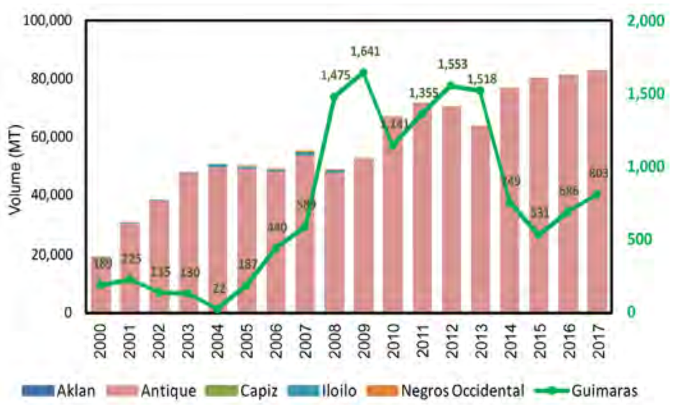

Figure 4. Seaweed production in the provinces of Region VI, Philippines from 2000 to 2017 (MT): Highlighting Guimaras, the numbers above the points of line graph indicate the volume of production

Source: Philippine Statistics Authority (2018)

The declining trends of production deterred the growing seaweed industry of the Province from investing more threatening the sustainability of this emerging major livelihood of the coastal communities, exacerbated by the variability of the climate and occurrence of natural calamities. It is known that the Philippines is frequently visited by typhoons every year. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Western Visayas Station reported that 71 tropical cyclones have crossed Region VI from 1950 to 2016. In 2017, a notable increase of 22 tropical cyclones passed by the Western Visayas Region, especially in Guimaras where intense rainfall occurred causing the Sibunag River – approximately 3.5 km away from the seaweed farming area in Panobolon Island – to overflow. Such phenomenon contributed to the sudden drop in the water salinity of the farming area to 20 ppt. Moreover, the summer season from March to May also remains a challenge to seaweed growers. Extreme sea surface temperatures (from 28 °C to 35 °C) and high salinities (35-36 ppt) could cause diseases and slow growth performance. In fact, the sudden fluctuations of temperatures and salinities stress the seaweeds resulting in the whitening or depigmentation of the thalli (branches) which eventually lead to breakage, and subsequently in mortalities as a consequence and hence, crop losses.

In addition, the incidence of "ice-ice" outbreak, *Neosiphonia* sp. epiphytic infestation, and attachment of the little wing pearl shells to the thalli have been the most prevalent problems observed (**Figure 5**) in the site. Apart from the environmental shifts, the occurrence of natural calamities such as tropical storms, intense monsoon rains, strong currents and winds, normally, from June to November, could also cause total damage to seaweed farms. Confronted by these seasonal outbreaks and calamities, growers practice immediate harvest of crops regardless of the current low market price of dried produce to refrain from incurring extensive production losses while securing healthy, non-infested seaweed cultivars to be used in the next cropping. Growers have acknowledged that over time, their seaweed farming practices have changed and at the same time, they have learned to adopt the climate-resilient practical approaches.

Figure 5. Infestations in seaweeds farms in Panobolon Island, Guimaras, Philippines, prevalent from March to May. *Left-right:* "ice-ice" disease, *Neosiphonia* sp. epiphytes, and little wing pearl shells

Way Forward

Extreme weather conditions, such as frequent and intense rainfall that cause fluctuation of sea surface temperature and salinity, pose threat to fisheries, fishery-dependent communities, and the aquaculture sector. A range of protocols are available for seaweed farming that have been successfully carried-out, yet there are still significant gaps in its biology, physiology and reproduction (Buschmann *et al*., 2017) that impede the better understanding on the effects of global climate change. The current study presented valuable indications that any aquaculture-related livelihood is likely vulnerable to climate change.

The findings of this study is expected to contribute to the creation of relevant policies and implementation strategies in seaweeds farming that adapt to climate change such as providing diverse livelihoods and other fishing-related activities, and conducting trainings for small-scale growers in Panobolon Island to develop their working skills in the other sectors (*e.g.* marketing, vocational endeavors) during the lean or off-season of seaweeds farming.

Aside from the Philippines, the other Southeast Asian countries such as Indonesia, Malaysia, and Viet Nam are also among the major farmed seaweed producers in the world (**Table 1**). Seaweed farmers in these other countries of Southeast Asia with similar climatic conditions could also benefit from the outputs of this study. In so doing, small-scale seaweed growers would not only be taking actions on responding to climatic change but also moving towards climate-resilient communities.

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About the Author

Ms. Raisa Joy Castel is an Associate Researcher at the Socioeconomics Section of SEAFDEC Aquaculture Department in Tigbauan, Iloilo, Philippines.

The Making of a Center of Excellence in Science and Technology on Inland Fisheries Management: The SEAFDEC/IFRDMD

Arif Wibowo, Takuro Shibuno, and *Virgilia T. Sulit*

As the global attention that focuses on the development of inland fisheries escalated in the early 2000s, the ASEAN-SEAFDEC Member Countries became concerned about the actual valuation of the Southeast Asian region's inland fisheries considering the major role that it plays in supplying food fish to the growing population of the region, especially to those in the rural communities. Given such a scenario, the ASEAN-SEAFDEC Member Countries adopted the "Resolution and Plan of Action on Sustainable Fisheries for Food Security in the New Millennium" during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security in the New Millennium "Fish for the People" in November 2001 that includes provisions encouraging the ASEAN Member States (AMSs) to consider the importance of inland fisheries in policy formulations to improve food security and secure livelihoods of rural people. Ten years later, the subsequent ASEAN-SEAFDEC Conference on Sustainable Fisheries to Food Security Towards 2020 "Fish for the People 2020: Adaptation to a Changing Environment" in June 2011 also adopted the revitalized "Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region towards 2020" including a provision for the AMSs to enhance their understanding and awareness of the potentials of inland fisheries, specifically, its contribution to food security and sustainable livelihoods in the Southeast Asian region.

Against such backdrop, the then Minister for Marine Affairs and Fisheries of Indonesia proposed to establish a Regional Center for Inland Fisheries under the umbrella of SEAFDEC, and offered Indonesia as host of such Regional Center. After reviewing the proposal of Indonesia and recognizing the role that inland fisheries would play in enhancing the contribution of fisheries to food security, the SEAFDEC Council during its Forty-fourth Meeting in 2012 considered the proposed establishment of the said Regional Center to be hosted by Indonesia. Thus, the Regional Center renamed as the Inland Fishery Resources Development and Management Department (IFRDMD) of SEAFDEC, was officially established on 2 September 2014 in Palembang, Indonesia. With such development, the core activities of SEAFDEC had expanded from the sustainable development of marine capture fisheries, aquaculture, and fisheries post-harvest technology to the development and management of inland capture fisheries. Only on its sixth year of operation since its establishment, IFRDMD continues to undertake its major task of developing policy recommendations and formulating guidelines for the sustainable development and management of inland fisheries in Southeast Asia, by unraveling the potentials for development of the region's inland fishery resources to enhance the contribution of fisheries to food security and economic stability of the region.

The SEAFDEC Inland Fishery Resources Development and Management Department

Established in September 2014 in Palembang, Indonesia, the SEAFDEC/IFRDMD (**Figure 1**) is tasked to serve as the center for establishing guidelines for the proper development and management of the inland fishery resources of the Southeast Asian region, which is endowed with bountiful inland water systems that consist of freshwater, saline water, a mixture of them, and distributed throughout land in the form of rivers, lakes, floodplains, reservoirs, wetlands, estuaries, as well as inland saline systems (Pongsri *et al*., 2015). The properties and utilization of such water systems are dominated by the permanent, seasonal or intermittent occurrence of flooded conditions. Nevertheless, these resources have the potentials to be tapped for fisheries development in order that there would be steady supply of food fish for the peoples in the region, especially those in the rural areas.

Figure 1. SEAFDEC/IFRDMD in Palembang, Indonesia

Fisheries Production of Southeast Asia

In 2016, the total fisheries production of the Southeast Asian countries amounted to a total of about 45.4 million metric tons (MT) increasing by about 13 % over the five year period from 2012 to 2016, and contributing about 23 % to the world's total fisheries production of about 202.2 million MT (FAO, 2016). From 2012 to 2016, Indonesia was the highest producer of fish from among the Southeast Asian countries, accounting for more than 51 % of the region's total fisheries production (**Table 1**) and about 12 % of the world's total fisheries production.

Table 1. Total fisheries production of Southeast Asia (in metric tons (MT)), 2012-2016

	2012	2013	2014	2015	2016
Brunei Darussalam	5,979	3,431	3,947	4,353	14,114
Cambodia	728,000	728,000	745,310	731,889	808,550
Indonesia	**18,763,893**	**19,245,632**	**20,600,772**	**22,154,423**	**23,172,872**
Lao PDR	136,000	164,228	150,592	158,600	166,880
Malaysia	1,760,840	1,749,314	1,988,302	1,998,439	1,987,984
Myanmar	4,417,676	4,715,840	5,040,311	5,316,950	5,598,003
Philippines	4,865,678	4,695,369	4,681,418	4,645,871	4,350,761
Singapore	6,202	7,210	6,695	8,161	7,347
Thailand	2,991,623	2,822,084	2,567,800	2,429,856	2,425,901
Viet Nam	5,816,100	6,019,700	6,332,500	6,549,700	6,803,900
TOTAL	**39,491,091**	**40,150,808**	**42,117,647**	**43,998,242**	**45,336,312**

Source: SEAFDEC (2018)

Fisheries production of Southeast Asia, by sub-sector (2012-2016)

As shown in **Figure 2**, the fisheries production during 2012-2016 by sub-sector, *i.e.* marine capture fisheries, inland capture fisheries, and aquaculture, had been dominated by aquaculture that increased by 16 % over the five-year period and accounted for 55 % of the region's total production in 2016. This is followed by marine capture fisheries which increased by 9 % for the same period and contributed about 38 % to the region's total fisheries production. Although the production from inland capture fisheries also increased (**Figure 3**) by about 10 % during the five-year period, it accounted for only 7 % of the region's total fisheries production.

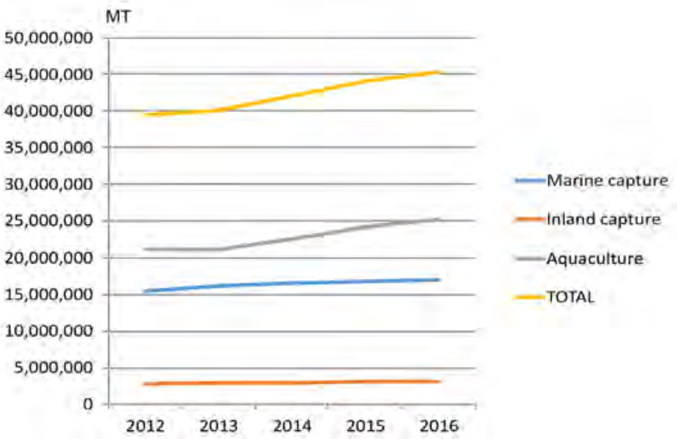

Figure 2. Total fisheries production of Southeast Asia by sub-sector

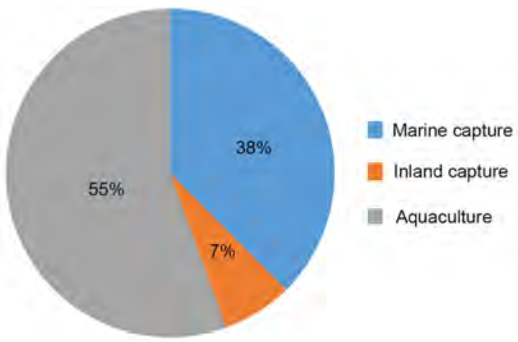

Figure 3. Fisheries production of Southeast Asia in 2016, by sub-sector *(Source: SEAFDEC (2018))*

It should be noted however that the data on production from inland fisheries is very limited considering that inland fisheries operations are small-scale, very seasonal, and mostly carried out by part-time fisheries, and where production is meant for domestic consumption and thus, is usually not recorded at landing sites (SEAFDEC, 2017). Nevertheless, the countries have been trying to exert efforts in improving their systems of compiling the data and information on inland fisheries as the sub-sector has the potentials to enhance the food sufficiency of the region in the future.

Production from the inland capture fisheries of Southeast Asia (2012-2016)

Although the fisheries production from inland capture fisheries of the Southeast Asian countries (SEAFDEC, 2018) had been slightly increasing (**Table 2**), in 2016, it contributed about 7 % to the region's total fisheries production (**Figure 3**). The highest producing country is Myanmar, where its inland fisheries production in 2016 accounted for about 51 % of the region's total production from inland capture fisheries, and about 4 % of the region's total fisheries production. However, the production data provided by Myanmar is indicated only as Osteichthyes or freshwater fishes *nei* and not by species. The next highest producing country is Cambodia, but its production was likewise not segregated by species. For Indonesia which was the third highest producing country, its production in 2016 comprised mainly the striped snakehead (*Channa striata*), Asian redtail catfish (*Hemibagrus nemurus*), freshwater fishes *nei*, Nile tilapia (*Oreochromis niloticus*), snakeskin gourami (*Trichogaster pectoralis*), and other freshwater fishes.

Table 2. Inland fisheries production of Southeast Asia (in metric tons (MT)), 2012-2016

	2012	2013	2014	2015	2016
Brunei Darussalam	...	...	...	...	...
Cambodia	528,000	528,000	505,005	487,905	509,350
Indonesia	393,552	391,324	446,509	455,270	426,874
Lao PDR	34,105	40,143	60,237	62,635	70,915
Malaysia	5,042	5,641	5,611	5,924	5,848
Myanmar	1,246,460	1,302,970	1,381,030	1,463,120	1,580,670
Philippines	195,804	194,615	211,941	203,366	155,509
Singapore	...	...	...	...	...
Thailand	219,428	210,293	181,757	184,101	187,300
Viet Nam	194,500	196,800	208,100	196,500	189,700
TOTAL	**2,816,891**	**2,869,786**	**3,000,190**	**3,058,821**	**3,126,166**

Source: SEAFDEC (2018)

Unfortunately, the rest of the producing countries could not also report their production by species which are just indicated as freshwater fishes *nei* (SEAFDEC, 2018). Moreover, few countries had also reported their inland fisheries production in 2016 by type of water bodies, such as Cambodia of which more than 68 % of its production came from reservoirs, about 29 % from floodplains and rice fields, and the rest from rivers (SEAFDEC, 2018). As for the other countries, the source of inland fisheries production in terms of water bodies had not been segregated, although Malaysia indicated that 65 % of its inland fisheries production in 2016 came from rivers, and the rest from reservoirs, lakes, floodplains and rice fields, and other inland water bodies.

Table 3. Inland fisheries production of major groups of species of the Southeast Asian region (metric tons: MT)

Major groups of species	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Thailand	Viet Nam	TOTAL	Percent of inland capture fisheries production
Asian redtail catfish	...	43,023	...	...	...	...	...	...	43,023	1.38
Climbing perch	...	25,822	...	...	...	2,068	7,900	...	35,790	1.14
Common carp	...	11,228	...	...	...	...	4,300		15,528	0.50
Cyprinids *nei*	...	...	...	...	...	14,662	...	...	14,662	0.47
Freshwater fishes *nei*	**509,350**	**39,575**	**70,915**	**5,383**	**1,580,670**	**9,333**	**97,700**	**189,700**	**2,502,626**	**80.05**
Freshwater mollusk *nei*	...	...	...	...	....	53,982	...	...	53,982	1.73
Freshwater prawn *nei*	...	8,499	...	465	...	...	1,000	...	9,964	0.32
Giant river prawn	...	10,908	...	...	...	1,297	...	...	12,205	0.39
Glass cat-fishes	...	21,084	...	...	...	...	...	...	21,084	0.67
Indonesian snakehead	...	18,442	...	...	...	...	...	...	18,442	0.59
Kissing gourami	...	10,232	...	...	...	...	...	...	10,232	0.33
Mozambique tilapia	...	13,163	...	...	...	...	...	...	13,163	0.42
Nile tilapia	...	35,551	...	...	...	...	20,700	...	56,251	1.80
Pangasius djambal	...	20,508	...	...	...	...	...	...	20,508	0.66
Silver barb	...	10,548	...	...	...	...	21,300	...	31,848	1.02
Snakeskin gourami	...	26,564	...	...	...	4,286	2,900	...	33,750	1.08
Striped snakehead	..	45,873	...	...	...	8,829	16,100	...	70,802	2.27
Three-spot gourami	...	13,187	...	...	...	...	...	...	13,187	0.42
Tilapias *nei*	...	...	...	...	...	41,677	...	...	41,677	1.33
Torpedo-shaped catfishes *nei*	...	14,492	...	...	...	5,735	8,400	...	28,627	0.91
Others	...	58,175	...	...	...	13,740	7,000	...	78,915	2.52
TOTAL	**509,350**	**426,874**	**70,915**	**5,848**	**1,580,670**	**155,509**	**187,300**	**189,700**	**3,126,166**	**100.00**

Source: SEAFDEC (2018)

Tapping inland water bodies of Southeast Asia for sustainable development

Many of the Southeast Asian countries have vast areas of natural and man-made inland water bodies that could be tapped for fisheries and aquaculture development (Pongsri *et al*., 2015). For example, Indonesia has the largest total area which is dominated by floodplains (33.3 million ha), dams (26.5 million ha), wetlands (20.1 million ha), and river deltas that could expand to about 1.9 million km^2. Myanmar has floodplains of about 6.0 million ha, reservoirs dams of about 1.8 million ha, river systems that could provide about 0.7 million km^2 area, and others of about 1.3 million ha. As for Cambodia, its inland water bodies comprise mainly wetlands of about 2.4 million ha, floodplains at about 0.7 million ha, and others at 0.3 million ha. Lao PDR, the land-locked country of Southeast Asia has floodplains of about 0.16 million ha, reservoirs of about 0.13 million ha, and river system of about 0.12 million km^2. The other countries are also endowed with vast areas of inland water bodies, which have huge potentials for fisheries development, and are reported to be under-utilized.

In terms of production of major groups of species, only Indonesia, Malaysia, Philippines, and Thailand reported their respective data by species, while Cambodia, Lao PDR, Myanmar, and Viet Nam reported their respective production data as freshwater fishes *nei*. Nonetheless, the major species caught include: striped snakehead, Nile tilapia, freshwater mollusks *nei*, Asian redtail catfish, tilapias *nei*, climbing perch, snakeskin gourami, silver barb, and others (**Table 3**). Based on such information, it can be gleaned that regional expertise on the identification of freshwater species remains inadequate. Considering therefore the significant contribution that the inland fisheries sub-sector could provide, if properly valuated, capacity building activities should be promoted in the Southeast Asian countries, specifically in the aspects of production data compilation and species identification by major species groups. Notwithstanding the need to also enhance the capacity of the countries in strengthening their systems and mechanisms of collecting data to make sure that the information on inland fisheries are properly recorded as this could lead to the accurate valuation of the inland fisheries sub-sector in ensuring food security in the future.

Ensuring Sustainable Development of Inland Fisheries in Southeast Asia: Role of SEAFDEC/IFRDMD

Recognizing therefore that inland fisheries could play the major role of enhancing the region's socio-economic development which is crucial for the region's food security by sustainably utilizing the vast inland resources that are available for sustainable development as well as the numerous indigenous fish species existing in the region, the SEAFDEC Council agreed to establish SEAFDEC/IFRDMD, which is being hosted by Indonesia. Thus, IFRDMD has been given the main tasks of developing the guidelines on basic data collection for routine monitoring of different types of inland habitats; establishing and promoting the tools for assessment and management of inland fishery resources; monitoring the state and levels of exploitation of inland fishery resources; providing scientific basis for the proper development and management of inland fishery resources to the Member Countries; and serving as the regional forum for cooperation and consultation on research, conservation and management of the region's inland fishery resources (Pongsri *et al*., 2015).

Conservation and management of tropical anguillid eels

At the very outset after its establishment, IFRDMD has been monitoring the state of exploitation and utilization of inland fishery resources in order to come up with scientific basis for their sustainable development and management. Therefore, as it continues to promote the responsible utilization of the inland fishery resources in Southeast Asia through meetings and consultations among the ASEAN Member States (AMSs), it has also become imperative for IFRDMD to coordinate the project "Enhancement of the Sustainability of Catadromous Eel Resources in Southeast Asia," the implementation of which had been endorsed during a series of SEAFDEC meetings.

The need to address the concern on the conservation and management of the tropical eel resources has been considered urgent as a proposal to list the Asian eel species under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is in the offing, and would possibly make impacts on this economically important species of the Southeast Asian region. In response to the recommendation for SEAFDEC to consider the development of appropriate measures for the sustainable management of eel resources to support the establishment of common position of the region if eel species, especially *Anguilla bicolor* (**Figure 4**) would be proposed for listing in the CITES Appendices, the SEAFDEC Secretariat convened regional meetings and consultations among the ASEAN-SEAFDEC Member Countries with funding support from the Japanese Trust Fund (JTF), and came up with the Regional Policy Recommendation on the Conservation and

Figure 4. Tropical anguillid eel (*Anguilla bicolor*)

Management of Eel Resources and Promotion of Sustainable Aquaculture. Upon its endorsement by the SEAFDEC Council during its Forty-seventh Meeting in April 2015, the said Regional Policy Recommendation enables SEAFDEC to initiate the conduct activities on the sustainable utilization and conservation of the tropical eel species.

After being fully organized, IFRDMD took on the responsibility of implementing the eel project in collaboration with the SEAFDEC Secretariat and with the cooperation of eel producing AMSs. With additional funding support from the Japan-ASEAN Integration Fund (JAIF), baseline and regular surveys have been started in the eel-producing AMSs, namely: Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam. Through a series of meetings and consultations and making use of the initial results of the surveys, the Information Document on the "Status and Resources Management of Tropical Anguillid Eels in Southeast Asia" was finalized. Describing the current progress of the regional initiative for tropical anguillid eels in Southeast Asia and containing the results of analysis of the status of exploitation of eel resources through fisheries and aquaculture, the said Information Document (SEAFDEC, 2018a) was submitted for review during the 30th Animals Committee Meeting in Geneva, Switzerland in July 2018, and during the subsequent 18th Meeting of the CITES Conference of Parties (CITES CoP18) in May 2019 in Colombo, Sri Lanka.

Promotion of responsible utilization of inland fisheries in Southeast Asia

Taking into consideration the two most important factors for the better management of inland fishery resources, *i.e.* improved data collection, and enhanced governance through the application of the ecosystem approach to fisheries management and co-management, IFRDMD has embarked on a project that generally aims to establish and strengthen the networking for the improvement of fisheries management and conservation of fishery resources in the inland waters of Southeast Asia. The project comprises three major activities, *i.e.*, investigation of the activities and methodologies for promoting inland fisheries in the AMSs that includes compilation of information on the current status of inland fisheries in the region; promotion of effective inland fisheries management measures by making use of the results of the analysis of the current status of the region's inland fisheries; and development of habitat conservation and resource enhancement measures suitable for the region through capacity building.

With funding support from JTF, IFRDMD has initiated field surveys in Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam, specifically compiling data on fishing activities and related fisheries socio-economic aspects, and also studying the biology of the indigenous inland fishes. With the information compiled

through the surveys, the picture of current situation of the region's inland fisheries could be established and the key issues could be taken in consideration during the development of the measures that are appropriate for the management of the inland capture fisheries in the AMSs.

Strengthening effective inland fisheries management through GIS and RS

For the sustainable management and utilization of inland fishery resources, IFRDMD with funding support from JAIF would be embarking on a project that would monitor the environmental changes of the habitats that affect the inland fishery resources through the use of Geographical Information System (GIS) and Remote Sensing (RS) technologies, and establish effective management of inland fisheries and aquaculture based on the analysis of the causal relationship between the amount of catch/production and the environmental data obtained through GIS and RS. Wanchana and Sayan (2018) listed down relevant aspects that could be derived from the information obtained through GIS, which include: clear picture on the condition of the fishery resources that could be used for applying better harvesting strategies; and status of fishing effort to be used as basis for controlling harvest/fishing effort levels especially in highly exploited fishing grounds. From the RS applications, forecasting the fishing grounds could reduce the inefficiency of fishing activities; and with real-time information through the RS-obtained data, the origin of fish and fishery products in the supply chain could be traced.

Fish stock assessment and production potentials of fisheries from inland waters: Indonesia in focus

With funding support from the Indonesian Government, IFRDMD has implemented a Departmental Program that deals with an assessment of the fishery resources in Indonesian inland waters, considering that Indonesia embraces the most extensive inland water bodies in Southeast Asia (Pongsri *et al*., 2015). As a matter of fact, Indonesia has the enormous potentials, viewing not only from the aspect of area but also in terms of biodiversity, especially fish. Nevertheless, in terms of the total catch by area, the information is still underestimated due to insufficient statistical data.

With Indonesia as the pilot site, stock studies would be carried out using analytical methods (more detailed and more reliable data) and holistic methods (simpler data), *i.e.* the 'swept area' method which is based on "catch per unit area" to estimate biomass and maximum sustainable yield (MSY), and the "surplus production model" method making use of the information on catch per unit effort. The results could be a compilation of information related to the potentials of and production from inland waters as well as national inland fisheries. Moreover, Indonesia has established a management tool used to delineate its inland fisheries areas. Known as the Fisheries Management Area KPP-PUD (FMA/KPP-PUD), it adopts the ecosystem approach in the management of inland capture fisheries and is meant to determine the amount of fish stocks, production potential, maximum sustainable yield (MSY), and total catch that can be used as a basis for fisheries management in the Indonesian inland waters. Results from the stock studies could then be disseminated to the other AMSs, especially those with vast inland water bodies that could be tapped for sustainable development.

Way Forward

The foregoing major projects and activities are aimed to prepare IFRDMD to be transformed into a Center of Excellence for Inland Capture Fisheries Management of Indonesia as well as of Southeast Asia. With such an objective, the Government of Indonesia had provided the necessary funds for the harmonization of the activities of IFRDMD and the Research Institute for Inland Fisheries and Extension (RIIFE), and for these centers to be able to jointly carry out 'implementative' research activities that could be used as reference in addressing the concerns on inland fisheries development and management, especially through the development of policies, capacity building, networking, and technology verification and dissemination. It is the goal of the Government of Indonesia to utilize the results from such research activities in enhancing the prosperity of coastal communities through an integrated inland fisheries management (IIFM) which would be implemented through the establishment of a data center for science and technology on inland fisheries in Indonesia; establishment of sustainable management measures for inland fisheries resources; and the enhancing the cooperation among stakeholders for the development of pilot areas for sustainable management of inland fisheries. Although IFRDMD is still at the early stage of development, the Government of Indonesia supports the vision that IFRDMD should be slowly developed and established into a center of excellence in science and technology for inland fisheries management with national and international standards, not only for the benefit of the whole country but also for the Southeast Asian region.

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About the Authors

Dr. Arif Wibowo is the Chief of SEAFDEC Inland Fishery Resources Development and Management Department based in Palembang, Indonesia, and concurrently Director of the Research Institute for Inland Fisheries and Extension also in Palembang.

Dr. Takuro Shibuno is the Deputy Chief of SEAFDEC Inland Fishery Resources Development and Management Department based in Palembang, Indonesia.

Ms. Virgilia T. Sulit is the Managing Editor of *Fish for the People* based at the SEAFDEC Secretariat in Bangkok, Thailand.

Invasive Apple Snails: Integrated Management in Lowland Ricefields of Cambodia and Probing their Utilization in Aquaculture

Sathya Khay, Ravindra C. Joshi, and *Soetikno S. Sastroutomo*

This article provides insights on the aquatic invasive apple snails of the genus *Pomacea* and rice cultivation in Cambodia. The first record or known date of introduction of this freshwater invasive snail is before 1995. It was deliberately introduced mainly as a food source for humans. Since then the snails quickly spread to many provinces, becoming a major pest of lowland rice fields and posing severe threat to natural wetland environments. To reduce damages to rice crops in Cambodia, researchers from the Cambodian Agricultural Research and Development Institute (formerly Cambodia-IRRI-Australia Project), conducted research to prevent further spread of the snails and developed integrated management options to reduce the misuse and abuse of pesticides meant to control the breeding of the snails. From the aquaculture point of view however, studies have been conducted on the possibility of utilizing the invasive apple snails as feed for various commodities being cultured.

Freshwater invasive apple snails (*Pomacea* spp.), commonly known to Cambodian farmers as "khyorng yuonto," belong to the family Ampullariidae. The apple snails were discovered by the Cambodia-IRRI-Australia Project (CIAP) in Svay Rieng in August 1995, through a farmer who purchased the snails from Phnom Penh and raised them in clay pots. CIAP and the Plant Protection and Phytosanitary Inspection Office of Cambodia searched the Phnom Penh area and found several places where people were breeding large numbers of the snails (CIAP 1995; Chanty 2002; Preap *et al*., 2006). In November 1995, it was found that farmers in Takeo Province were intentionally placing them in their rice fields to be raised as food, just as they would normally place the native snails. These farmers were not aware that the introduced snails would later become pests in rice fields.

Map of Cambodia showing the provinces where the invasive apple snails were bred by communities

Aside from those found in Phnom Penh, the snails were also raised in at least 10 provinces: Kampong Chhnang, Kampong Cham, Kampong Speu, Kandal, Prey Veng, Pursat, Siem Reap, Svay Rieng, Battambang, and Takeo (Anonymous 2005; Chanty 2002; Preap *et al*., 2006). The spread of *Pomacea* spp. (**Figure 1** and **Figure 2**) to rice fields in various provinces of Cambodia has also been enhanced in some other ways, for example, through the poorly developed Cambodian irrigation systems, and also through waterways from the rice fields along the Vietnamese border in the provinces of Svay Reing, Kandal, Takeo, and Kampot.

Figure 1. Invasive apple snails (*Pomacea* spp.) invading newly established direct-seeded rice **(A)** and transplanted rice **(B)**

(Photo Credits: Ravindra C Joshi)

The snails were deliberately introduced into Cambodia primarily as food for humans, because of their large size, capacity to grow rapidly and high reproductive potential, as well as its high protein contents (Cowie *et al*., 2017).

Species of *Pomacea* and Their Impacts

Many publications prior to 2012, failed to distinguish *Pomacea canaliculata* and *Pomacea maculata*, until the advent of molecular approaches (Hayes *et al*., 2008). For example, the *Pomacea* snails from Cambodia were mentioned as *P. canaliculata*, but are in fact *P. maculata* (Cowie, 2002). In Cambodia, there are two species of invasive apple snails:

Figure 2. Invasive apple snails (*Pomacea* spp.) egg masses on rice **(A)** and in weeds along the rice field bunds **(B)**, Takeo Province, Cambodia

(Photo Credits: Khay Sathya)

P. canaliculata and *P. maculata* (Cowie 1995; Hayes *et al*., 2008), where *P. maculata* was originally referred to as *P. insularum*. *P. canaliculata* is listed among the world's 100 worst invasive alien species (GISD, 2018), largely because of the extensive damage that the snails could cause to both wetland rice and native ecosystems.

In addition, *Pomacea* species are also important transmitters of the rat lungworm parasite (*Angiostrongylus cantonensis*) that could cause major health consequences to humans when the snails are eaten raw. The name golden apple snails or GAS has been used widely in Asia for the introduced *Pomacea*, often without clarifying specifically which species, perhaps both was involved, or indeed simply assuming it to be *P. canaliculata* (Cowie *et al*., 2017). For clarity, this article avoids this ambiguous common name designation.

Rice Cultivation in Cambodia

In Cambodia, rice is cultivated twice a year both in wet (monsoon) and dry seasons, either by transplanting or direct-seeding. However, majority of farmers usually grow one crop of rice per year with a small portion of the farmers doing it twice a year. The total rice area accounted for about 3.21 million ha, with rice crop in the monsoon season accounting for about 77 % of the total country's paddy production. Majority of the farmers (more than 90 %) practiced direct-seeding method by manually broadcasting the rice seeds for almost in all rice growing seasons.

Nonetheless, with the climate change influencing precipitation, the country's rice planting calendar has shifted and has been adjusted. Now, the planting time for wet season rice starts from June to July (depending on the rain water), and harvesting is done from November to December (depending on the rice variety: early, medium or late maturity). For early maturing rice varieties, harvesting is made in October. In some places nearby water sources (*e.g.* lakes, rivers, reservoirs), farmers do recession rice (grow rice when water starts to decrease) in October. The national average rice yield is 3.29 tons/ha, with the total rice production of 10.52 million tons. Generally, the price of un-milled rice in the farm depends on the rice variety, moisture content, among others, and ranges from 700 to 1,300 Riel/kg (4,000 Riel=1U$D). At market places, the price of milled rice varies largely with the rice variety. Usually, rice harvest is bought by middlemen and milling companies.

Integrated Management of Invasive Apple Snails

Integrated management options against invasive apple snails were developed since it was first discovered in Cambodia, to address the misuse and abuse pesticides, aside from their impacts on farmers' health and the environment. As means of preventing the growth of snail population and eventual crop damage, some necessary culture techniques had been recommended for adoption in rice culture, as shown in the **Box**.

Box: Recommended techniques of rice culture to hamper the growth of snail population

- transplanting older seedlings as these are less preferred by snails for consumption
- adopting increased-seeding rate in direct-seeded rice fields as this compensates for the seedlings consumed by the snails
- installing screen traps on water inlets prevents snails from entering newly-established rice fields
- hand-picking of the snails in the morning and afternoon when they are active
- removing snails from rice paddies any time before final harrowing

The snails collected from rice fields could be used as feeds for ducks and livestock, and if completely cooked, could be eaten by humans. Moreover, direct control techniques are necessary when snail densities reach 2-3 snails/m^2, which could include: herding ducks through the rice fields immediately after harvest and 30 to 35 days after transplanting early maturing rice, or 40 to 50 days after transplanting late maturing rice; and placing bamboo stakes around the fields to provide places for snails to lay eggs and facilitate collection of eggs after which these should be destroyed (Jahn *et al*., 1997).

Table 1. Molluscicides active ingredients registered to be used in Cambodia

Active Ingredient (a.i.)	Dose (a.i. g/ha)	Country of Origin
Metaldehyde	240-360	Viet Nam, People's Republic of China
Niclosamide	175-210	Viet Nam, People's Republic of China
Saponin	750-1200	Viet Nam, People's Republic of China

Pesticides could also be used but properly and with extra care. In Cambodia, there are active ingredients allowed as molluscicides. These are: metaldehyde, niclosamide, and saponin, of which metaldehyde and niclosamide are synthetic molluscicides, while saponin is a plant-based molluscicide. These pesticides (**Table 1**) are imported from Viet Nam and the People's Republic of China.

The selected formulated products traded and approved for use in Cambodia are shown in **Table 2**. These products come either in small sachets or in 1 kg packaging. On an average, a rice farmer spends about US$ 16/ha (for one time application), and farmers usually apply twice per rice cropping season. The time of applying the molluscicides is either before crop establishment (direct-seeding or transplanting) or 1-2 weeks after crop establishment.

Presently most of the snail management techniques could not be easily adopted by farmers as these are labor-intensive (Cowie, 1995), not economical, not effective to reduce snail numbers at non-damaging levels, and not environment friendly (Joshi, 2007). Thus, new innovative approaches should be developed and promoted to manage the overpopulation of invasive snails, especially in direct-seeded rice fields.

Conclusion

Since these were first detected in 1995, the invasive apple snails have widely spread across the lowland rice areas in Cambodia, causing serious crop losses. In recent years, especially with increased flooding caused by climate change adversities, the snails have invaded new areas. With more farmers resorting to wet direct-seeding, more snail damages had been triggered resulting in increased usage of molluscicides. Aside from the direct rice damages and based on the aspects of snail bio-ecology, the negative impacts on non-target fauna and flora including human health and the environment are still unknown.

Nevertheless, some aquaculture research studies have shown that the invasive apple snails could be used as a cheap alternative to traditional processed feeds for various cultured commodities to lower production costs and increase income (Casal *et al.* 2017; Heuzé and Tran, 2017). In China, it is quite common for the crushed snails being used as protein supplement for rice-prawn farming (IIRR *et al.*, 2001). Bombeo-Tuburan *et al.* (1995) established that the fatty acid profile of these introduced snails could provide the essential fatty acid required for the culture of black tiger shrimp (*Penaeus monodon*).

Based on the review of Castillo and Casal (2006), and Casal *et al.* (2017), invasive apple snails are utilized in small-scale aquaculture, where it was used as feed in the culture of the giant freshwater prawn (*Macrobrachium rosenbergii*) and the Japanese koi (*Cyprinus carpio*) in the Philippines. Also in the Mekong Delta of Viet Nam, some 20 to 25 tons of apple snails are collected annually and used as feed in giant freshwater prawn farming (Hasan and Halwart, 2009). The study of Jintasataporn *et al.* (2004) showed that in Thailand, apple snail meal could successfully replace 25 % of the fish meal for giant freshwater prawn culture in short period only, but not exceeding two-months. Moreover, *Pomacea canaliculata* meal had been a good source of protein for rabbitfish (*Siganus guttatus*) culture as established by Visca and Palla (2018).

The potentials for using of invasive apple snails as alternative feeds in aquaculture should therefore be explored through more intensive research, in order that the problem of snail infestation in rice fields could be reduced, and invasive apple snails would no longer be considered as pests but rather as an economic resource. It is in this regard that concerted efforts are necessary to develop ecologically sustainable snail management integrated approaches, through inter-country collaboration among the ASEAN Member States.

Table 2. Molluscicidal formulated products traded in Cambodia

Product Name	Company Name (Supplier)	Active Ingredient (a.i.)	Package Size (kg/g)	Price/Package
Molucide 6GB	Can Tho Pesticides Joint Stock Company, Viet Nam	metaldehyde 6 %W/W	1 kg	US$ 2.50
Toxbait 120AB	Anbio,Viet Nam	metaldehyde 120G/KG	1 kg	US$ 2.82
Nill 70WP	Sinamyang Company, Viet Nam	niclosamide 70 %WP	36 g	US$ 0.75
Snailicide 700WP	Nóng Phát, Viet Nam	niclosamide 700G/KG	36 g	US$ 0.70

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About the Authors

Mr. Sathya Khay is working with the Cambodian Agricultural Research and Development Institute, Ministry of Agriculture, Forestry and Fisheries, National Road No 3, Prateah Lang Commune, Dangkor District, Phnom Penh, Kingdom of Cambodia.

Dr. Ravindra C. Joshi is the Technical Advisor on Invasive Apple Snails to DELTAMED (Asociación de Deltas del Mediterráneo), Amposta, Spain; Senior Adviser on Invasive Apple Snails, NEURICE Project-Funded by European Commission, Spain; CABI-SEA Associate; Tropical Agriculture Association (UK) Pacific Coordinator; SAFE-Network Pacific Islands Coordinator; and Visiting Adjunct Professor at the University of the South Pacific, Fiji (*rcjoshi4@gmail.com*, *ravindra.joshi@usp.ac.fj*)

Mr. Soetikno S. Sastroutomo is working with the ASEANET c/o CABI Southeast Asia, Building A 19, MARDI, Serdang 43400, Selangor, Malaysia.

Managing the Spread of Invasive Apple Snails and Possible Utilization in Aquaculture: A Case in Myanmar

Aung Ko Win, Htar Htar Naing, and *Ravindra C. Joshi*

In literature, many *Pomacea* spp. have commonly been referred to as golden apple snails (GAS), often without clarifying specifically which species was involved or indeed simply assuming it to be *Pomacea canaliculata* (Cowie *et al*., 2017). For clarity, this article avoids this ambiguous common name designation, especially because at this time, it is very difficult to pinpoint the number of *Pomacea* spp. that have been introduced to Myanmar, unless preserved specimens are examined using molecular and morphological approaches (Hayes *et al*, 2008). Nonetheless, correct identification of the invasive species is the most fundamental prerequisites when attempting to control the spread of such species (Joshi *et al*., 2017).

Invasive apple snails (*Pomacea maculata* and perhaps, also *Pomacea canaliculata*) were first introduced to the Northern Shan State of Myanmar from the People's Republic of China in the early 1990s as food for humans, and later for the biological control of aquatic weeds in lakes. Aside from the deliberate introductions, the other pathways for invasive apple snails are river floods during the rainy season. A few years after such deliberate introductions, the non-native apple snails quickly spread to many parts of the country (**Figure 1**) through irrigation canals, irrigated fields, rivers, waterways, and waterlogged areas. As the result, the snails have become a major pest of the country's rice industry damaging rice nurseries, direct-seeded rice fields as well as the fields with newly transplanted rice (Khin *et al*., 2006; Win, 2017; Myint and Ye, 2017).

Species of *Pomacea* are listed as one of the world's 100 worst invasive species (GISD, 2018). When the snails invade and get established in rivers and wetlands, they pose high risk to the sustainability of the areas' native biodiversity and in particular, to the survival of endangered species such as the native aquatic plants, fish, amphibians, and birds. Occurrence of snails also reduce the macrophyte biomass through selective herbivory, seriously impacting the ecosystem services such as availability of fresh and good-quality water, thereby reducing the availability of plants and fish as food, and making recreation activities less attractive due to diminished bird and fish populations, and growth of algal bloom (Carlsson, 2017). The exact area infested by invasive apple snails in Myanmar is not known because of the lack of systematic field surveys.

Figure 1. Map of Myanmar showing the distribution of invasive apple snails (*Pomacea* spp.) as of 2017

(Source: Win AK, 2017)

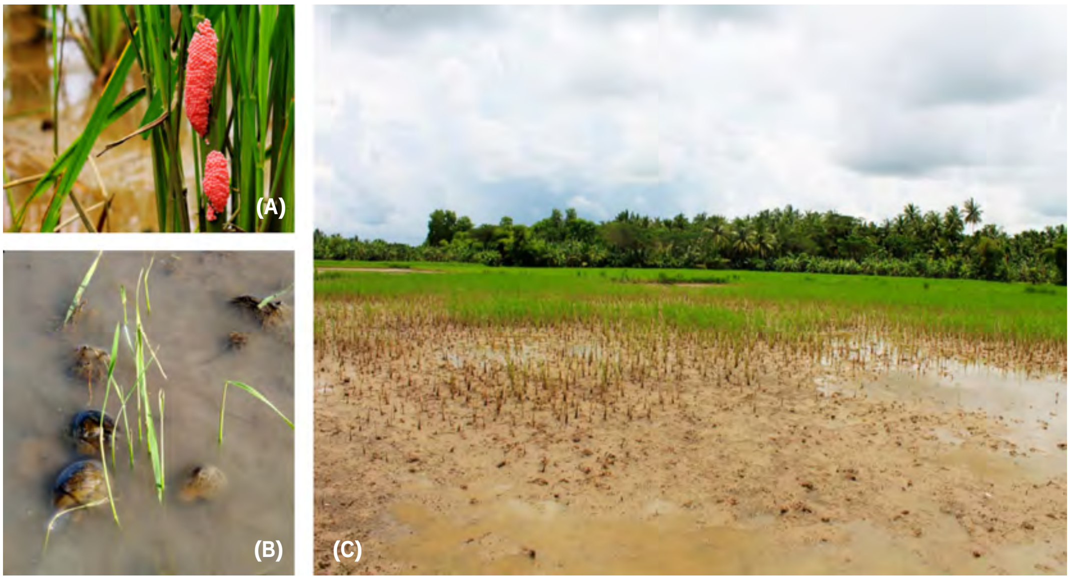

Figure 2. Invasive apple snails (*Pomacea* spp.) egg masses on rice plants **(A)**, and damages on transplanted rice **(B)** and direct-seeded rice field **(C)**, Dedaye Township, Ayeyarwaddy Region, Myanmar

(Photos: Win AK)

However, during the rainy season, 100 % damage to rice nurseries and young seedlings could be observed due to snail infestations (**Figure 2**). Thus, many farmers have become reluctant to grow rice.

Management Measures

Majority of the rice farmers in Myanmar have resorted to hand picking of the snails and egg masses. Molluscicides application had also been used followed by duck herding and adopting some cultural control measures (**Figure 3**). Two kinds of synthetic molluscicides active ingredients are registered in Myanmar (**Table**).

The cost for molluscicides, hand pickings, and replanting ranged from Kyats 15,814 to 79,488 per acre (**Figure 4**). More international, regional collaboration efforts are needed to develop sustainable, easy to-do, cost-efficient, and environment-friendly management techniques to reduce crop losses from apple snail invasions in the midst of the changing climate.

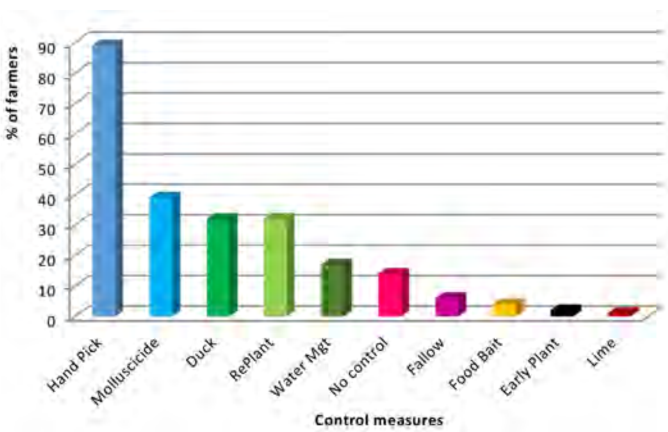

Figure 3. Practices adopted by Myanmar rice farmers to control the invasive apple snails (*Pomacea* spp.) in the surveyed areas

(Source: Win AK, 2017)

Table. Molluscicides registered in Myanmar as of 2016

Trade Name	Active Ingredient	Distributor
Bayluscide 70WP	Niclosamide 70 % w/w	Bayer AG, Germany
Rainlucide 70WP	Niclosamide 70 % WP	Close Friend Company Ltd.
Kensamide 250EC	Niclosamide 250 EC	Grand Agrocare Company Ltd.
Benride 700WP	Niclosamide 700g/ kg WP	Huynh Zaw Company Ltd.
Snailcide 70WP	Niclosamide 70 % WP	Myanma Awba Group Company Ltd.
UNIK	Niclosamide 70 % WP	Myanma Awba Group Company Ltd.
Khayu Sae 70WP	Niclosamide 70 % WP	Myanmar Arysta Life Science Company Ltd.
Agro-Kharu 70WP	Niclosamide 700g/ kg WP	Myanmar Asiatic Agricultural Company Ltd.
Snail Out	Niclosamide 70 % WP	Wah Agricultural Chemicals Trading Company Ltd.
Mercury	Metaldehyde 10 % G	Myanma Awba Group Company Ltd.

Source: Pesticides Registration Board, Plant Protection Division, Department of Agriculture, Myanmar

Way Forward

One novel way of controlling the further spread of the invasive apple snails throughout Myanmar could be to pursue research studies on the use of the snails in aquaculture activities.

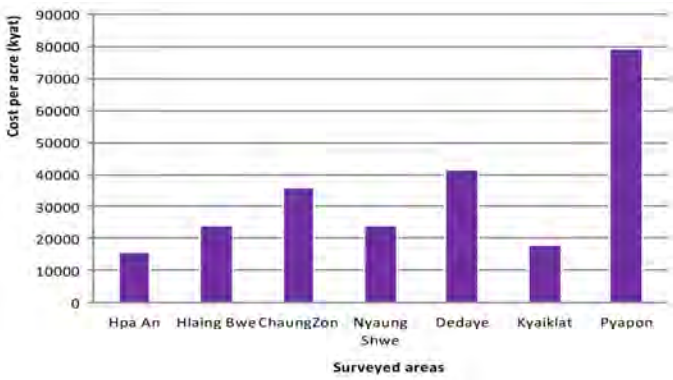

Figure 4. Comparison of average cost per acre to control invasive apple snails (*Pomacea* spp.) in the surveyed areas, Myanmar

(Source: Win AK, 2017)

As mentioned by Sathya Khay *et al*. (2018), a number of aquaculture research studies have shown that the invasive apple snails could be used as cheap alternative to fish meal in the preparation of feeds for the culture of various aquatic species, lowering aquaculture production costs and increasing the incomes of fish farmers. Considering that Myanmar is also engaged in rice-prawn farming (Khin Ko Lay, 2007), the use of the snails as protein supplement in the preparation of feeds for the giant freshwater prawn should be specifically explored to improve production of prawns from the rice-prawn culture system. Moreover, based on the experiences of many countries (Sathya Khay *et al*., 2018), the invasive apple snails have also been successfully used as feeds in the culture of other freshwater as well as marine aquatic species, *e.g.* common carps (*Cyprinus carpio*), black tiger prawn (*Penaeus monodon*), siganids (*Siganus guttatus*).

Through such research activities, the extent of snail infestation in rice fields could be reduced. In such cases, the invasive apple snails would no longer be considered as pests but rather as an economic resource for the aquaculture industry. In line with the suggestions of Sathya Khay *et al*. (2018), in pursuing such endeavors, international and regional concerted efforts should be pooled for the development of ecologically sustainable invasive apple snail management approaches for the Southeast Asian region.

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About the Authors

Mr. Aung Ko Win is Extension Communication Specialist of the International Fertilizer Development Center, Myanmar.

Dr. Htar Htar Naing is Associate Professor of the Department of Entomology, Yezin Agricultural University, Myanmar.

Dr. Ravindra C. Joshi is Associate of CABI-SEA, Malaysia; Technical Advisor on Invasive Apple Snails to DELTAMED (Asociación de Deltas del Mediterráneo), Amposta, Spain; Senior Adviser on Invasive Apple Snails, NEURICE Project-Funded by European Commission, Spain; Pacific Coordinator, Tropical Agriculture Association (UK); SAFE-Network Pacific Islands Coordinator; and Visiting Adjunct Professor at the University of the South Pacific, Fiji. E-mail: *rcjoshi4@gmail.com*, *ravindra.joshi@usp.ac.fj*

Tale of Two Successful Fisheries Management Schemes Adopted in Japan

Akito Sato, Kom Silapajarn, and *Virgilia T. Sulit*

The SEAFDEC Regional Guidelines for Responsible Fisheries in Southeast Asia: Responsible Fisheries Management (SEAFDEC, 2003) indicates that **fisheries management** refers to the "*integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources, and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of other fisheries objectives.*" In addition, SEAFDEC (2003) declares that **innovative fisheries management** implies the "*decentralization of selected fisheries management functions to the local level and progressive introduction of rights-based fisheries through …*" where **rights-based fisheries** is defined as "*fisheries where the right to fish or use of the fisheries resources is licensed or permitted by the competent government authority, giving the licensed fishers access and use rights to the fishing ground. Such rights are accompanied by obligations to comply with the rules and regulations of the right-based regime.*" Nevertheless, Garcia *et al*. (2003) explained that although there are "no clear and generally accepted definitions of fisheries management, its working definition pinpoints to *the activity of protecting fishery resources so sustainable exploitation is possible, drawing on fisheries science, and including the precautionary principle.*" Moreover, Garcia *et al*. (2003) also prescribed that the concept of **modern fisheries management** refers to *a governmental system of appropriate management rules based on defined objectives and a mix of management means to implement the rules, which are put in place by a system of monitoring control and surveillance, and based on an **ecosystem approach to fisheries management***. Guided by their respective adaptations of the generally-accepted definitions of fisheries management, the Fisheries Cooperative Association of Toushi Island and the Gifu Prefecture in Japan have adopted their particular fisheries management schemes that have proved to be successful through the years, and which could be referred to as mainly *quasi*-democratic and *quasi*-persuasive, respectively.

FAO (1995) declares that modern fisheries management has been practiced everywhere for the sustainability of the fishery resources for future generations. Although strongly based on the ecosystem theory, it is primarily focused on the practice of responsible fishing operations taking into consideration the health of the target fish stocks. In marine ecosystems, where there could be limited forms of direct human intervention, fisheries management strategies are focused in controlling the fishing activities while observing local laws and regulations on the utilization of the resources. In such cases therefore, Cochrane (2002) indicated that fisheries management refers to "*the integrated process of information gathering, analysis, planning, decision-making, allocation of resources, and formulation and enforcement of fishery regulations by which the fisheries management authority controls the present and future behaviors of the interested parties in the fishery, in order to ensure the continued productivity of the living resources*." This implies the need to optimize the use of the fishery resources as source of human livelihood, food and recreation, dynamically regulating fishing activity, meeting resource-related objectives or constraints. In the inland waters, being more affected by environmental problems and where fisheries management has been developed as an extension of wildlife management, Lackey (1999) suggested that substantial amount of direct intervention on the fishery habitat and resources is necessary.

Fisheries Management Scheme Adopted in Toushi Island, Japan: *Quasi*-democratic

Toushi Island (**Figure 1**) is one of four isolated islands under the administration of Toba City in Mie Prefecture, Japan with a unique folk culture and history, and a population of less than

Figure 1. Map of Toba, Mie Prefecture, Japan

Source: Google maps

3,000 people. Situated in Ise Bay of Japan, the Island embraces one of the most active fishing grounds in Japan. It was once, *i.e.* during the Sengoku period, a home-base for pirates. Now, the main livelihoods of the Island's inhabitants are commercial fisheries, aquaculture, and tourism. Toba City, which is known as the sea gateway of the Ise-Shima area, is endowed with rich natural resources and delicious local cuisine, and where the lifestyle of the people, the *Kaijin* (*people who live with the ocean*) fascinates the tourists. Famous for Mikimoto pearl, Toba also boasts for the world's first successful pearl culture during the Meiji Period.

Some 15 years ago, the Fisheries Cooperative Organization in Toushi Island was re-established as the Fisheries Cooperative Association - Wagu Branch of the Japanese Fisheries Tobaisobe, and now has 240 members. The most common fishery commodities (**Figure 2**) produced by the Island's fishers are snappers and other high-value fishes, as well as seaweeds, *e.g.* gracilaria, wakame.

Figure 2. Fisheries in Toushi-jima Island and the main produce

Toushi Island is also known as one of the famous bases of marine fisheries in the Ise Bay with good quality and high-value fishes, which after landing, are immediately sold fresh to wholesalers at the local fish market fully equipped with hygiene management facilities/services in Toushi Island. In view of the good practice of fishing activities and fish handling measures, nobody, not only middle wholesalers but also fish processors and consumers, is worried about the quality of any fish landed at Toushi Island.

The fisheries management promoted by the members of the Association in Wagu Branch could be referred to as quasi-democratic, where decisions are made by the majority of the members, who act rigidly and work hard to implement such decisions for the good of all members in the Wagu Branch and where bringing benefits to the people of the Island as a top priority. It is also a form of collaborative-participative management because all members contribute to the development of the fisheries vision by taking part in the establishment and enforcement of the rules and regulations for fishing activities, as well as in the fishery resources enhancement and management activities, among others.

Under such management scheme, the Association takes it as their responsibility to teach the younger generation including high school students about the value of fishing as a livelihood and industry, as well as about the Association's system of fish stock conservation and enhancement. This way, the concept of sustainable fisheries through a natural system of conservation is instilled in the minds of the people including the younger generation. So, when big fishes, especially broodstock and spawners are caught, these are released back to the sea to produce more fish in the future, while small fishes could either be released back to the waters to allow them to grow to marketable size, or in some cases, these are cultured in cages for fattening until marketable sizes. In addition, for example, the fishers in Toushi Island agree to take fishing holidays for two days per week, as a form of closed season allowing in a way, the fish stocks to recover. Nevertheless, fish landing amount has been increasing from 120 million Japanese Yen in 2003 to 198 million Japanese Yen in 2016, which means that the Island fishers produce the high value from their target species, and their value is not expressed in terms of quantity (heads or weight) but in terms of Toushi Brand reliability ensuring that freshness is maintained for good quality fishes that are landed in Toushi Island.

Contribution from fisheries to the communities in Toushi Island

For a long time, the Association in Wagu Branch has continued to support the various activities of the communities in Toushi Island. For example, the fishing communities have been organizing the largest three-day God festival on this Island every year supported by the fishers from their catch incomes. During this festival, fishers also make efforts to promote fishery resources enhancement and management activities, and advocate continued fishing activities in a sustainable way. Every people in Toushi Island look forward to participating in this festival. As another example, auction for fish catch organized at the local fish market in Toushi Island is opened not only to registered middle-wholesalers but also to fish processors/owners of hotels/inns within Toushi Island and the Association in Wagu Branch itself.

The Association in Wagu Branch operates a fish processing factory, where local fish and seaweeds bought by the Association are processed into a variety of Toushi Brand fish products by the women's groups in the Island for domestic consumption and local trade. As the result, the economy of the Island is activated through the promotion of tourism and circulation of money within the Toushi Island. Such regionalism leads to the wealthy daily lives of inhabitants in Toushi Island, and the population of the Island as well as the number of fishers has been maintained with a considerable number of young generations.

The *Quasi*-persuasive Fisheries Management Scheme in Gifu Prefecture, Japan

Gifu Prefecture (**Figure 3**) is located in the center of Japan and is one of its few landlocked prefectures. It is famous for cormorant fishing, which has a history of over 1,300 years. Although agriculture is a major industry because of its vast arable plains, Gifu's forests also provide materials for woodworking and for constructing the viewing boats used in cormorant fishing.

Figure 3. Map of Japan showing Gifu Prefecture

Source: Google maps

Cormorant fishing is a traditional fishing method in which fishers make use of trained cormorants (*Phalacrocorax* spp.) to fish in rivers. Historically, cormorant fishing has been taking place not only in Japan, but also in China and Korea. To control the birds, the fishers tie a snare near the base of the bird's throat to prevent the birds from swallowing larger fish held in their throat, although the birds could still swallow the smaller fish.

In the Nagara River of Gifu Prefecture, the Japanese cormorants (*Phalacrocorax capillatus*), larger in size and stronger than the common cormorants, are used for the cormorant fishing. When a cormorant catches a fish in its throat, the fishers brings the bird back to the boat and has the bird spit up the fish. Once a very successful industry, cormorant fishing in Gifu Prefecture now serves primarily the tourism industry of the Prefecture.

Nagara River System of Gifu Prefecture

Aside from cormorant fishing, the Nagara River System of Gifu Prefecture is famous for its sustainable production of "ayu" (*Plecoglossus altivelis*), also known as sweetfish, from inland capture fisheries. The fish which can grow to about 20-30 cm long (**Figure 4**), is celebrated as one of the tastiest river fishes, especially when grilled or skewered (**Figure 5**). "Ayu" feeds mainly on water weeds and algae that the fish scrapes from rocks, although the juvenile fish also feeds on aquatic insects.

"Ayu" is highly territorial when it comes to their feeding grounds and attacks any fish entering their territory of about 10-20 m^2. In March, the adult fish swim down the river to spawn and the larvae enter the ocean and feed on plankton over the winter, returning to rivers in the spring. Some fish survive to spawn for two or three years in succession, although others manage to do it only once.

Figure 4. Commercial size *ayu*

Source: japantimes.co.jp

Figure 5. Skewered *ayu*, a delicacy in Japan

The "***Ayu of Nagara River System***" of Gifu Prefecture has been declared as Globally Important Agricultural Heritage System (GIAHS) in December 2015 by the Food and Agriculture Organization of the United Nations (FAO). Established by FAO in 2002, GIAHS aims to ensure the balanced use of the environment and land in a globally important region, while its biodiversity is protected in the practice of traditional agriculture, forestry and fisheries that form a comprehensive system (GIAHS, 2017). The Nagara River System links the aquatic environment and fishery resources to the daily lives of the people inhabiting the upper and lower basins of the River.

Although the Nagara River basin has a population of 860,000 people and the river flows through urban areas, the waters of the river remain clear and clean in the midst of the daily lives of the people. In order to preserve, inherit and develop the Nagara River System, the Gifu Prefecture certifies its products as "Products of Excellence" blessed by the clear waters of the Nagara River. The waters of the River are kept clean because of the cooperation of the people and their sense of responsibility in preserving the environment that had been instilled in their minds. Moreover, in preserving the whole environment, residents from downstream not only contribute the necessary money for reforestation but also go upstream to help the people in their efforts to conserve the mountain system by volunteering in tree planting activities, recognizing the mountain as the source of clear water for the Nagara River. Such close collaboration between the upstream and downstream people has been preserved through the years.

Management scheme for *Nagara "ayu"* capture fisheries

Arlinghaus *et al*. (2002) described the approaches to the management of habitat, people and fish stocks that make up freshwater fisheries, and recommended that re-stocking could be useful in situations where there is no natural recruitment or there is a need to restore the diminishing stocks. In making the necessary interventions, they also suggested that these should be based on principles of adaptive management and structured decision-making. Parallel to such approaches, Gifu Prefecture promotes their own scheme for "ayu" capture fisheries management in Nagara River, which could be considered as a form of a quasi-persuasive system. Orchestrated by competent manager-experts led by the Governor of Gifu Prefecture and his cohorts including the GIAHS "Ayu of the Nagara River" Promotion Association, Ayu Hatchery Centers by the fisheries cooperative associations, and the Tourism and International Affairs Bureau of Gifu Prefecture which promotes the "ayu" traditional cooking culture, such form of fisheries management scheme allows the inland fishers to carry out their tasks efficiently, having been persuaded in a friendly manner that complying with the rules and regulations would yield in results that best impact on the sustainability of the fisheries in Nagara River. Considering that the waters of the Nagara River are utilized by many stakeholders, the authorities of Gifu Prefecture also makes sure that their own version of fisheries management for "ayu" is based on an integrative, stakeholder-inclusive approach. Through their sustained promotion of such system, Gifu Prefecture has been a very proud recipient of the GIAHS Award.

"Ayu" Hatchery Centers of the Gujo Fisheries Cooperative Association

In order to maintain the stable fishery of "ayu" at the Nagara River System, the "Ayu" Hatchery Centers located in Gujo City in Gifu Prefecture started to operate seed production from 1983 through the initiative of the Gujo Fisheries Cooperative Association. The hatchery has since then been supplementing the shortage of wild "ayu" by providing juvenile "ayu" for release into the River system. The current production of "ayu" from the hatchery is more than 60,000 kg of juveniles annually. The annual plan of operation of the hatchery starts in the fall when eggs are collected from wild matured "ayu." In winter, the eggs are raised to larvae, and during the spring, the fry of "ayu" is released into the River system. In keeping the genetic diversity specific to "ayu" in the Nagara River, only matured "ayu" coming from the River are used for the hatchery's operations.

Gifu Prefectural Inland Fisheries Training Center

To contribute to the development of the GIAHS declared "Ayu of the Nagara River System" as well as inland fisheries in general, the Gifu Prefectural Inland Fisheries Training Center was established in 2016. Specifically, the Center also takes charge of the dissemination of knowledge, techniques, experiences, and systems of inland fisheries and aquaculture. The Center offers training programs that are tailored to the needs and requests of countries but focusing mainly on fishing ground management, stock enhancement, and aquaculture techniques of inland fish species. The Center also dispatches its researchers to developing countries for on-site technical support regarding inland fisheries. In May 2016, SEAFDEC and Gifu Prefecture signed the Memorandum of Understanding (MOU) for the promotion of educational and technical cooperation for the sustainable development of inland fisheries in the Southeast Asian region. Since then, representatives from the Southeast Asian countries had availed of the training courses organized by the Center. It is therefore expected that through the said MOU, the development of inland fisheries in the region would be enhanced for food security and economic stability, especially in communities where inland fisheries is the main livelihood.

Way Forward

Regarding the quasi-democratic fisheries management in Toushi Island and the quasi-persuasive fisheries management in Gifu Prefecture, both successful fisheries management schemes are examples of decentralized fisheries management by promoting rights-based fisheries to fisheries cooperative associations or fishers in their regions/communities. A common key point for both success stories is that fisheries cooperative associations or fishing groups make all fishers follow the decisions or rules/regulations, including fishers in local communities. This is a basic and important feature in rights-based fisheries, and the two examples have been carried out, in particular with leadership by leaders and strong local patriotism in each region that led to the formulation of good fisheries management with ecosystem approach as the result. Although not very easy to promote, such systems could also be possibly realized in other regions not only in Japan but also in the Southeast Asian countries. In addition, it should be noted that Toushi Island is located at the Ise Bay, where the Nagara River brings abundant nourishment and formulates the favorable fishing ground. The above examples therefore demonstrate that well-preserved forests on the upstream and unpolluted rivers that go downstream are indispensable to heighten the biological diversity of the coastal waters and habitats.

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About the Authors

Mr. Akito Sato is the Deputy Secretary-General of the Southeast Asian Fisheries Development Center (SEAFDEC) in Bangkok, Thailand and concurrently, the Deputy Chief of SEAFDEC Training Department, Samut Prakan, Thailand.

Dr. Kom Silapajarn is the Secretary-General of SEAFDEC, in Bangkok, Thailand and concurrently, the Chief of SEAFDEC Training Department, Samut Prakan, Thailand.

Ms. Virgilia T. Sulit is the Managing Editor of *Fish for the People* based at the SEAFDEC Secretariat in Bangkok, Thailand.

Mr. Akito Sato, Dr. Kom Silapajarn, and **Ms. Virgilia T. Sulit** comprised the September 2018 SEAFDEC Mission Team to Japan, visited among other places, Toushi Island and Gifu Prefecture in Japan where they learned lessons from their respective fisheries management schemes that have proven to be successful, and observed that such schemes could also be adapted for the sustainability of fisheries in the Southeast Asian countries.

Promoting Responsible Aquaculture for the Sustainable Production of Soft-shell Crabs

Jon Irish L. Aquino

Soft-shell crabs command a high price because these could be eaten whole when cooked. Myanmar, Viet Nam, and Thailand are among the Southeast Asian countries that produce considerable quantities of soft-shell crabs mostly sold to local restaurants as well as exported to Australia, Europe, Hong Kong, Japan, Singapore, South Korea, Taiwan, and the USA. Production of soft-shell crabs is an emerging technology in the Philippines, where the demand for this product has been increasing and the technology becoming a growing interest. With prices that could range from US$ 10 to US$ 15 US$ or higher per kilogram depending on the size, soft-shell crabs are bought in bulk by elite restaurants in the Philippines that usually serve this delicacy with complimentary food or drinks. Although the demand for soft-shell crabs is high, production is still unstable due to lack of seedstocks, which are mainly sourced from the wild. To reduce the pressure on the natural population, SEAFDEC/AQD has initiated the development of soft-shell crab technology using hatchery-produced seedstocks, and is currently promoting the use of hatchery-produced seedstocks for soft-shell crab farming to local and international stakeholders all over the Southeast Asian region through its training courses. With funding support from the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) of the Department of Science and Technology (DOST) through its National Mud Crab Science and Technology Program (NMCSTP), SEAFDEC/AQD has intensified the development of the soft-shell crab technology. Applicable to all mangrove (mud) crab species, the technology for the production of soft-shell crabs could now be pursued using hatchery-produced seedstocks is described in this article.

Soft-shell crab in this article refers to any mangrove or mud crab (*Scylla*) species that has undergone a process in its life cycle called molting. In some countries, crab species like the blue swimming crabs (*Portunus pelagicus*) (Azra and Ikhwanuddin, 2015) and blue crabs (*Callinectes sapidus*) (Oesterling, 1988) are used for soft-shell crab production. As part of development, crabs often molt during their life cycle in order to grow, metamorphose, and reproduce. Crabs shed their old exoskeleton to be replaced by a new membranous sheath of decalcified, hydrated, and brief soft shell. With this temporary period of having a very pliable and soft exoskeleton, the crabs are referred to as "soft-shell" or "softy" crabs (Tavares, Silva, Pereira, & Ostrensky, 2017; Hungria *et al*., 2017; Quinitio *et al*., 2015; Kuballa and Elizur, 2007).

Crabs undergo four stages of the molting cycle starting with the molt stage, when the crabs tend to shed off their exoskeleton by quick adsorption of water and air from the environment, then the old shell breaks. Although this stage is considered the weakest part of the crabs' growth cycle and is also the most stressful, the crabs increase 30-50 % in size after molting. The second stage is postmolt where crabs are inactive and start to uptake water to expand the new and soft exoskeleton, then, the exoskeleton mineralizes and starts to harden. The third stage is the intermolt, considered as the longest among other molt stages where crabs slowly develop their tissue. At the fourth stage, crabs separate the exoskeleton from the membranous sheath (**Figure 1**) and prepare for the onset of another cycle of ecdysis or molting. Movement and feeding are reduced as the crabs lose its muscle insertions during this stage (Kuballa and Elizur, 2007).

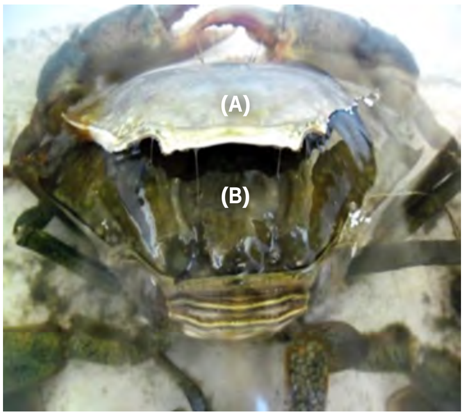

Figure 1. A molting mangrove crab (*Scylla serrata*): old and molted exoskeleton **(A)** pulling off; the membranous layer **(B)** could be observed

(Photo: ET Quinitio)

Mangrove Crab Species

The "mangrove crab" became the standard common English name for the *Scylla* species based on the Resolution adopted during the First National Mud Crab Congress in Iloilo, Philippines in 2015, which prescribed that the *Scylla* species should be called "mangrove crab" replacing the term "mud crab" as this connotes a negative impact to the marketability of the crabs. Also, the term "mangrove crab" links the four *Scylla* species to their natural habitat, the mangrove areas, and emphasizes the significance of mangrove forest conservation (Quinitio, Parado-Estepa, & Coloso, 2017).

Keenan *et al*. (1998) has identified the four distinct *Scylla* species of mangrove crabs as *Scylla serrata* (giant or king crab), *S. tranquebarica* (purple mangrove crab), *S. olivacea* (orange mangrove crab), and *S. paramamosain* (green mangrove crab). Primarily, the four species differ in the shapes and heights of their frontal spines; number and height of spines located on their chelipeds, and the pattern of markings on their legs and color of their shell (Quinitio and Estepa, 2008).

Table 1. Morphological features of *Scylla* species

Scientific name and common English name	Frontal spines		Chelipeds		Color and markings
	Shape	Height	Carpus spines	Propodus spines	
Scylla serrata giant or king mangrove crab	pointed	high	both obvious	obvious	Carapace green to almost black; polygonal pattern visible on chelipeds and legs of both sexes and the abdomen of the mature female
S. tranquebarica purple mangrove crab	blunt	moderate	both obvious	obvious	Carapace green to almost black; polygonal pattern obvious on last two pairs of legs but obscure on chelipeds and other legs of both sexes
S. olivacea orange mangrove crab	rounded	low	inner absent, outer reduced	Reduced	Carapace is brownish to brownish green in color; chelipeds and legs rusty brown and polygonal pattern absent
S. paramamosain green mangrove crab	triangular	moderate high	inner absent, outer reduced	obvious	Carapace green to light green; the obscure polygonal pattern on chelipeds and legs in both sexes

Source: Quinitio & Parado-Estepa (2008)

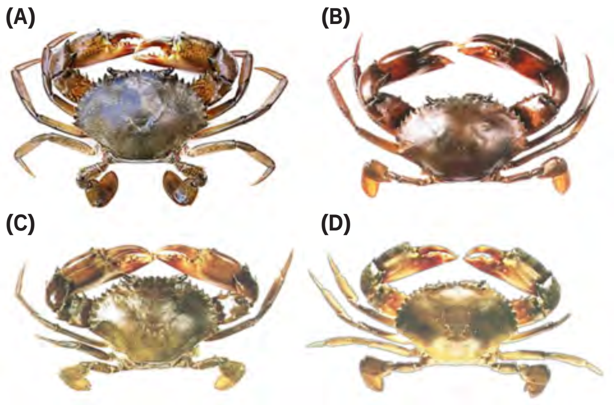

Figure 2. The four mangrove crab species: **A.** *Scylla serrata* or giant or king mangrove crab; **B.** *S. tranquebarica* or purple mangrove crab; **C.** *S. olivacea* or orange mangrove crab; and **D.** *Scylla paramamosain* or green mangrove crab

(Photos: Keenan et al., (1998))

The four *Scylla* species are illustrated in **Figure 2**, and the morphological features of each mangrove crab species are described in **Table 1**.

Farming of Soft-shell Crabs

In the Philippines, the production of mangrove crabs entails long- and short-term cultures, taking four to six months to produce marketable size in long-term grow-out culture. On the other hand, short-term culture engages in the fattening of lean crabs for 15-45 days (Williams and Primavera, 2001) and production of soft-shell crabs (Quinitio and Noe Lwin, 2009; Ganesh *et al*., 2015; Quinitio *et al*., 2015).

For soft-shell crabs, production could be done on a communal or an individual setup, starting with the outsourcing of 60-100 g body weight (BW) hard-shell crabs in intermolt and premolt stages (Quinitio and Noe Lwin, 2009). In communal rearing, the crabs are stocked in tanks or bamboo or net cages installed in ponds. The chelipeds are removed to avoid cannibalism when the crabs molt, for although removal of the crabs' limbs could induce molting (Hopkins, 1982), this could also lead to mortalities. In individual rearing, each crab is maintained in perforated plastic boxes held in pontoons or floating platforms in a pond. When the pond is not available, the indoor crab boxes set-up with recirculating water system (RAS), as practiced in Indonesia and Malaysia, could be utilized. However, the operational expenses in RAS could be high due to the maintenance of water and power supply (FAO, 1984). In any system used, the newly molted crabs are retrieved, sorted, held in freshwater, packed, and stored in the freezer before marketing (Quinitio and Noe Lwin, 2009; Quinitio *et al*., 2015). Nonetheless, sustainable aquaculture practices should be adopted in the production of soft-shell crabs as summarized in the following:

- **Site selection**

Any brackishwater earthen pond designed for the culture of fish, shrimps, or mangrove crab can be used for the farming of soft-shell crabs. The total area needed for the culture is at least two hectares where 0.10 ha, 1.50 ha, and 0.40 ha are intended for the nursery, grow-out, and soft-shell crab operations, respectively. The criteria used to evaluate the

Box. Criteria for evaluating the suitability of a site for soft-shell crab farming

- The site should be near the source of crablets
- The type of soil should be clay or clay-loam (compact and has low permeability) which is necessary for diking and retaining water
- Brackishwater should be clean and free from sources of pollution (*e.g.* factories, food processing plants, oil depots, densely populated areas)
- The area should not be populated and protected from calamities (*e.g.* flood, siltation)
- Materials for construction of the nursery and grow-out ponds, and fabrication of nets should be available
- Ponds with several compartments should be available for the nursery of hatchery-reared crablets (2,500 m^2), grow-out compartments (5,000-10,000 m^2), and soft-shell crab production (3,000 m^2)
- Food for the stock should be available
- The electric power source should be reliable
- Transport system should be accessible (*e.g.* crablets source to farms, from farm to market)

suitability of the site for soft-shell crab farming (Quinitio *et al*., 2015; SEAFDEC-AQD *et al*., 2010) are shown in the **Box**.

- **Farming facilities**

Soft-shell crab facilities include a fully timbered roofed bridge constructed across the pond for servicing, inspection, and collection of crabs during the operation; an area for weighing, sampling, acclimation, holding newly harvested soft-shell crabs in aerated freshwater, and stocking of trays; and a freezer for storage. The demonstration farm for soft-shell crab farming at AQD's Brackishwater Station in Dumangas, Iloilo, Philippines is shown in **Figure 3**.

Figure 3. Demo farm for soft-shell crab farming at AQD's Dumangas Brackishwater Station: Working hut **(A)** connected to the roofed bridge **(B)** in the middle of the pond

(Photos: ET Quinitio)

- **Hatchery rearing of 60-100 g crab juveniles**

Outsourcing of crab juveniles from the natural stocks is discouraged to avoid further depletion of the crab population in the wild. Seed production of mangrove crabs in hatcheries could serve as good source of seedstocks. Nursery phase can be integrated into the grow-out pond for the further culture of the hatchery produced small crabs. Alternately, crab instars from the hatchery can also be stocked directly in growth ponds skipping the nursery phase as long as grow-out ponds are well prepared and no predators. Stocking of 60-100 g crabs is preferred due to shorter molt frequency than the bigger-sized juveniles. With this size, a fast recovery of investments and the production cost could be feasible. **Table 2** and **Figure 4** describe the production of 60-100 g crab juveniles for soft-shell crab farming.

- **Individual rearing of soft-shell crabs**

Scylla species with 60-100 g BW reared in the hatchery and grown in grow-out ponds are stocked individually in perforated crab boxes (**Figure 5-A**). Individual perforated plastic containers are set in PVC floating platforms called pontoons that are set in ponds (**Figures 5-B** and **5-C**). At least 5,600 crab juveniles in the intermolt and premolt stages are stocked within a month. Milkfish or siganid fingerlings can be stocked at 0.3-0.5 individuals/m^2 in the same pond compartment, as the fish can serve as 'aerators' and eat the algae that grow around the crab boxes.

The crabs are fed with wet feed such as fish and mollusks every 2-3 days at 8 % BW. Water in the pond is changed every spring tide or when necessary. Molting is monitored every 4-6 hours, and the crab has molted if two exoskeletons are present in the box. Usually, the old exoskeleton is smaller than the soft-shell crab (**Figure 6**). The hardening of the new shell starts in a few hours immediately after molting, and the crab rapidly restores its movement and defence mechanism. Thus, soft-shell crabs must be harvested immediately to retain its commercial value (Tavares *et al*., 2017).

- **Harvesting and packaging**

Newly molted crabs are transferred into a bucket containing freshwater provided with aeration. After an hour or less, the harvested soft-shell crabs can be sorted (small: < 90g BW and

Table 2. Hatchery rearing of crab juveniles for soft-shell crab farming

	Culture phase		
	Nursery	Grow-out	Soft-shell crab production (individual rearing)
Body weight, BW (g)	0.2-0.4	60-100	80-120
Carapace width, CW (cm)	1.0-1.5	6.0-9.0	7.0-11.0
Duration (day)	15-21	30-45	14-21
Culture media	Net cages in ponds	grow-out ponds	perforated boxes

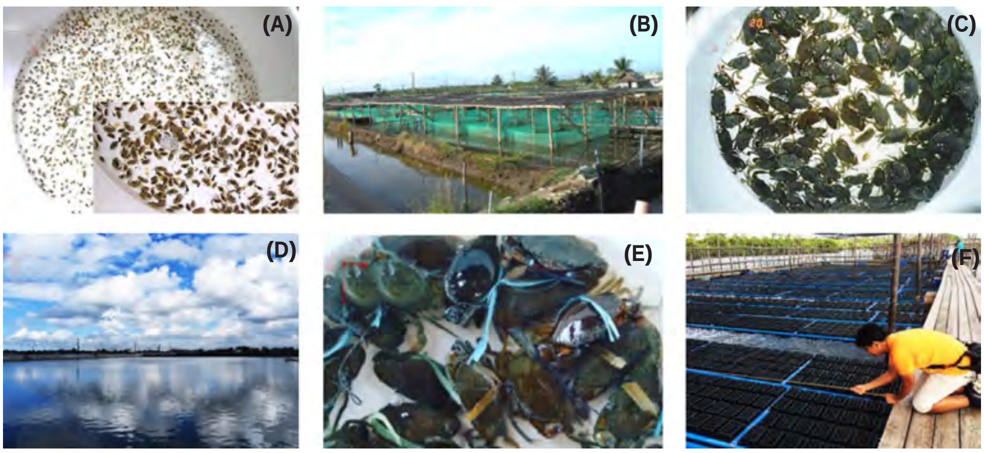

Figure 4. Production of crab juveniles for soft-shell crab farming using hatchery-sourced crab instars: **A.** crab instars; **B.** Nursery in net cages installed in a pond; **C.** 3.0-4.0 cm CW crablets; **D.** grow-out pond for stocking; **E.** 6.0-9.0 cm CW with 60-100g BW crab juveniles; and **F.** soft-shell crab production set up)

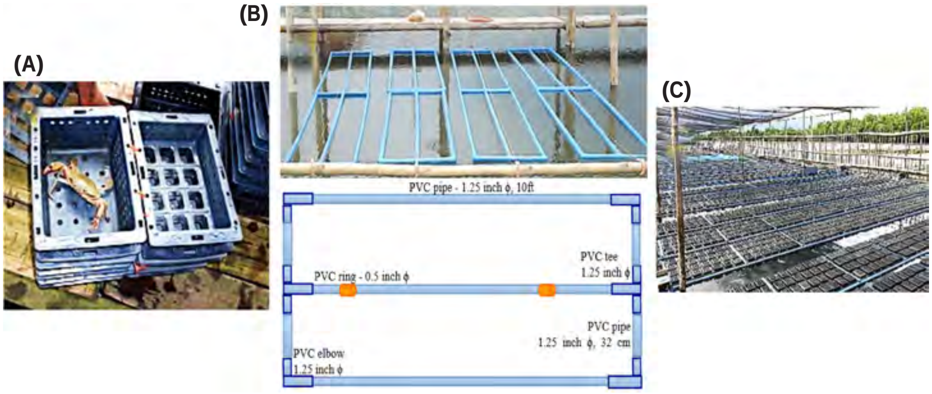

Figure 5. Set-up for individual rearing of soft-shell crab farming: **A.** individual stocking of mangrove crab in a perforated plastic container *(Photo: ET Quinitio)*; **B.** pontoons and its dimensions *(Photos: GX Libunao)*; **C.** individual setup for soft-shell crab in a pond

Figure 6. A newly molted crab juvenile and its old exoskeleton

big: > 90g BW) and packed individually in food grade plastic bag and kept in the freezer at -18 °C. For bulk orders, packed soft-shell crabs are placed in big high-density polyethylene (HDPE) plastic bag before fitting into a styrofoam box. The plastic bag is covered with used papers to maintain the cold condition of the crab in the styrofoam box, which is sealed and placed inside a bigger HDPE bag prior to shipment. The transport box must have complete details of its destination (**Figure 7**).

Figure 7. Packaging of harvested soft-shell crabs: **A.** sealing in a food grade plastic bag; **B.** sorting; **C.** packing in HDPE plastic bag; and **D.** properly labeling the styrofoam box for shipping

The Economics of Soft-shell Crab Production

Based on actual runs, the technical parameters needed for the cost and return analysis of soft-shell crab production are presented in **Table 3**. The total pond area needed for the culture is 2 ha where 0.10 ha, 1.50 ha, and 0.40 ha are intended for the nursery, grow-out, soft-shell crab, and milkfish operations, respectively. The total production of soft-shell crabs (≥ 90 g BW) is 6,150 pieces that could earn US$ 9,937.91/crop, excluding gross income from milkfish production of US$ 1,066.58/ crop. The selling prices are US$ 16.16 and 2.37, for soft-shell crab and milkfish, respectively, from the farm gate. These prices are based on the average of the existing prices for big soft-shell crabs and milkfish (4:1) in the Philippines. Nevertheless, the supply and demand chain of a particular area determines the price of soft-shell crabs.

The total investment cost, annual depreciation, and re-investment after three years for soft-shell crab farming are shown in **Table 4**. The cost of perforated crab boxes (US$ 21,202.33) constitutes 62 % of the initial investment costs. From the total variable cost of US$ 20,209.33 (**Table 5**), labor

Table 3. Technical considerations for soft-shell crab farming

Technical Parameters	Nursery	Grow-out	Soft-shell crab	Milkfish
Project duration (mo)	1.0	1.5-2.0	1.5	4
Total area of facilities for cages, ponds, tanks, and workspace (ha)	0.10	1.50	0.40	0.40
Number of crops/year	4	4	4	3
Total number of stock per crop (pcs)	24,116	14,470	7,235	2,000
Survival rate (%)	60	50	85	90
Total recovery at harvest per crop (pcs/m^2/crop)	14,470	7,235	6,150	1,800
Milkfish total harvest (kg/crop)				450
Average weight per piece at harvest (g/pc)	2-4	70-80	100	250
Cost of seeds (US$/pc)	0.13			0.13
Farm gate selling price of ≥ 90 g soft-shell crabs (US$/kg)			16.16	2.37
Gross value of harvest per crop (US$/crop)			9,937.91	1,066.58

Table 4. Investment items and costs, depreciations, and re-investment requirement for soft-shell crab production

Item	Price/unit (US$)	Quantity	Cost	Lifespan (years)	Depreciation cost/year (US$)	Re-investments on year 3 (US$)
Nursery setup	1,508.30	1	1,508.30	5	301.66	
Grow-out setup	1,077.35	1	1,077.35	5	215.47	
Pontoons	21.98	260	5,714.29	10	571.43	
Perforated crab boxes	3.45	6,150	21,202.33	5	4,240.47	
Freezer, 11 cubic feet	538.68	2	1,077.35	10	107.74	
Generator set 15kVA	538.68	1	538.68	5	107.74	
Weighing scale (50 kg)	43.09	2	86.19	3	28.73	86.19
Weighing scale (500 g)	21.55	2	43.09	3	14.36	43.09
Refractometer	280.11	1	280.11	10	28.01	
pH meter	64.64	2	129.28	3	43.09	129.28
DO meter	861.88	1	861.88	10	86.19	
Thermometer	2.15	3	6.46	3	2.15	6.46
Paddlewheel 1-unit, 1 HP	646.41	1	646.41	10	64.64	
Working area	646.41	1	646.41	8	80.80	
Electrical system	215.47	1	215.47	10	21.55	
Impulse sealer	64.64	1	64.64	5	12.93	
Other supplies	87.27	1	87.27	3	29.09	87.27
Total investment cost			**34,185.52**			**352.29**
Annual depreciation cost					**5,956.04**	

Table 5. Variable costs for soft-shell crab production

Items		Cost/crop (US$)	Annual cost (US$)
Crab instars (1-1.5 cm CW)		3,117.78	12,471.11
Milkfish juveniles (10-15 g)		258.56	775.69
Feed	Nursery	20.75	83.00
	Grow-out	128.30	513.22
	Soft-shell crab	312.76	1,251.04
	Milkfish	91.58	274.73
Chemicals for Pond Preparation		107.74	107.74
Labor, 2 technicians at US$ 7.54/d		904.98	3,619.91
Gasoline for generator set		64.64	265.57
Other supplies		265.57	531.14
Total		**5,272.66**	**20,209.33**

is found to be more expensive than any other items. It must be noted that monitoring of nursery and grow-out operations would require labor force, thus, in the production of crab juveniles and soft-shell crabs, the labor cost would usually comprise about 18 %.

Table 6 shows the yearly fixed cost for soft-shell crab production which amounts to US$ 11,711.64. Thus, the total production cost (variable costs + fixed costs) is US$ 8,200.56/crop or US$ 31,920.97/year, given that four runs are conducted annually. Also, it must be considered that labor and material cost would differ in every region. Based on the production technology efficiency indicators (**Table 7**), soft-shell crab farming using crab juveniles from the hatchery seeds is a

Table 6. Fixed costs for soft-shell crab production

Items	Cost/crop (US$)	Annual cost (US$)
Pond lease	242.40	969.62
Maintenance and repairs (2 % total cost)	170.93	683.71
Depreciation costs	1,489.01	5,956.04
Interest on investment (12 %/yr)	1,025.57	4,102.26
Total fixed cost	**2,927.91**	**11,711.64**

Table 7. Cost and return analysis of soft-shell crab and milkfish production

Economic efficiency indicators	Per crop (Soft-shell Crabs)	Per crop (Milkfish)	Per year
Gross revenue (US$)	9,937.91	1,066.58	42,951.39
Net income (US$)			11,030.42
Return on investment (ROI, %)			32.27
Payback period (years)			2.01
Break-even price of soft-shell crabs (US$/kg)			12.98

feasible enterprise. The initial investment could be recovered within 2.01 years with an annual net income of US$ 11,030.42.

Dissemination of Technology on Soft-shell Crab Production

The soft-shell crab production technology was disseminated to interested crab growers, businessmen, and other stakeholders through the regular training course on mangrove crab nursery and grow-out operations at SEAFDEC/AQD. This has enabled four private sectors in the country, namely: Aquascapes in Cavite, RC2 Aquaventures in Palawan, Ragus Soft-shell Crab Farm in Iloilo, and Tuason Crab Culture in Davao del Norte to produce soft-shell crabs for local consumption. The Philippine Bureau of Fisheries and Aquatic Resources (BFAR) in Pagbilao, Quezon has also adopted the technology of SEAFDEC/AQD with slight modifications.

Conclusion and Way Forward

Through the application of responsible aquaculture, the production of soft-shell crab using hatchery-produced seedstocks would be sustainable, and the technology introduced by SEAFDEC/AQD can be easily adopted. The Philippines and other countries engaged in soft-shell crab farming should source their seedstocks from the hatcheries to avoid dependence on wild resources.

Presently, an ongoing study is being conducted at SEAFDEC/AQD adopting the use of spinach extract to hasten the molting of mangrove crab in laboratory scale prior to the application in the farm set up. Spinach extract, a good source of phytoecdysteroids (Schmelz, Grebenok, Ohnmeiss, & Bowers, 2000), has been tested to induce molting in crabs (*Scylla olivacea, Portunus pelagicus*) (Aslamyah and Fujaya, 2011; Fujaya, 2011; Sorach Pratoomchat, Hanna, and Suksamrarn, 2013). Phytoecdysteroid, an ecdysteroid-analog that is found in plants was proven to hasten molting in crustaceans (Aslamyah and Fujaya, 2011; Dinan, 2001; Fujaya, 2011; Putchakarn, 1991; Sorach et.al., 2013; Tamsil, Yasin, & Fujaya, 2015). Thus, this project would aim to address one of the problems encountered in soft-shell crab farming, which is the asynchronous molting of crabs, thereby, prolonging the duration of culture and staggered harvesting of soft-shell crabs.

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About the Author

Mr. Jon Irish Legaspi Aquino is an Associate Researcher based at the Technology Verification Section (TVS) of the Technology Verification and Extension Division (TVED) of SEAFDEC/AQD in Tigbauan, Iloilo, Philippines.

Scaling an EAFM at the Sub-Regional Level:
Catalyzing Regional and National Actions in the Sulu-Sulawesi Seascape

Robert Pomeroy, Len Garces, Michael Pido, John Parks, and *Geronimo Silvestre*

The establishment of appropriate fisheries management mechanisms is vital to ensuring the sustainability of the fishery resources and long-term food security in the Southeast Asian region. By adopting an Ecosystem Approach to Fisheries Management (EAFM), the ecological and human well-being aspects of fisheries would also be addressed. However, for an EAFM to be effective, management scales must be considered and broadened. Transitioning toward an EAFM often involves "scaling up" or "scaling down" fisheries management, and there are various scales across which an EAFM can be applied depending on the goal and objectives of management including political, governance, ecosystem, fishery, and human use, as seen through the regional example of the Sub-regional Sulu-Sulawesi Seascape EAFM Plan.

To guarantee sustainable fishery resources and long-term food security in Southeast Asia, appropriate fisheries management mechanisms should be established. Currently, policies, legal, and regulatory frameworks are focused on fisheries management driven by increased concerns about the decreasing and over-exploited fish stocks. In order to enhance national fisheries management frameworks, especially in the region, there is a need to incorporate innovative management approaches for sustainable fisheries such as the Ecosystem Approach to Fisheries Management (EAFM).

Under an EAFM, the ecological and human well-being or welfare aspects of fisheries are focused equally, providing a broader framework for marine resource management to achieve sustainable development goals through improved ecological and human well-being, including habitat protection and restoration, pollution reduction and waste management, sustainable utilization of fishery resources, as well as food security, sustainable livelihoods, and equitably-distributed wealth. Transitioning towards an ecosystem approach requires broadening the scale of what is being managed—spatially and temporally—which also involves more attention to governing across scales. One of the greatest shortfalls of conventional fisheries management—indeed, conventional environmental management—is a misalignment between the scales of governance to the scales of the system being managed. Identifying appropriate spatial, temporal, and governance scales is therefore among the most important aspects of transitioning into an EAFM.

Scale and EAFM

Transitioning toward an EAFM enables fisheries management to be "scaled up" or "scaled down" to address multiple management goals and objectives, some examples of which are shown in **Box 1**.

Box 1. Examples of "scaling up" or "scaling down" fisheries management

- Single-species management **to** management of multi-species assemblages
- Managing fish with home ranges limited to sites within country boundaries **to** transboundary/straddling stock fisheries
- Looking at isolated drivers of change **to** considering broader environmental and human impacts
- Design of individual protected areas **to** planning networks of protected areas
- Conservation of a fragment of habitat **to** comprehensive spatial management
- Larger national fisheries management area down **to** smaller-scale integrated management unit (IMU)
- Single local government **to** multiple local governments surrounding an ecosystem, *i.e.*, a bay or gulf
- One national government **to** several national governments in a region

Issues of scale include determining the appropriate scale of the marine ecosystem for fisheries management purposes and "scaling up" or "scaling down" from other management arrangements such as community-based management to a sub-regional ecosystem scale. The issues of scaling up or scaling down refer to the transferability of concepts, methods and approaches, and organizational structures from one level to another in the dimensions of space, time, and governance. Several factors that constrain scaling include, but not limited to, funding, resources, legal authorities, management structures, and voluntary basis of participation. Under an EAFM, a scale should be considered in three primary ways (**Box 2**).

Chua (2006) stated that scaling up in integrated coastal management (ICM) refers to three different contexts: 1) geographical expansion; 2) functional expansion; and 3) temporal considerations. The same contexts hold true for the scaling up in an EAFM. Geographically, a management area could be scaled up from a single small coastal community operating in a nearshore area to include a broader geographic dimension, *e.g.*, an enclosed bay being shared by several villages or municipalities/districts, a long strip of coastal area that transcends several provinces, a marine seascape.

Functionally, scaling up also involves taking into consideration new program interventions. For example, if the current intervention relates largely to enforcement, the functional expansion would include adding new interventions such as conserving or expanding livelihoods and/or increasing educational opportunities. Scaling up also includes integration of fisheries management into broader administrative programs of government agencies or departments. Temporally, scaling up

Box 2. Three primary ways in scaling under an EAFM

- First, it is important to understand whether the many social, economic, and institutional considerations in implementing the EAFM vary depending on the scale of the fishery (*e.g.*, local, national, regional (involving two or more countries); broader international scale that covers several sub-regions; continents) and in what manner.
- Second, in implementing the EAFM it will be important to address the challenges in managing fisheries in which: human (social, economic, and institutional) scales are different from that of the resource, or that of the harvesting activity, or there can be differences in the scales that are appropriate to deal with each component of a fishery – fish stocks, fishers, gear, science, enforcement, policy, among others.
- Third, management of a given fishery is required at multiple scales. This involves a process of "scaling up" or "scaling down." For example, if fisheries management (and an EAFM) is already implemented at a broad geographical scale (*e.g.*, state, province, nation), this would need to be scaled to work at a local level. Equivalently, when local-level or community-based management is in place within local ecosystems, this needs to be "scaled up" while allowing for spatial heterogeneity, and differing human and institutional arrangements. These situations imply the need for 'cross-scale linkages.' So that if local or decentralized approaches to management are needed to account for local conditions but the fish stocks range over larger geographical areas, an institutional arrangement is needed to help coordinate across boundaries. This could be the case for a fishery of a highly migratory stock, such as tuna, where the biological aspects are on a large scale, crossing national boundaries, while a national or sub-national scale would fit for the fishers and the management system, and indeed very local management of fleets would also be effective.

includes shifting from focusing solely on near-term issues like annual catch limits to considering and incorporating long-term climate change and ocean acidification into the management process.

Thus, the initial scale for an EAFM will vary significantly depending on the geographic area, governance structures, socio-economic conditions, and current priority issues. In general, starting at smaller spatial and governance scales, in terms of stakeholders, issues, and jurisdiction, would increase the likelihood of initial success that could be used to foster expansion. Scaling up is often easier once initial activities succeed and are sustained at demonstration sites; and undertaken to include more stakeholder groups, manage a larger jurisdiction or integrated management unit (IMU), and/or address new issues or a greater range of issues. Generally in scaling up, a new EAFM plan and agreements should be developed or existing plans modified. Spatial expansion of the IMU will require the collection and analyses of additional information as the IMU profile is expanded. New stakeholder groups and organizations should be organized and coordinated with existing stakeholder groups. As an EAFM scales up, additional funding would be needed, although scaling up also provides opportunities to broaden the funding base and potentially increase inefficiencies as communities leverage capabilities and resources for the common good. If the new scale involves multiple political jurisdictions, new legal support would be necessary.

Scaling EAFM at the Sub-regional Level to Catalyze Action

Development of a sub-regional EAFM plan can complement local, national, and regional fisheries management priorities, and help to catalyze action at all levels that may otherwise not occur. A sub-regional approach can support the development of joint or coordinated management plans for fisheries and habitats, management and control of fishing effort, and the strengthening of cooperation on monitoring, control, and surveillance (MCS) to be able to verify and certify the legal status of the fisheries, thereby reducing levels of illegal, unreported and unregulated (IUU) fishing (Torell, 2017). Harmonizing an EAFM among multiple levels is an important prerequisite for catalyzing fisheries management action successfully across multiple scales. One of the challenges of an EAFM is to establish ways to ensure that the actions of the coastal and fisheries institutions at each level of government are harmonized with one another and are consistent with agreed EAFM goals and policies. Similarly at a regional level, disconnects may occur between or across all the participating nations in the region, regardless of whether they share transboundary fish stocks or have abutting Exclusive Economic Zones.

Scaling an EAFM could also be applied at a sub-regional level, where a sub-region is defined as a space of planning that is smaller than a region but larger than a local authority, such as a nation, and is usually based on location. Within the Southeast Asian region, the Sulu-Sulawesi Seascape (SSS) can be considered a sub-region. Some of the benefits and costs or challenges of scaling an EAFM at the sub-regional level are shown in the following **Table**.

Nonetheless, harmonization across scales calls for consistent approaches across the levels between national and local government and reinforces the importance of having a legally authorized inclusive framework that allows for effective harmonization of policy and operational objectives. Management decisions would be more successful in achieving ecosystem objectives when they are matched to the spatial scale of the ecosystem, to the programs for monitoring all desired ecosystem attributes, and to the relevant management authorities.

Current Applications of a Scaled EAFM Plan: Taking a Sub-regional EAFM Approach in the SSS Sub-region

The SSS sub-region, like the South China Sea and Andaman Sea, is one component of the wider Indo-Pacific Ocean Region within Southeast Asia (**Figure**), also known as the Coral Triangle Region. The SSS is one of the priority seascapes in the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF) and its boundary functions as the regional fisheries management unit (FMU). Deterioration of the environmental conditions in the SSS indicates that resource extraction has exceeded the natural capacity of this marine ecosystem for recovery (CTI-CFF, 2015). Shared boundaries,

Table. Benefits, costs, and challenges of sub-regional EAFM scaling

Benefits	Costs/challenges
• Management of broader ecosystem and social systems relevant to fisheries • Supports multiple objectives - fisheries, ecosystem, and socioeconomic goods and services • Improved coordination, consultation, planning, and implementation of management within and across regional, national, provincial, and local levels • Greater recognition of ecological and social connections and effects that different components of the ecosystem can have on each other • Fisheries management within broader multi-sectoral approaches - such as ecosystem-based management (EBM) and integrated coastal management (ICM) • Provides framework to recognize conflicts that impact or are impacted by fisheries, accommodate multiple uses, and reduce conflict • Connects regional and national planning and policy goals with practical goals and implementation through local government • Supports determination of multiple spatial and temporal scales reflecting the natural hierarchy of the ecosystem • Capacity building and development through shared knowledge and skills • Improved transboundary management decision-making, matched to the spatial and temporal scale of the ecosystem	• Higher levels of cooperation, coordination, and participation across governments, sectors, with the public, and across jurisdictional boundaries • May require new policy and legal framework(s) • More diverse data and information to support decision-making across sectors and stakeholders • Higher management costs due to increased data and information needs, coordination, planning, and staff • Effort to organize and coordinate new stakeholder groups and organizations with existing stakeholder groups • A wider scope in monitoring, control and surveillance (MCS) and enforcement • National political and economic priorities • Harmonized work plans and budgets supporting integration across governments • Establishment of a lead organization to oversee coordination and integration

ecosystem dynamics and resources, as well as transboundary environmental issues, including human migration, justify a sub-regional approach to conserving the SSS (Miclat, Ingles, & Dumaup, 2006; CTI-CFF, 2009).

As such, a sub-regional EAFM planning approach has been undertaken for the SSS sub-region, under which an entirely voluntary agreement is proposed with all management actions ‘offered’ and ‘maintained’ at the discretion of each participating nation implementing the plan. The development of a sub-regional SSS EAFM Plan commenced in June 2015 when a workshop generated the Plan’s vision, goals, and objectives, after the workshop participants revisited the results of the Transboundary Diagnostic Analysis (Sulu Sulawesi Marine Ecoregion Tri-National Committee, 2013), prioritized, and agreed on the key issues. Subsequently, the Fisheries Management Unit was defined, common vision for the SSS established, and the sub-region’s main issues and threats identified, including the unsustainable exploitation of fishery resources, transboundary IUU fishing, habitat loss, and community modification.

In August 2017, the USAID Oceans and Fisheries Partnership (USAID Oceans) and SEAFDEC organized the second regional fisheries management workshop which was participated in by fisheries management agency representatives (USAID Oceans, 2017). During this workshop, the participants revised the 2015 vision, *viz*:

> *“By 2030, the transboundary fisheries of the Sulu Sulawesi Seas are ecologically healthy, and deliver ecosystem services that provide equitable benefits to our people through collaborative, safe, and legal regional fisheries management.”*

From this vision, the SSS Sub-regional Plan was developed that calls for an immediate (near-term) focus on five species of high-value and economically-important transboundary small pelagic fisheries, and for a longer-term focus on seven target species of high-value and economically-important transboundary large pelagic and neritic tuna fisheries, as well as six target species of coral reef-associated transboundary fish species. The Plan’s sub-regional goals, objectives, and management actions are linked to the three pillars of an EAFM, *i.e.* ecological well-being, human well-being, and good governance (*https://www.seafdec-oceanspartnership.org/resource/overview-of-the-sub-regional-plan/*). In July 2018, the sub-regional EAFM Plan was finalized during the third workshop.

The Sub-regional Plan has been developed to enable “scaling up” to link to several existing regional fisheries organizations and legal and policy instruments, including regional fisheries organizations such as the Southeast Asian Fisheries Development Center (SEAFDEC); Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF); and the Regional Plan of Action to Promote Responsible Fishing Practices including Combating Illegal, Unreported and Unregulated Fishing (RPOA-IUU). The Plan also supports the existing related management efforts that are focused at the sub-regional level, *e.g.*, the Ecoregion Conservation Plan (ECP) for the Sulu-Sulawesi Marine Ecoregion (SSME) (SSME, 2003), the SSME Regional Strategic Action Program (Sulu Sulawesi Marine Ecoregion Tri-National Committee, 2013), the Comprehensive Action Plan for SSME (Asian Development Bank [ADB], 2011).

Figure. Map of the Sulu-Sulawesi Seascape

The Plan can also be "scaled down" to link to relevant national, provincial, and local fisheries management plans within each of the three implementing countries. For example in Indonesia, the SSS Plan is linked to and supports the National Tuna Fisheries Management Plan, as well as provincial fisheries planning within Fisheries Management Area (WPP) 716, including implementation of local fisheries management efforts at the provincial and district levels within WPP 716.

To support the SSS Plan and support coordination, a voluntary coordinating governance mechanism should be established, and the existing regional fisheries organizations, such as CTI-CFF, SEAFDEC, or the Tri-National Committee for the Sulu-Sulawesi Marine Ecoregion (Miclat, Ingles, and Dumaup, 2006) and the SSME Sub-committee on Sustainable Fisheries (ADB, 2011), could serve in this institutional or organizational role. Implementation and management of the Plan could also be coordinated through the CTI-CFF Seascape and EAFM working groups, and the National Coordinating Committees in Indonesia, Malaysia, and Philippines.

Conclusions

Transitioning towards an EAFM will involve broadening the scale of what is being managed, spatially and temporally, which will also require more attention to governance across scales. Identifying appropriate spatial, temporal, and functional governance scales are among the most important aspects of transitioning to an EAFM, and in almost all situations—regardless of the degree of management centralization—implementing institutions should consider the mechanisms to scale up and scale down management decision-making within and across the community/village, municipality/district, province/state, national, and regional levels.

Torell (2017) stated that strengthened sub-regional cooperation with development of joint or coordinated fisheries management plans should be promoted, including research and studies on the social, ecological, and economic importance of fisheries, and aquatic resources utilization. This would highlight and increase the understanding of the very strong national and regional dependence on fish and fishery products for domestic food security, employment opportunities for millions of people, and in support of the very profitable fish export industries.

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About the Authors

Dr. Robert Pomeroy and **Dr. Michael D. Pido** are consultants to the USAID Oceans and Fisheries Partnership (USAID Oceans). **Dr. Pomeroy** is the Fisheries Extension Specialist at the Connecticut Sea Grant and **Dr. Pido** is the Director of the Center for Strategic Policy and Governance in Palawan State University, Puerto Princesa City, Palawan, Philippines.

Mr. Len R. Garces (Fisheries Management Specialist), **Mr. John Parks** (Chief of Party), and **Mr. Geronimo Silvestre** (former Chief of Party) are members of the USAID Oceans' team based in Bangkok, Thailand and Manila, Philippines.

About USAID Oceans

The United States Agency for International Development Oceans and Fisheries Partnership (USAID Oceans) works to strengthen regional cooperation to combat illegal, unreported, and unregulated (IUU) fishing and to promote sustainable fisheries to conserve marine biodiversity in the Asia-Pacific region. USAID Oceans is implemented through a partnership between USAID's Regional Development Mission for Asia (USAID/RDMA) and the Southeast Asian Fisheries Development Center (SEAFDEC), in collaboration with regional and U.S. government agencies, including the Coral Triangle Initiative for Coral Reefs, Fisheries and Food Security (CTI-CFF) and the United States National Oceanic and Atmospheric Administration (NOAA). Learn more about USAID Oceans at www.seafdec-oceanspartnership.org.

CALENDAR OF EVENTS

Date	Venue	Event	Organizer(s)
2018			
8-10 October	Yangon, Myanmar	On-site Training on Optimizing Energy and Safety at Sea for Small Fishing Vessels	SEAFDEC/TD
9-10 October	Kuala Lumpur, Malaysia	Core Expert Meeting on Research for Enhancement of Sustainable Utilization and Management of Sharks and Rays in the Southeast Asian Region	SEAFDEC/MFRDMD
11-12 October	Yangon, Myanmar	On-site Training Program on Proper Fish Handling Techniques Applicable to Local Fishing Vessels in Myanmar	SEAFDEC/TD
15-18 October	Vientiane, Lao PDR	Consultative Meeting for Promotion of the "ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain" in Lao PDR	SEAFDEC/MFRDMD
18-19 October	Bangkok, Thailand	2nd Regional Meeting on Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia	SEAFDEC Secretariat
22-26 October	Rizal, Philippines	Training Course on Catfish Hatchery and Grow-out Operations	SEAFDEC/AQD
24-25 October	Palembang, Indonesia	Workshop on Regional Awareness Raising in Asia on Prospective Species Proposals to CITES COP18 and Preparation of Fisheries Related Information to Support Review of Species Proposals Against CITES Listing Criteria	SEAFDEC/IFRDMD
29-30 October	Chiang Rai, Thailand	Bilateral Dialogue between Thailand and Lao PDR	SEAFDEC Secretariat
1-2 November	Pattaya, Thailand	7th Meeting of the Gulf of Thailand Sub-region	SEAFDEC Secretariat
5-7 November	Langkawi, Malaysia	41st SEAFDEC Program Committee Meeting (PCM)	SEAFDEC
8-9 November	Langkawi, Malaysia	21st Meeting of the Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic Partnership (FCG/ASSP)	SEAFDEC
12-15 November	Bangkok, Thailand	Consultative Meeting for Promotion of the "ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain" in Thailand	SEAFDEC/MFRDMD
13 November	Bangkok, Thailand	Gulf of Thailand Tonggol Tuna FIP Inception Meeting	SEAFDEC/TTIA/WWF/ DOF Thailand
15-16 November	Bangkok, Thailand	Regional Dialogue on Gender Dimension in Coastal and Fisheries Resources Management in South Asia and Southeast Asia: Opportunities and Challenges	SEAFDEC Secretariat & IUCN/SEI
19-23 November	Samut Prakan, Thailand	Regional Training Course on Fish Handling Technique Applicable to Various Fishing Operations in Southeast Asia	SEAFDEC/TD
20-21 November	Thailand	4th Meeting of the Andaman Sea Sub-region	SEAFDEC Secretariat
20 Nov-4 Dec	Rizal, Iloilo	Training Course on Community-Based Freshwater Aquaculture for Remote Rural Areas of Southeast Asia	SEAFDEC/AQD
21-22 November	Palembang, Indonesia	Workshop on the Quantitative Study to Estimate Freshwater Fish Stock	SEAFDEC/IFRDMD
23 November	Bangkok, Thailand	Planning Meeting for the JAIF Project on "Strengthening the effective Management of Inland Fisheries and Aquaculture in ASEAN Member States with Geographic Information System (GIS) & Remote Sensing (RS) Technology"	SEAFDEC Secretariat
25-28 November	Hanoi, Viet Nam	Consultative Meeting for Promotion of the "ASEAN Guidelines for Preventing the Entry of Fish and Fishery Products from IUU Fishing Activities into the Supply Chain" in Viet Nam	SEAFDEC/MFRDMD
4-5 December	Samut Prakan, Thailand	Project Steering Committee (PSC) Meeting of the SEAFDEC/UNEP/GEF Fisheries *Refugia*	SEAFDEC/UNEP/GEF/ Fisheries *Refugia* Project
12-13 December	Samut Prakan, Thailand	Regional Meeting on the Regional Fishing Vessel Record (RFVR) for 24 Meters in Length and Over as a Management Tool Toward Combating IUU Fishing in ASEAN	SEAFDEC/TD
19-20 December	Bangkok, Thailand	Meeting on Results DNA Indo-Pacific Mackerel for Gulf of Thailand Sub-region	SEAFDEC Secretariat
2019			
9-11 January	Indonesia	5th Meeting of the Scientific Working Group (SWG) for Stock Assessment on Neritic Tunas in the Southeast Asian Region	SEAFDEC/MFRDMD & Secretariat
15-17 January	Iloilo, Philippines	SEAFDEC Training Workshop on Sharks Data Collection	SEAFDEC Secretariat & MFRDMD

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.


Secretariat


TD


MFRD


AQD


MFRDMD


IFRDMD

SEAFDEC Addresses

Secretariat

P.O. Box 1046
Kasetsart Post Office
Bangkok 10903
Thailand
Tel: (66-2)940-6326
Fax: (66-2)940-6336
E-mail: *secretariat@seafdec.org*
http://www.seafdec.org

Training Department (TD)

P.O. Box 97
Phrasamutchedi
Samut Prakan 10290
Thailand
Tel: (66-2)425-6100
Fax: (66-2)425-6110 to 11
E-mail: *td@seafdec.org*
http://www.seafdec.or.th

Marine Fisheries Research Department (MFRD)

2 Perahu Road
off Lim Chu Kang Road
Singapore 718915
Tel: (65)6790-7973
Fax: (65)6861-3196
E-mail: *ava_mfrd@ava.gov.sg*
http://www.seafdec.org

Aquaculture Department (AQD)

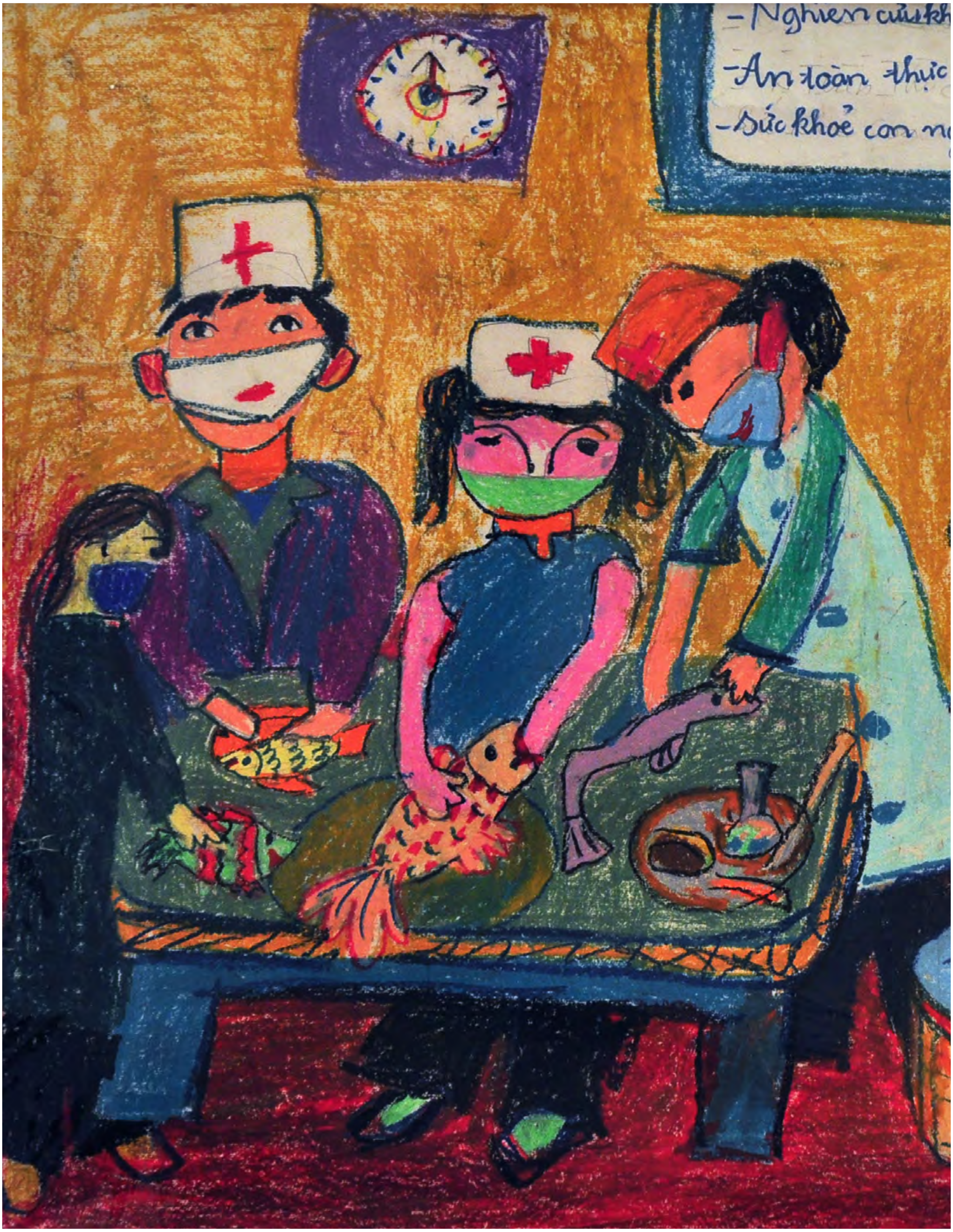
Main Office: Tigbauan,
5021 Iloilo, Philippines
(63-33) 330-7000
Fax: (63-33) 330-7002
Manila Office: Rm 102 G/F
Philippine Social Science Center (PSSC)
Commonwealth Avenue, Diliman
Quezon City 1101 Philippines
Tel & Fax: (63-2) 927-7825
E-mail: *aqdchief@seafdec.org.ph*
http://www.seafdec.org.ph

Marine Fishery Resources Development and Management Department (MFRDMD)

Taman Perikanan Chendering,
21080 Kuala Terengganu, Malaysia
Tel: (609) 617-5940
Fax: (609) 617-5136
E-mail: *mfrdmd@seafdec.org.my*
http://www.seafdec.org.my

Inland Fishery Resources Development and Management Department (IFRDMD)

Jl. Gub. HA. Bastari No.08
RT.29 RW.27 Kel. Silaberanti
Kec. Seberang Ulu I, Jakabaring, Palembang 30252
Sumatera Selatan, Indonesia
Tel: +627115649600; Fax: +627115649601
E-mail: *ifrdmd@seafdec.id*
http://www.seafdec.id



The second prize winner, *Bui Thu Teang*, from the national drawing contest in Viet Nam

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.