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

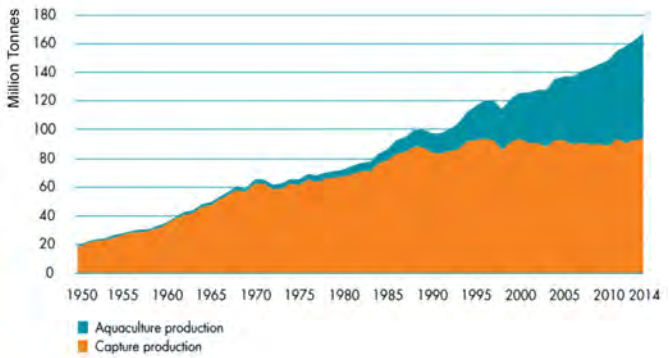

Figure 1. World's fisheries production from capture fisheries and aquaculture (FAO, 2016)

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)

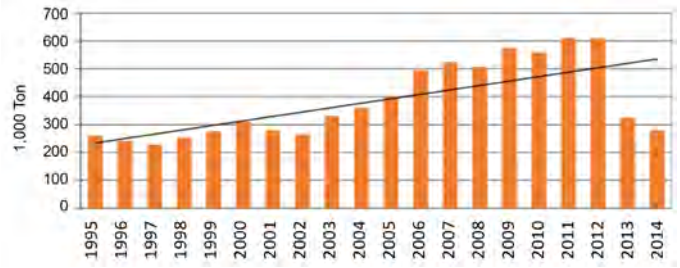

Figure 3. Aquaculture shrimp production of Thailand in 1995-2014 (Information and Communication Technology Center, 2016)

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

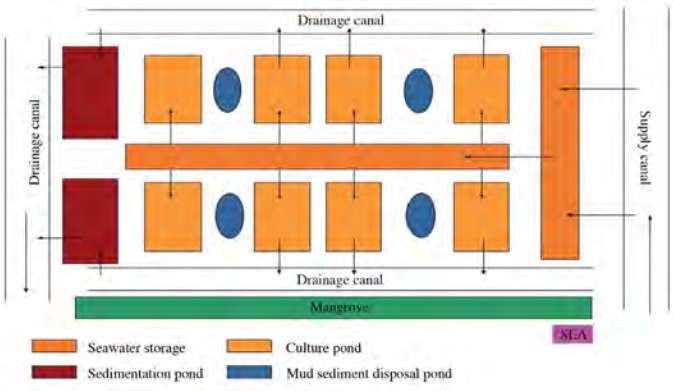

Figure 7. Recommended layout of a responsible intensive shrimp farm (Ekmaharaj, 2005)

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.**

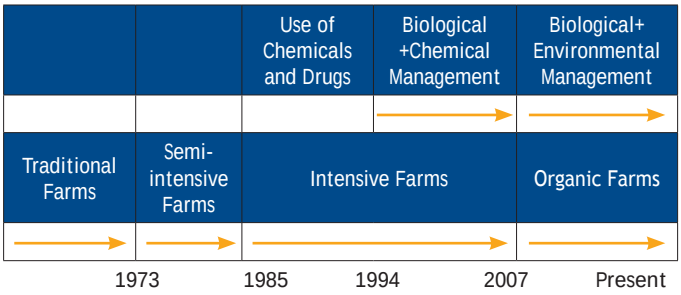

Figure 8. Development of marine shrimp aquaculture in Thailand (Adapted from Ekmaharaj, 2005)

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.

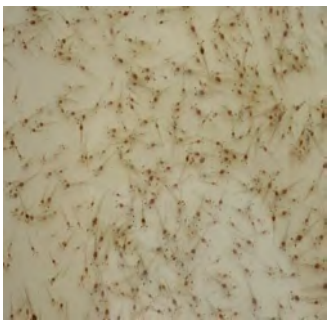

Figure 14. Healthy tiger shrimp fry at PL 15-20 ready for stocking in ponds

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.

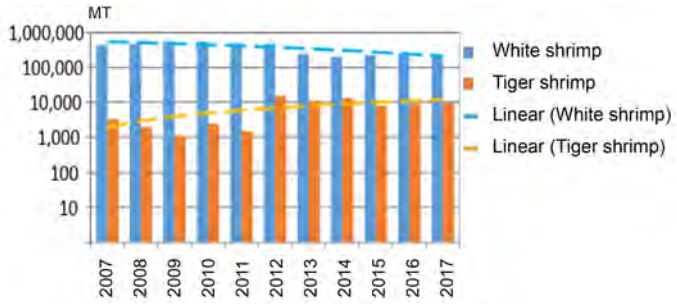

Figure 31. Thailand's production of white and tiger shrimps in 2007-2017 (DOF, 2018)

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**).

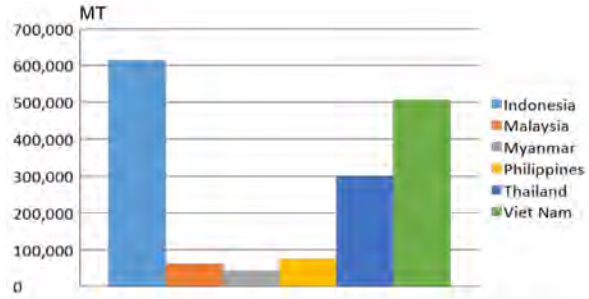

Figure 32. Production of marine shrimps of selected Southeast Asian countries in 2014 (FAO, 2016)

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

My deep appreciation goes to the persons and organizations supporting the preparation and presentation of my Keynote Lecture during 45th Year Anniversary of SEAFDEC/AQD in Iloilo, Philippines.

References

Ekmaharaj, S. (2005). Shrimp Farming in Thailand: Environmental Management System and Action Plan for Development. Proceedings of the JSPS-NRCT International Symposium - Joint Seminar 2005 on Productivity Techniques and Effective Utilization of Aquatic Animal Resources into the New Century. 19-21 December 2005, Kasetsart University, Thailand; pp 10-26

Ekmaharaj, S. (2006). Aquaculture of Marine Shrimp in Southeast Asia and China: Major Constraints for Export. ***In***: Fish for the People 4 (1): 2006. Southeast Asian Fisheries Development Center, Bangkok, Thailand; pp 38-43

FAO. (2016). The State of World Fisheries and Aquaculture 2016. Contributing to Food Security and Nutrition for All. Rome; 200 p

Hemarak, K. (2018). Aquaculture Techniques; Three Clean Key Factors for Shrimp Farming Rehabilitation, Thai Shrimp News, 16 (187) 66-73

Information and Communication Technology Center. (2016). Fisheries Statistics for Thailand 2014, Information and Communication Technology Center, Department of Fisheries; 87 p

Surasak Dirakkait. (2018). Coordinator, Shrimp Aquaculture Network of Thailand, pers communication

Tookwinas (Ekmaharaj), S. and P. Songsangjinda. (1999). Study on Water Quality and Phytoplankton Community in Intensive Marine Shrimp Culture at Kung Krabaen Bay, Eastern Thailand. Journal of the World Aquaculture Society, 30(1): 36-45

Tookwinas (Ekmaharaj), S. and D. Yingchareon. (1999). Seawater Irrigation System for Intensive Marine Shrimp Farming. Aquaculture Asia, 4(3): 33-38

Tookwinas (Ekmaharaj), S. and S. Suwannarangsi. (1996). Hazard Control in Aquaculture. ***In***: R.E. Martin, R.L.Collette and J.W. Slavin (eds). Fish Inspection, Quality Control, and HACCP: A Global Focus. Proceedings of the Conference, 19-24 May 1996, Arlington, Virginia, Techinnomic Pub.Co., Inc., USA; pp 338-391

Department of Fisheries of Thailand. (2018). Shrimp Aquaculture Statistics, Coastal Aquaculture Research and Development Division, Bangkok, Thailand (data sheet) *www.fisheries.go.th/stat/*

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*).