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

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

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

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

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

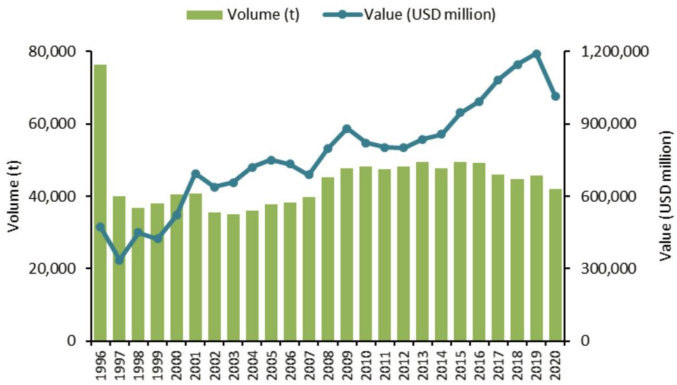

Figure 2. Production volume (t) and value (USD million) of black tiger shrimp in the Philippines from 1996 to 2020
Source: *Philippine Statistics Authority (2021)*

OPLAN *Balik Sugpo*

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

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

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

Eco-friendly strategies and biosecurity protocols

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

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

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

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

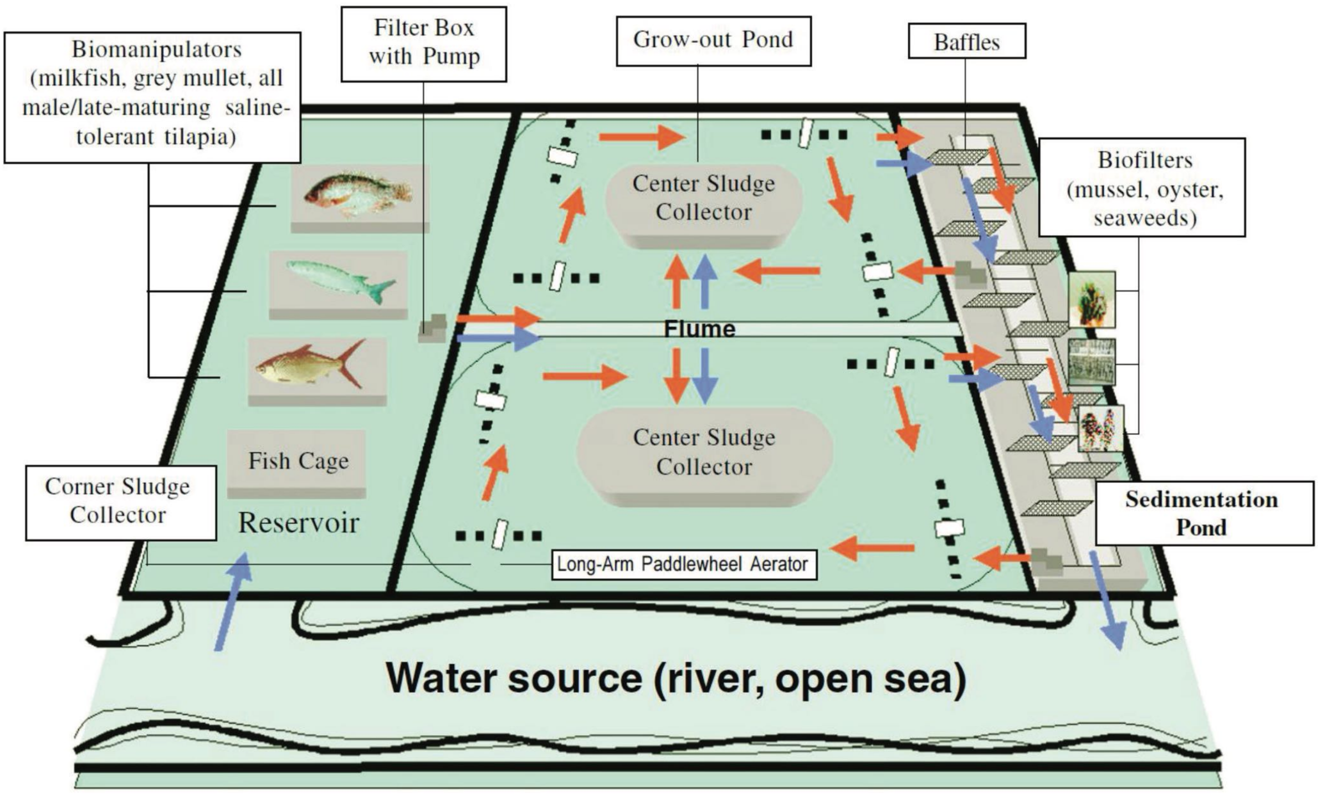

Figure 3. Suggested pond layout of low-discharge and closed-recirculation shrimp farms (blue arrows indicate a low-discharge system, and red arrows indicate closed-recirculation system)

Box 1. Essential factors for effective low-discharge and closed-recirculation systems
Crop rotation: Producing the same crop in the same field over the year may reduce soil fertility and collect harmful nutrients in the pond bottom (Yi & Fitzsimmons, 2004). As a sanitary practice, crop rotation involves shifting shrimp ponds to finfish culture in about one to two cropping. This process will help reduce cultivated land, flooding, and the spread of disease (Yuvaraj *et al.*, 2015; Paclibare *et al.*, 1998).
Construction of head and tail reservoirs: The system should include a head reservoir as source of quality water with good plankton profile. Sediments and other suspended organic solids are settled for about a week in the head reservoir before its water is used. The head reservoir should comprise at least 50 % of the total grow-out pond area. A tail reservoir serves as a treatment pond with biofilters e.g. seaweeds, oysters, and finfishes, and a sedimentation pond with a baffle system. The tail reservoir is meant to lengthen the flow of water and allow sediments to settle before the water is drained out or recirculated back to the grow-out pond (Paclibare *et al.*, 2002).
Installation of filter box: A mechanical filtration or filter box is installed in ponds to ensure that hosts and carriers of pathogens such as crustaceans are reduced, if not eliminated. The filter box is fitted with a two-horsepower submersible pump operated for six to 12 hours per day about three times a week, depending on the quality of the water. 
Salinity reduction: The desired salinity of the grow-out pond should be about 18 to 20 ppt, and which should be maintained through the continuous introduction of freshwater in culture ponds. Lower salinity can decrease the potency of luminous bacteria and can also make shrimps grow faster. Thus, a freshwater source (groundwater) should be established (Abraham & Sasmal 2009; Prapaiwong & Boyd, 2012).
Installation of long-arm paddlewheels: Intensive shrimp culture ponds should be aerated appropriately, and paddlewheels should be positioned strategically to create a circular motion in the water for the wastes to be concentrated in the center of the pond and create a wider and cleaner feeding area for the shrimp stock.
Establishment of sludge collectors: There are two types of sludge collectors: center sludge collector which should comprise 3–5 % of the total grow-out pond area, and corner sludge collector of about 2 % of the total pond area. With this set-up, sludge, sediments, dirt, and uneaten feeds in all areas of the pond are collected to ensure adequate water circulation. Efficient water circulation prevents stratification and lessens the accumulation of nitrogenous compounds in spots where sludge accumulates. Organic matter made up of feces, uneaten feeds, and biological waste is produced during shrimp pond operation. With the presence of pond waste, growth of phytoplankton and the general productivity of the pond will be significantly affected, thus, affecting also shrimp survival and production (Bera *et al.*, 2018). Increase in sludge production in pond can lead to increase in oxygen demand and create anaerobic conditions resulting in production of hydrogen sulfide which affects shrimp appetite and leads to poor feed conversion ratio. In addition, suspended particles cause turbidity of the water which reduces light penetration leading to decreased photosynthetic activity and dissolved oxygen levels (Turkmen & Toksen, 2010).   Corner *(left)* and center *(right)* sludge collectors
Stocking of biomanipulators: Inside the corner sludge collector, adult or juvenile tilapia and milkfish could be stocked to serve as biomanipulators at standing biomass of 1.5 to 2.5 t/ha and 0.5 to 1 t/ha, respectively. As biomanipulators, they produce green water and suppress the growth of harmful bacteria. Tilapia integration in shrimp culture practice has been attributed to lowering luminous *Vibrio* load throughout the period of the shrimp culture, as well as improving the soil and water quality, enhancing nutrient cycle, and providing continuous supply of fertilizer that can maintain optimal and constant phytoplankton biomass (Paclibare *et al.*, 2002; Huervana *et al.*, 2006). Fish mucus contains an antibacterial property that helps in preventing microbial colonization by inhibiting bacterial growth. Mucus layer of fish skin and gills contains epidermal cells which produce numerous immunological molecules like lysozyme, lectins, complements, and immunoglobulin (Thanh *et al.*, 2017; Lio-Po *et al.*, 2005; Tendencia *et al.*, 2004). Also, bivalves are efficient filter feeders of organic materials that increase efficacy in maintaining good water quality and healthy culture system and can also reduce suspended organic and inorganic matters and bacteria in the pond culture system (Jones *et al.*, 2002; Shpigel & Neori, 2007).

Box 1. Essential factors for effective low-discharge and closed-recirculation systems *(Cont'd)*
Provision of high-quality feeds: Successful intensive shrimp farming requires efficient feeding management. Feeds should be palatable and stable with high protein contents and good attractant. A complete feed is formulated to provide all nutrient and protein requirements of the animal. Ideally, crude protein should be 35–45 %, and crude lipid should be 10–12 % (Alava & Lim, 1983; Millamena & Pascual, 1990). Feeds should translate to a feed conversion rate ranging from 1.1 to 1.4, thus, reducing waste accumulation in the ponds as well as the cost of production. To ensure the freshness of the ingredients, feeds should be stored in short duration.
Maintaining substrates: In intensive shrimp culture system, substrates are utilized to reduce the negative effects of increased stocking density. Substrates provide an additional surface area for the shrimp to avoid space competition and cannibalism. The periphyton that grows in the substrates can serve as a natural food source as well as maintain good water quality. Substrates could be made up of polyethylene and fine mesh net and installed up to the first 45-50 days of shrimp culture (Schveitzer *et al*., 2013).
Introduction of bioaugmentation or microbial inoculants: Over time, viruses and diseases develop drug resistance due to the extensive use of antibiotics in shrimp ponds. This has led to a shift in alternative use of environment-friendly schemes such as the utilization of probiotics in aquaculture. To reduce toxic gases in the sediment and water as well as enhance the growth of beneficial bacteria, probiotics for bioaugmentation are applied in both grow-out and reservoir ponds. These factors could accelerate degradation of decomposing organic matter in pond bottom, and prevent the proliferation of pathogenic bacteria, particularly luminous bacteria (Ninawe & Selvin, 2009). Probiotics increase the innate defense mechanisms of an animal before exposure to a pathogen or improve survival during exposure to a pathogen. In shrimp culture systems, probiotics aid shrimp to overcome stressful conditions. Supplementation into feed is more effective in conveying probiotics into animals compared to direct application into rearing systems (Jamal *et al*., 2019).

Box 2. Biosecurity protocols for shrimp farming
Pre-stocking protocols: Shrimps are bottom dwellers; hence, it is necessary to remove the layer of black soil, sludge, or debris accumulated on the pond bottom from previous cropping. This is necessary, particularly in ponds with high stocking densities of up to 8 PL/m^2. Proper removal of bottom sludge can be achieved through drying, scrapping, and tilling of the pond bottom, application of lime and fertilizer in pond preparation, and disinfecting of the pond water. These practices could reduce the risk of disease outbreaks in low stocking density farms. Using a twin bag filter of 250 µm mesh size is the best way to filter the water. Water should also be conditioned from 10 to 15 days before stocking. Installing physical biosecurity measures, including car and foot baths, bird scare, and crab fencing, could reduce the risks of animals catching diseases from neighboring ponds and other farms.
Seed selection and stocking: Shrimps are most vulnerable during the PL stage that even with the best pond preparation the PLs could die during stocking if they are not healthy. Uniform in size and color, and actively swimming against the water current are some of the characteristics of a healthy PL. Poor quality shrimp seeds are usually less active. Weak or sick PLs were eliminated through disease surveillance with the help of polymerase chain reaction (PCR) screening. Transport time can also affect the PLs as longer transport time (> 6 h) of seeds from hatchery or nursery to pond can increase the chances of disease outbreak. Stocking into green water and avoiding transparent water should also be observed. However, the most helpful tip at this stage is to get high quality and disease-free fry from hatcheries with enhanced biosecurity measures.
Post-stocking management: Monitoring and record-keeping are essential and can be used as basis for water management and other treatments to maintain optimum pond conditions for shrimp growth. Performing visual inspection of the animals, observing clinical signs, should be conducted daily. While weekly sampling of shrimp and water should be observed. The shrimp's gut can give tell-tale signs of the animal's health. Checking the presence of food in the shrimp's intestinal tract can help monitor its food intake, while look for changes in gut's color can predict onset diseases. 

Economic analysis

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

Promising demonstration runs

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

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

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

Way Forward

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

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

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

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