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Environmental Impacts of Shrimp Farming and Benefit of Pond Intensification for Sustainable Aquaculture: A Review

Prihanik Marlina Widiyanti
PT ITS Science Indonesia, Life Science Division, Sentra Bisnis Artha Gading, Jl. Boulevard Artha Gading Blok A-6-A No. 3, Kelapa Gading Barat, Jakarta Utara, Indonesia 14240, Phone (+62) 21 451 6222. Fax (+62) 21 451 6223.
Email: lina@its-indonesia.com

Abstract. The goal of sustainable aquaculture is to provide a continued supply farmed aquatic nutrients beneficial for human sustenance without harming existing ecosystems or exceeding the ability of the planet to renew the natural resources required for aquaculture production (Nevin, 2020). Shrimp is the single most valuable seafood product that enters world trade today. Some of these farms are built in mangrove areas. To accommodate for this high demand farmers, intensify their production, thus effecting the environment by surpassing the areas carrying capacity. Factory farming, has the potential to deplete soils, reduces genetic stock, degrades coastal ecosystems and local water quality. These problems are mainly associated with pondconstruction and operation (Bolanos, 1999). Shrimp aquaculture can be environmentally sustainable with the proper design, operation, management, and monitoring. The use of a closed or recirculating system for growing shrimp is the best method for protecting the environment. Water quality needs to also be checked for both semi-intensive and intensive systems for managing the health of the shrimp and preventing disease and viral outbreaks. PAS offer a potential advantage over other culture systems because waste nutrients can recycle back into a crop, greatly increasing feed-use efficiency. Waste nutrients in ponds are assimilated by endogenous microflora, thereby transforming waste into a potential food source (biofloc). BFT is reliable for the cost effective, environment friendly fish production. BFT is a preferable technique for facing economic, ecological, and social issues relevant to current aquaculture. The system has advantage in intensive farming practices. An important feature of this technology is ammonia wastes are consumed by bacteria for their growth that increases the microbial biomass yield as well as improves the water quality. Previous studies indicated that the addition of probiotics in the water or feed increases growth, immunity, reduces animals to expose pathogenic bacteria and stops the growth of harmful pathogens. There is rapidly growing literature on the application of probiotics which indicates that it is one of the important methods developed to control disease at the farm; therefore, the addition of probiotics is common practice in fish farming (Daniel and Nageswari, 2017).

Keywords: Aquaculture, mangroves, ponds, biofloc, probiotic, water, shrimp.

Abbreviation: BFT (Biofloc technology), PAS (ponds aquaculture system), NP (nitrogen phosphor), NPK (Nitrogen phosphor kalsium), C (carbon), N (nitrogen), USA (United State of America)

Running Title: Pond Intensification for Sustainable Aquaculture (Widiyanti, 2020)

INTRODUCTION

Aquaculture is defined as the farming of aquatic plants and animals in land-based, (pond, raceways, or tanks) or water-based enclosures (cages) in fresh, salt, an'/or brackish waters. Aquatic organisms were raised under controlled parameters of salinity, pH, light intensity, and water temperature. organism currently farmed include fish, mollusk, crustaceans, and aquatic plants, raised with the goal of enhancing production through interventive methods of regular stocking, feeding, and protection from predators.

Shrimp aquaculture has significant benefits in socioeconomic terms, and its high profitability and generation of foreign exchange have provided major driving forces in the expansion of the industry. In order to keep up with the demand, many shrimp farmers adopted intensive farming practices. Strategic construction of the ponds regarding the prevailing wind direction facilitates water movement and thus, aeration, or the mixing of the air and water of the ponds. Due to poor planning and management and a lack of appropriate regulations, many environmental impacts and social conflicts have occurred. Objections are often associated with environmental consequences (mangrove destruction, saltwater intrusion, disease outbreak and pollutions) (Uddin, 2013).

Aquaculture has been subjected to an intense learning curve with a slope that no other food industry has had to climb. The trajectory for aquaculture to achieved the goal of sustainability is no different than any other form of food production, that is, limit, counteract, or isolate its pollution on the localized environment, and accelerate the efficiency of natural resource use. Four areas of focus that should effectively coalescence for the goal of sustainable aquaculture to be realized are the preservation of intact habitat, efficient use of natural resources, traceability, and transparency. Traceability and transparency are fundamental to demonstrating accountability. Every stakeholder should be concerned with them because their accomplishment will produce clear economic, societal, and environmental benefits (Nevin, 2020). In practice, environmental sustainability becomes a question of selecting the best alternatives among different practice and procedures. Typically, when faced with an operating or investment decision an aquaculture venture can choose among solutions with different environmental consequences. Ideally, the best technologies allow a combination of producers increasing productivity while reducing environmental footprint (Juarez, 2020).

This paper reviews the production trends, environmental condition, and culture patterns of shrimp farming in most Asian country. The aim of the review is to provide a firm foundation for advancing knowledge on the environmental impacts of shrimp farming and multi-solutions for it. Finally, this review will lead to an empirical viability study of management approach for sustainable shrimp farming.

MATERIALS AND METHODS

Literature search

The literature review is designed to compile the relevant contributions from previous publications and a literature search of following themes:

- Shrimp farming
- Aquaculture
- Environmental impact of aquaculture
- Mangrove impact of aquaculture
- Pond intensification
- Biofloc in aquaculture
- Biofloc in shrimp farming
- Probiotic in aquaculture

The reviewed studies were sourced from mainly scientific papers and journals. It covers journal articles and conference papers in English and Bahasa. There was no limitation on the publication years for the literature search. All sources, whether scientific papers, journals, or news, were collected from internet with keywords associated to the previously mentioned themes. The selection was based on:

- Relevant information of the studies addressing the issues presented by this paper
- Information that raise important ideas for exploring the results of unanswered issues
- Information that provide relevant insights for future research directions

Methods

This review paper used descriptive qualitative method. Descriptive qualitative method is a method to investigate objects that cannot be measured with numbers or other exact measurements and tend to use analysis with inductive approach (Fachrul and Rinanti, 2018).

Analysis

According to the analysis of the selected articles, the focuses of the reviewed literature are divided into two aspects: Environmental impacts of shrimp farming and the future sustainable aquaculture.

Tabel 1. Summary of literature review of two aspects of this review paper.

Environmental impacts of shrimp farming	The future sustainable aquaculture
Destruction of the mangrove ecosystem Pollutions Antibiotics and drugs	Partitioned pond Mechanical aeration and water circulation Biofloc Probiotic

RESULTS AND DISCUSSION

3.1 Environmental impacts of shrimp farming

3.1.1 Destruction of the mangrove ecosystem

A lot of literature points to the fact that the biodiversity of mangrove forest has degraded due to the unabated destruction of the diverse mangrove ecosystem (Iftekhar, 2006; Hoq, 2007; Iftekhar and Takama, 2008). Mangrove destruction in the world is caused by two major factors: aquaculture and agricultural expansion, as well as industrial and settlement development (Primavera, 1997; Giri et al, 2008). Destruction of mangroves due to shrimp aquaculture has been reported by several investigators in different parts of the world (Primavera, 1997; Dierberg and Kiattisimkul, 1996; Heinz, 2002). The study of Sahid and Islam (2003) revealed that approximately 9.734 ha of mangrove were lost in the southeastern part of Bangladesh could be directly attributed to shrimp culture. In indonesia, Philippines, Thailand, Vietnam, and Mexico mangrove forest were damaged due to shrimp cultivation 55, 67, 84, 37 and 30%, respectively (WRI, 2000).

Brackish water pond development is the most damaging and widespread activity contributing to the loss of mangroves since 1800 in Indonesia (Ilman et al, 2016). Other major contributors have been timber exploitation, although in the last 30 years, through combination of strict silviculture methods and limiting the number of mangrove concession areas, the Government and private sector have begun exploiting timber in a more sustainable way. Over the same period, the conversion of mangroves into brackish water ponds has continued an unprecedented scale. The conversion rate is likely to spiral up in the next two decades as the global demand for farmed shrimp from South East Asia region is expected to triple (World Bank, 2013).

Table 2. Estimated changes of mangrove area in major mangrove regions of Indonesia (Ilman et al, 2016).

Region	Area of mangroves (ha)		Percentage of loss (%)
	Original area[1] (estimated at 1800)	Current area[2] (2012)	
Java	173,000	45,000	75
Sumatra	860,000	600,000	30
Sulawesi	273,000	165,000	39
Kalimantan	945,000	595,000	37
Maluku and Lesser-Sunda Islands (MLS)	232,000	210,000	9
Papua	1,650,000	1,600,000	3
Total	4,133,000	3,220,000	22

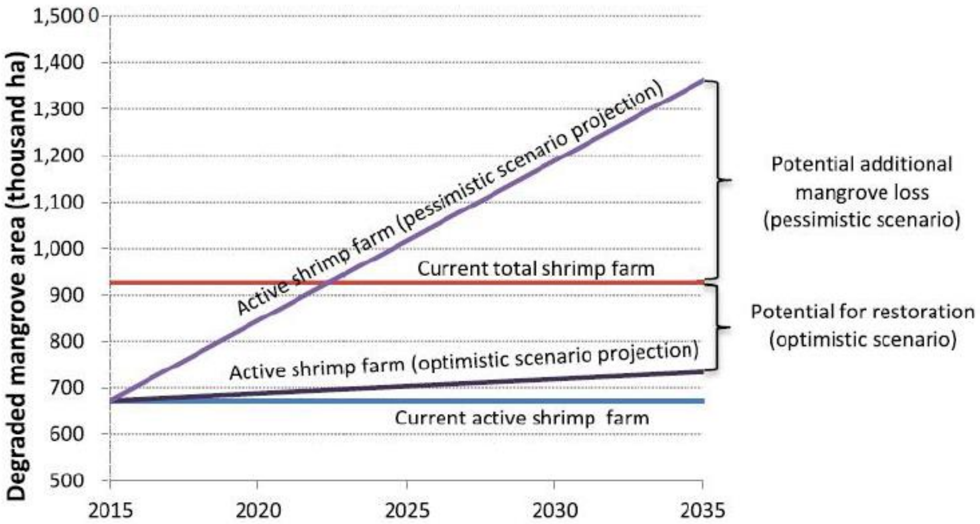
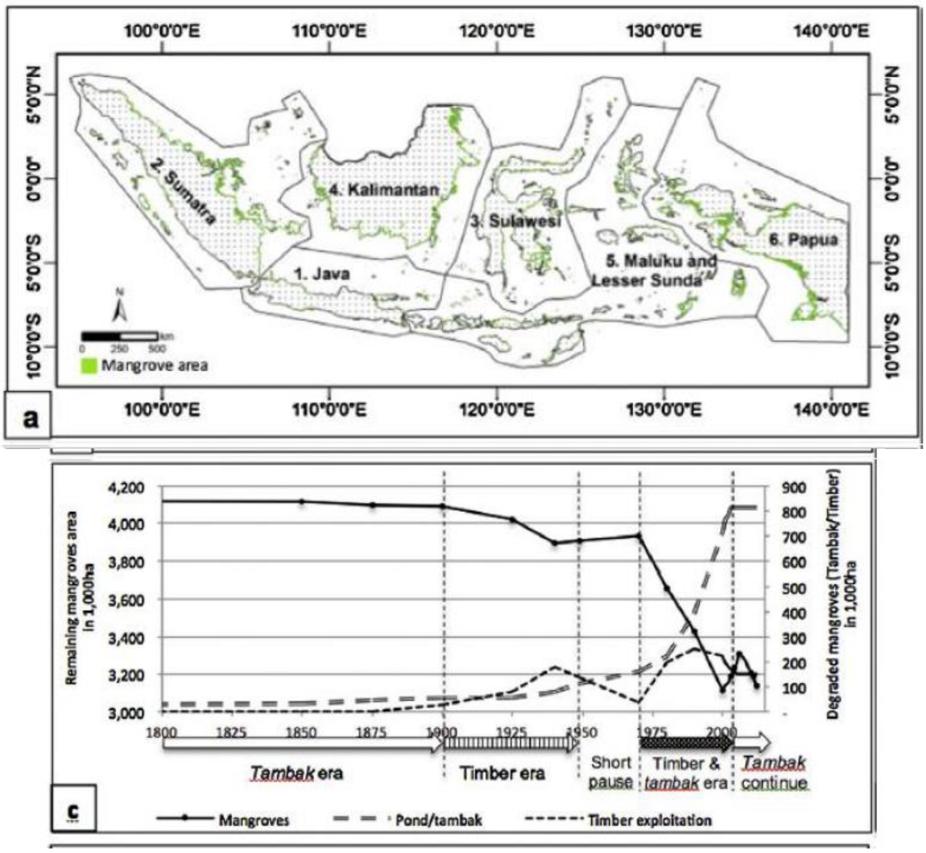


Figure 1. Projection of potential loss and gain of mangroves due to brackish water pond activities (Ilman et al, 2016).



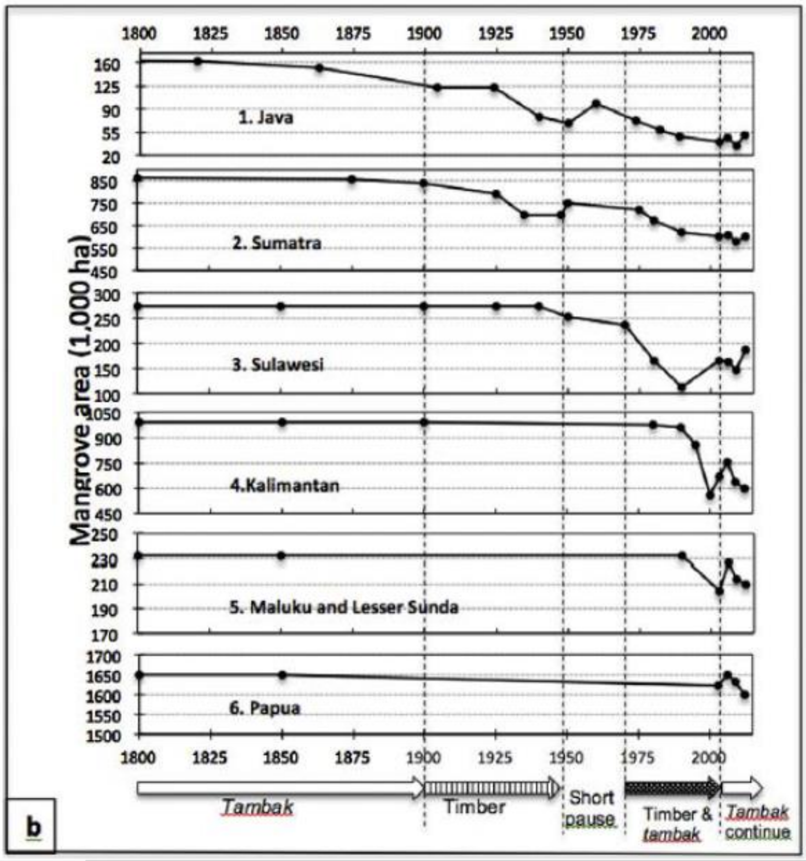


Figure 2. The six mangrove regions in Indonesia: major destruction of mangroves started in Java, followed by Sumatra, Sulawesi, Maluku and Lesser Sunda, and Papua (Ilman et al., 2016).

3.1.2 Pollution

Poor quality feed is the main pollution source of the farming and its adjacent waters, although the soluble organic matter is the important element of water quality of the environment (Yang et al, 1999). Feed reacts with many elements (pH, temperature, osmotic pressure, wave strike and chemical reaction) by resolving, swelling, breaking, pulverization, and desquamation etc. (Uddin and Fakhruddin, 2013). Intensive shrimp farming requires a daily change of water, approximately 5-10 % of the total pond volume per day during earlier, and 30-40 % during later stages of growth period (Flaherty and Karnjanakesorn, 1995). In intensive shrimp farming, water gets changed for 6 days at full and new moon in every fortnight at a rate of 0-10 % of the total volume (Wahab et al. 2003). Directly discharged effluents can easily pollute the surrounding water and soil quality (Deb, 1998). The discharging effluents can reduce the dissolved oxygen, create hypernutrification and eutrification, increade sedimentation load, and cause changes in the benthic communities (Flaherty and Karnjanakesorn, 1995).

Table 3. Pollution load and recommended water quality parameter values for shrimp culture.

Parameters	Pollution load from shrimp culture			Recommended water quality parameter values for shrimp culture		
	Sebastian (2009)	Islam et al. (2004a, b)	Kumar et al. (2012)	Nunes et al. (2005)	Alves and Mello (2007)	Chávez (2008)
Temperature (°C)		31.81	29.8	22–32	26–32	18–33
DO (mg/l)		7.07	7.1	>3.0	≥5.0	2.5–10
pH	8.5	8.27		6–9	7–9	7–10
Ammonia Nitrogen (mg/l N–$NH_{3,4}$)	0.1	0.017 (NH_3)		<0.1[a]	<0.3[a]	<0.20[b]
Nitrate (mg/l N–$N0_3$)	0.2	1.80	0.00087	<60	0.2–20	0.4–0.7
Nitrite (mg/l N–NO_2)		0.009		<1.0	<0.3	0.001–0.2
Orthophosphate (mg/l)		0.633	0.0084	<0.5	<0.4	0.01–0.20
Silica (mg/l)				>1.0	≥2.0	5–20
Chlorophyll-*a* (mg/l)				35–50	–	–
Salinity (ppt)		15	31		15–25	–
Transparency (cm)		26.66		35–50	40–60	–
Total Alkalinity (mg/l CaCO3)	90	180.34		>100	–	50–150
Total Hardness (mg/l CaCO3)	1,580			>150	–	5,700–6,600
Calcium (mg/l)				>100	–	350–450
Magnesium (mg/l)				>50	–	1,200–1,350
Potassium (mg/l)			778	–	–	375–400
Marine (UFC/ml)				<10,000	–	–
TCBS (UFC/ml)				<1,000	–	–
Turbidity (FTU)		274				
Total suspended solids (mg/l)	74	420	75			
TDS (mg/l)		570.7				
COD (mg/l)	21.7	8.00				
BOD (mg/l)	9.4					
Primary productivity ($gC/m^3/h$)		0.352	0.392			

Source Ferreira et al. (2011)

[a] NH_3 (not-ionized ammonia): toxic form

[b] $NH_{3,4}$ (total ammonia)

3.1.3 Antibiotics and drugs

When physio-chemicals factors such as pH, temperature, dissolved oxygen, etc. fluctuate frequently, shrimps become susceptible to stress, leading to disease (Paez-Osuna, 2003). Such as red colour, soft shell, tail root, and black gill (Primavera, 1991; Alam, 2007). High stocking density and excessive use of feed lowers water quality, which contributes to stress and disease among shrimp in intensive farming system (Flaherty and Vandergeest, 1998; Paez-Osuna, 2003). It is dangerous when redundant feed and waste are discharged directly to environment, which renders it extremely susceptible to carrying diseases. The intake of polluted water from neighboring farms often spreads water-borne disease from farm to farm (Paez- Osuna, 2001). Shrimp culture in Asia relies on the input of artificially formulated feed and the application of agrochemicals, antibiotics, and disinfectants. Overuse of antibiotics results in too much antibiotics residues in the aquaculture products, which leads to not only the decrease in the immunity of the aquaculture products, but also decrease in the disease resistance of consumers and the increase in the possibility of infecting the disease (Gräslund and Bengtsšon, 2001; Holmstrőm et al., 2003; Cabello, 2006). Excessive and unwanted use of such chemicals results in problems related to toxicity to non-target species (cultured species, human consumers, and wild biota), development of antibiotics resistance and accumulation of residues (Primavera, 1998).

Table 4. Common antibiotics usage in the shrimp hatcheries in Bangladesh

Antibiotics	Half life	Persistance	Disease names	Pathogens
Prefuran	–	–	Vibrio infaction	*Vibrio parahaemolyticus*
Furazolidone	18 h	9 days[a]		*Vibrio anguillarium*
Oxytetracycline	125 days	>185 days[b]		
Chloramphenicol	1.6–4.6 h[c]	–	Luminiscent bacteria	*Vibrio harvey*
Erythromycin	2–3 h[d]	–		*Vibrio aplendious*
Furazolidone				
Malachite green	2.1 h	80 days[e]		
Neomycin sulphate	–	–		
Chloramphenicol			Filamentous bacteria	*Leucothrix mucor*
Neomycin sulphate				
$KmnO_4$	–	–		
Formalin + malachite green				
Malachite green			Shell disease	Bacteria belonging to *Vibrio*, *Aeromonas* and *Pseudomonas* group
Formalin (37–40 % formaldehyde)	2–3 days[f]	–		
Oxytetracycline				
Treflan	2–3 days[g]	–	Larval mycosis	*Legenidium* spp.
Malachite green				
Malachite green			Protozoan infection	*Zoothamnium* spp.
Formalin				*Vorticella* spp.
Methelene blue	–	–	Blac Gill disease	Chemical contamination
Prefuran	–	–		
Malachite green				
Flumequine	155 days	>185 days[b]	–	–
Ormetoprim	–	<30 days[h]	–	–
Oxolinic acid	165 days	>185 days[h]	–	–
Sulfadiazine	–	>180 days[h]	–	–
Sulfadimethoxine	–	>180 days[h]	–	–
Trimethoprim	–	>30–<60 days[h]	–	–

Source Primavera et al. (1993), Alderman and Hastings (1998), Gräslund and Bengtsson (2001), Uddin and Kader (2006)

Table 5. Chemicals and biological products used in the brackish water ponds culture of whiteleg shrimp (*L. vannamei*) in Pesawaran Regency Lampung Province, Indonesia.

Group	*Sub-group*	*Type of product*
Disinfectant	Chlorine	Calcium hypoclorites
	Lime	Burned lime
Pesticide	Inorganic pesticide	Copper sulfate
	Organic pesticide	Tea seed
Fertilizer	Inorganic fertilizer	Urea
		TSP
		NSP
	Organic fertilizer	Guano phosphate
Soil and water improvement	Lime	Burned lime
		Builder's lime
		Dolomite
		Agricultural lime
	Probiotic	Fermentation
		Akuasium bacillus
		EM-4
		Bacteria
		Starbio
		Probiotik
		Biobacteria
		Sel multi
		Nitrosomonas
		Nitrobacter
		Probacter
		Biomak
		Episin
		Prowel
		Biou T
		Abusekam
		Argon
		Super PS
		Super NB
	Others	Zeolit
		Biorin
		Roksin
		Pur
		Arang batok
		Pond plus
	Vitamin	Multivitamin
		Vitamin C
		Vitamin B complex
	Plant	Garlic
		Cisan
	Others	Azomite
		Molsit
		Kalpros
		Boster shrimp
		Biofit
		Vitaral shrimp
		Biozyme

Source Mustafa, Sapo and Paena, (2009)

Table 6. Chemicals used by 80 shrimp farmers in Songkhla and Nakhon Sri Thammarat in southern Thailand (Philip, 1995).

Chemicals	% Farmers	Reason for use
Lime	24.5	pH control in pond preparation
Dolomite	6.4	Pond preparation
Zeolite	26.1	Water quality control
Teaseed cake	31.8	Predator control
Benzalkonium chloride	9.6	Water disinfectant
Oxytetracycline	17.3	Control of bacterial diseases
Other chemicals	6.7	Control of diseases

3.2. The future sustainable aquaculture

3.2.1 Partitioned ponds

Intensifying pond aquaculture without resorting to water exchange is daunting technological challenge. One approach is to increase the pond's internal waste-removal capacity by either redesigning the pond to enhance phytoplankton growth (the dominant ecological process in conventional ponds) or by radically changing the internal biological processes responsible for waste treatment. This internalenhancement concept of waste removal spawned two innovative technologies-partitioned ponds and biofloc ponds. Another approach to address intensification is to enhance waste-treatment capacity on a whole-farm basis rather than in individual ponds. These disparate management technologies have broken the barriers that limit productivity in conventional ponds while improving land and water-use efficiencies and reducing pollution (Tucker, 2019).

Partitioned ponds were developed in the 1990s to integrate fish culture with zero-discharge wastewater treatment (Brune, Schwartz, Eversole, Collier, and Schwedler, 2014). The original partitioned aquaculture system (PAS) confines fish at high density in concrete raceways that comprise about 5% of the total pond area. Waste produced during fish culture are circulated through a large, well-mixed pond based on "high-rate algal ponds"originally designed for domestic wastewater treatment (Oswald, 1963). Potential fish production increases because of the system's improved waste treatment capacity. In theory, if you double the rate of net algal photosynthesis, you can double the removal rate of ammonia and other waste products, thereby doubling both the maximum safe feeding rate and fish production (Boyd and Tucker 2019).

Figure. 3 Split ponds for ictalurid catfish in Mississippi, USA. The middle pond is highlighted to show partitioning of the original 3.2-ha pond into a 0.6-ha fish-holding basin and a 2.6-ha algal waste-treatment lagoon. Arrows show direction of daytime pumped-water circulation through culverts. Photograph by Danny Oberle (Boyd, Abramo, Glencross, Huyben, Juarez, Lockwood, McNevin, Tacon, Telechea, Tomasso, Tucker, Valenti (2019).

3.2.2 Mechanical aeration and water circulation

An especially critical research needs for dissolved oxygen management in ponds in the investigation of the relationship between aeration and water circulation. Most aerators, and particularly floating electric paddlewheel aerators, were designed for maximum oxygen transfer efficiency, and the characteristics of water current produced by aerators have not been thoroughly studied. Devices that induce water circulation in ponds have been designed, fabricated, and tested (Howerton, Boyd and Watten, 1993). A preliminary study suggested that the combination of aerators and water circulations might be more efficient in maintaining dissolved oxygen concentrations in ponds than that achieved by application of aeration alone

(Tucker and Steeby, 1995). Research to determine the conditions under which water circulators could be efficiently used to enhance aeration practices should be highly prioritized.

Both fish and shrimp cannot hold position in ponds if water currents become too strong, and in laboratory studies, shrimp grow best at water velocities of 0.63-2.78 cm/s (Dai, Zhang, and Zhang, 2008). In earthen culture ponds, shrimp avoid areas where water velocities were <3 cm/s (apparently because of sedimentation) and tended to avoid areas where water velocities were >5 cm/s (Wijesekara, Nomura and Matsumura, 2005). Experience in shrimp culture has revealed that for each additional horsepower of aeration produced by Asian-style paddlewheel aeration, 400-500 kg more shrimp can be reared (Boyd et al., 2019). Nevertheless, due to the variability of pond dissolved oxygen budgets, the accuracy of the production to aerators horsepower ratio selected in a pond should be continually verified by monitoring the dissolved oxygen concentration.

Figure 4. A "Taiwan-style" paddlewheel aerator on a fish farm (photograph courtesy of Wikimedia Commons) (Boyd, Abramo, Glencross, Huyben, Juarez, Lockwood, McNevin, Tacon, Telechea, Tomasso, Tucker, Valenti (2019)).

Although mechanical aeration has become a common practice, and aerators that are efficient in transferring oxygen to water and of excellent mechanical reliability have been developed, the knowledge of efficient aerator use to contribute to sustainable production system is poorly developed. Minimum dissolved oxygen concentration that can be maintained without causing a decrease in feed consumption and feed conversion efficiency and greater susceptibility to disease need to be determined for the different aquaculture species (Boyd et al, 2019). The placement of aerators in ponds also deserves additional investigation. In the interest of the promotion and achievement of sustainable aquaculture production, the reduction of resource use per unit of aquaculture production is a pervasive goal. Ultimately, direct resource use is conserved by reducing inputs per unit weight of aquaculture production as well as the quantity of waste generated per unit weight of productions (Boyd et al., 2017; Chatvijitkul, Boyd, Davis, and Mc Nevin, 2017).

3.2.3 Biofloc

In general, biofloc is the macro-aggreagation of bacteria, algae, detritus, and other decomposed components (Avnimelech et al., 1995). It is the combination of bacteria, diatoms, zooplankton, protozoa, macro-algae, feces, uneaten feed, and exoskeleton from dead organism (Decamp et al, 2008). It is a group of biotic and abiotic particulate components suspended in the water which includes bacteria, plankton, and other organic materials (Hargreaves et al., 2006). Large Flocs can be seen with the naked eye, but most of them are microscopic. Floc size range from 50-200 microns (Vikaspedia, 2020). Biofloc technology (BFT) has been amply studied and contributes to the maintenance of adequate water quality in aquaculture systems and to the nutrition of farmed aquatic animals. It has been shown that BFT systems not only keep ammonia below toxic levels and improve the efficiency of nutrient utilization of farmed animals, but also provide additional nutrients and exogenous digestive enzymes. BFT application can also support greater growth, survival, and reproductive performance of the cultured animals (Ekasari et al, 2019).

Table 7. Some of the study conducted in fish with reference to biofloc based culture systems (Daniel and Nageswari, 2016).

S. No	Species studied	Duration of study	Results acquired in the study with biofloc
1.	*Litopenaeus vannamei*	35 days	Significant growth increment and reduced feed cost[78].
2.	*Oreochromis sps.*	14 weeks	Improvement in the water quality, fish survival and minimization in the external feed requirement[42].
3.	*Litopenaeus vannamei*	30-day	Promoted the animal growth, health, digestion and feed utilization performances[144].
4.	*Farfantepenaeus paulensis*	15 days	Increased survival and growth rates of shrimp[44].
5.	*Rhamdia quelen*	21-day	Increased the larval survival and stress mitigation[104].
6.	*Marsupenaeus japonicus*	106-day	Comparing with the control group, the ammonium and nitrite concentration was significantly reduced in the bioflocs treatment groups[147].
7.	*Labeo rohita*	90 days	Reduced the artificial feed reliance and improved the utilisation of bioflocs as feed to 50%[124].
8.	*Oreochromis niloticus*	N/A	Fish survival was 100% and results in the utilization of biofloc as food[13].
9.	*Litopenaeus vannamei*	2 weeks	Biofloc improved the growth and immune-related gene expression[75].
10.	*Litopenaeus vannamei*	34 days	There was a significant increase in the survival rate, in addition to increases in growth[120].
11.	*Litopenaeus vannamei*		Effectively improved the water quality, bacterial activities and zooplankton growth; consequently resulted in the better growth performances[53].
12.	*Litopenaeus vannamei*	13 weeks	Affected the nitrogen cycling pathways and de-nitrification process[109].
13.	*Penaeus monodon*	60-day	Gave the beneficial effects on growth performances and digestive enzyme activities[6].

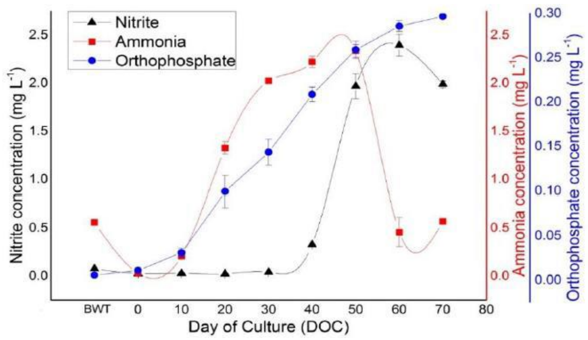


Figure 5. The ammonia, nitrite, and ortho-phosphate concentration in each DOC of shrimp pond. The error bar indicates standard deviation of nutrients (nitrite, ammonia, and orthophosphate) for each DOC (Kasan et al., 2018).

Nitrite concentration was the highest during DOC 60 with 2.40 mg/L while DOC 20 was found to have the lowest nitrite concentration with only 0.02 mg/L. Throughout all DOC, nitrite concentration showed increasing trend from DOC 30 to DOC 60. However, at DOC 70, nitrite concentration showed declining (Kasan et al., 2018).

Table 8. Comparison of survival rate and shrimp production in control pond and super-intensive 2-phase biofloc system (Kasan et al., 2018).

Production ($1500m^2$ pond)	Grow-out 1 (Treatment-BFT)	Grow-out 2 (Control)
	Survival Rate (%)/ Production (kg)	Survival Rate (%)/ Production (kg)
Cycle 1	82/2471	-
Cycle 2	98/2646	88/2568
Cycle 3	94/3602	82/2541
Cycle 4	83/3608	82/3170

A variation in BFT pond production with an average of 3.1 tons per pond per cycle was achieved (table 2). This is equivalent to average of 2.06 kg/m2 of shrimp production. As for comparison, the control pond generates between 0.8 to 1.0 kg/m^2 of shrimp production. From the population density between 240,000 to 340,000 pieces, an average survival rate (SR) of 89% was achieved. This finding showed that with high stocking density, the 89% of SR achieved is relatively high and sustainable (Kasan et al., 2018).

Figure 6. Observation of biofloc volume in Imhoff cone (Daniel and Nageswari, 2016).

Figure 7. An intensively aerated biofloc shrimp pond in Guatemala. Photograph by John Hargreaves (Boyd, Abramo, Glencross, Huyben, Juarez, Lockwood, McNevin, Tacon, Telechea, Tomasso, Tucker, Valenti (2019)).

3.2.4 Probiotic

Various studies have analyzed the use of probiotic bacteria to promote the health of the organism (Dohail et al., 2011; Ghareeb et al., 2008; Souza et al., 2012). Conducted research on probiotics has shown many beneficial impacts to the health of cultured animals, including growth and immunity (Decamp, 2008; Tseng, 2009; Verschuere, 2000). Probiotics have many mechanisms of action: the competitive exclusion of pathogenic bacteria, serving as a nutrient source and contributing to enzymatic digestion of animals, beneficial effects on water quality, and improvement of the animal immune response. Many bacteria are being explored to be used as a probiotic strain as they contain the growth, immune stimulatory effect, and resistance against pathogenic microbes (Kesarcodi-Watson, 2008).

Table 9. Some of the study conducted in fish with reference to probiotics supplementation (Daniel and Nageswari (2016).

S. No	Species studied	Strains used for study	Days of study	Results acquired in the study
1.	*Litopenaeus vannamei*	*B. subtilis*	60 days	No improvement on survival, final weight, FCR and water quality[49].
2.	*Oreochromis niloticus*	*B. subtilis* and L. acidophilus	60 days	Improved the disease resistance and growth performance[5].
3.	*Litopenaeus vannamei*	*B. subtilis*	14 days	Improved the larval survival rate, development, stress resistance and immune status[82].
4.	*Litopenaeus vannamei*	Bacillus species	N/A	Improved the growth, survival and some water quality parameters such as pH, ammonia and nitrite as compared to controls[97].
5.	*Clarias gariepinus*	*L. acidophilus*	21 days	Significantly improved the haematology parameters and histopathology[4].
6.	*Penaeus vannamei*	*B. coagulans*	N/A	Significantly increase survival rate and digestive enzyme activities[149].
7.	*Penaeus* vannamei	*Bacillus sp*	28 days	Positive effects on enzyme activity and resulted in an increase in the growth performances[140].
8.	*Clarias gariepinus*	*Lactobacillus and Bifidobacterium*	90 days	Improved the growth performance and blood parameters[12].
9.	*Oncorhynchus mykiss*	*Enterobacter amnigenus*	N/A	Improved the health status[20].
10.	*Litopenaeus vannamei*	*B. licheniformis, B. megaterium*	60 day	Effectively enhanced both digestive enzyme activity and non-specific immunity simultaneously[80].
11.	*Sparus aurata*	*Lactobacillus spp.*	31 days	No effect on growth parameters and digestive enzyme activities128.
12.	*Paralichthys olivaceus*	*L. lactis*	5 weeks	Enhanced the immune response and effectively controlled bacterial infection67.
13.	*Penaeus monodon*	*Bacillus S11* (probiont)	90-days	Enhanced both cellular and humoral immune defense[93].
14.	*Penaeus monodon*	*B. subtilis*	N/A	The growth of pathogenic V. harveyi was effectively controlled[137]

CONCLUSIONS

Partitioned aquaculture system (PAS) or in this case, partitioned pond, represents the ultimate degree of intensification for ponds where phytoplankton metabolism is the dominant process affecting the environment. However, the original PAS was not widely adopted by fish farmers because the system operationally complex and costly to build (Boyd et al., 2019). Although mechanical aeration has become a common practice, and aerators that are efficient in transferring oxygen to water and of excellent mechanical reliability have been developed, the knowledge of efficient aerator use to contribute to sustainable production system is poorly developed. Minimum dissolved oxygen concentrations that can be maintained without causing a deceased in need to be determined for the different aquaculture species. The placement of aerators in ponds also deserves additional investigation (Boyd et al., 2019). Biofloc technology offers an ample advantage ensuring zero water exchange through minimal consumption of water and less water pollution. Biofloc technology is applied for decreasing the effluent discharge, preventing risk from the disease outbreak, protecting the water free from pathogen entry; thus, ultimately improve the biosecurity at the farm level (Burford, 2003). However, the monitoring techniques for floc characteristics, composition, and nutritional quality (amino acid, fatty acid, and vitamin content) need to be developed (Nahar and Nabi, 2019). Result of the recent studies supported that supplementing the probiotics to biofloc helps in the growth, digestion, metabolism, and disease resistance to the animals together with improving the water quality in the culture system (Daniel and Nageswari, 2016). The only confounding problem is that large variations in bacterial community composition that exist for different time point, feed composition, fish lifecycle stages, rearing systems, water temperature, and external-internal factors. Only a small number of probiotic studies that analyze gut microbiota and additional data are needed to evaluate the effects of probiotics on a range of aquaculture species (Boyd et al., 2019).

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