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SHORT COMMUNICATION

Status of Water Quality in Fishponds Surrounding Manila Bay

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ABSTRACT

Fishponds around Manila Bay contributed an average of 41.19% of the total aquaculture production in the country. However, massive productions entail the intensification of ponds, which resulted in water quality deterioration. In 2016, Opinion et al. reported water quality in the aquaculture farms around the bay but does not include the other significant parameters required to be monitored, as stated in the DENR AO (2016). Thus, this study investigated the status of water quality in different pond systems surrounding Manila Bay. Extensive, semi-intensive, and intensive fishponds from adjoining provinces of Cavite, Pampanga, Bataan, and Bulacan were monitored throughout the rearing period. Results showed that levels of NH_3-N (0.90 mg/L – 2.35 mg/L) and PO_4^{-3} (1.02 mg/L – 2.42 mg/L) were not suitable for the culture of fish. Nevertheless, NO_3-N, NO_2-N BOD, TSS, DO, pH, and temperature were within the safe levels. Furthermore, results suggested that there should be a regular monitoring of water quality to regulate and manage fishponds surrounding the bay. Finally, strict compliance of the Code of Good Aquaculture Practices (GAqP) must be imposed to achieve water quality standards.

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All organisms grow best within particular environmental conditions (Hargreaves and Tucker 2004). Water quality is critical for maximum growth and fish survival to ensure successful propagation in pond aquaculture (Mannan et al. 2012; Bhatnagar and Devi 2013). Improved productivity can be achieved if water quality is maintained within the optimum range (Bhatnagar and Devi 2013). Prolonged fish exposure in poor environmental conditions will negatively affect its growth and survival (Shoko et al. 2014). Overall, fish production is determined by water quality (Alam and Al-Hafedh 2006). Hence, successful pond management requires an understanding of the latter (Bhatnagar and Devi 2013). Furthermore, constant checking of water parameters is a significant measure to assess pond water's suitability for culture and control harmful crisis in the whole production process (Mohanty et al. 2018).

Fishponds surrounding Manila Bay contributed an average of 41.19% of the total aquaculture production from 2011 to 2018 (PSA 2014, 2016, 2019). This indicates that fishponds from the surrounding provinces are among the most important areas in the country with the bulk of production. However, huge production entails the intensification of the pond system that requires more inputs, which resulted in waste production and water quality deterioration (Henriksson et al. 2018; Montojo et al. 2020). Opinion and Raña (2016) reported the farmers' non-compliance around the bay to the standard practices in aquaculture. Thus, maintaining the suitability of water for farming is indeed a major challenge.

In the previous study by Opinion et al. (2016), ammonia, phosphate, nitrate, and nitrite in the aquaculture farms around Manila Bay were reported. Ammonia and maximum phosphate level were above the limit set for the propagation and growth of fish (DENR AO 2016). Conversely, the parameters reported in the previous study do not include the biological oxygen demand (BOD) and total suspended solids (TSS), which were considered as the significant parameters to be determined in the aquaculture (DENR AO 2016). Moreover, there is still no follow up studies on the status of water quality on fishponds surrounding Manila Bay.

Thus, this study was carried out to investigate on the present status of water quality such as BOD, TSS, dissolved oxygen (DO), pH, salinity, temperature, ammonia (NH_3-N), nitrate (NO_3-N), nitrite (NO_2-N), and phosphate (PO_4^{-3}) during water exchange in the fishponds surrounding Manila Bay.

A total of 25 ponds from Cavite, Pampanga, Bataan, and Bulacan were sampled (Table 1). Fishponds were classified into extensive, semi-intensive, and intensive culture systems according to the stocking density, degree of management, and production (FAO 1998; Howerton 2001; BFAR 2007; Boyd et al. 2007; Montojo et al. 2020).

Table 1. Profile of the sampled fishponds provided by the owners or operators

Type of Culture	Total Area (ha) (BFAR and BAS 2003)	Sampling Location	Station No.	Area (ha)	Cultured Species	Stocking Density (total)	Culture duration (mos)	Inputs	
								Fertilizer (kg)	Feeds (kg/ day)
Extensive	7,817.69	Bulakan	1	3.00	Milkfish/Prawn/Crab	41,000	6.00	---	---
		(Bulacan)	2	1.70	Milkfish/Prawn/Crab	8,000	4.00	25.00	---
			3	3.00	Milkfish/Prawn/Crab	22,000	4.00	150.00	---
		Meycuayan	4	2.00	Milkfish	200,000	6.00	100.00	---
		Paombong	5	0.50	Milkfish/Prawn/Crab	100,000	4.00	---	---
			6	0.50	Tilapia	10,000	6.00	---	---
		Abucay	7	0.70	Milkfish/Crab	20,000	4.00	50.00	---
		(Bataan)	8	2.00	Milkfish/Shrimp	200,000	4.00	---	---
		Kawit	9	0.50	Prawn	10,000	4.00	---	---
		(Cavite)	10	0.08	Prawn/Crab	50,000	4.00	---	---
		Noveleta	11	3.00	Milkfish/Prawn	30,000	6.00	---	---
			12	5.00	Shrimp	50,000	6.00	---	---
			13	5.00	Milkfish/Prawn	50,000	9.00	---	---
			14	3.00	Milkfish/Prawn	40,000	6.00	---	---
		Ternate	15	0.50	Milkfish/Prawn/Crab	30,000	6.00	---	---
		Sasmuan	16	3.00	Shrimp	30,000	6.00	120.00	---
		(Pampanga)	17	1.50	Tilapia	40,000	9.00	---	---
		Masantol	18	2.00	Milkfish/Prawn Tilapia/Crab	40,000	6.00	25.00	---
			TOTAL	36.98				470.00	---
Semi-Intensive	21,415.30	Bulakan, (Bulacan)	19	0.80	Shrimp	100,000	4.00	30.00	8.00
		Malolos	20	1.50	Milkfish/Prawn	100,000	6.00	120.00	2.00
		Paombong	21	0.80	Milkfish/Tilapia/Crab	56,000	4.00	---	1.00
		Abucay (Bataan)	22	6.00	Milkfish/Shrimp	150,000	4.00	125.00	2.00
			TOTAL	9.10				275.00	13.00
Intensive	7,817.69	Sasmuan,	23	12.00	Tilapia	800,000	3.00	---	139.00
		(Pampanga)	24	8.00	Tilapia	1,000,000	3.00	---	113.00
			25	7.00	Tilapia	400,000	3.00	---	160.00
			TOTAL	27.00				---	412.00

(---) indicate no fertilizer or feed used.

The sampling was conducted from April to December 2018, covering the flooding and draining of the fishpond. The culture duration of fishponds varies from three to nine months (Table 1). Flooding represents the water sources, while draining corresponds to the water extruded from the pond, which includes the farmers' input. Water samples were collected between 9:00 AM-4:00 PM in consideration of the DO (DENR AO 2016). A total of 5.00 L of composite pond water was collected from three points at a depth of about 30 m below the surface. It was then transferred into the acid-washed polyethylene (PE) containers and placed in an ice chest with a temperature not exceeding 6°C for transport. Samples for nitrogen analyses were preserved with concentrated H_2SO_4 to pH < 2 (Environment Protection Agency 2007). For the levels of DO (mg/L), pH, salinity (psu), and temperature (°C) multi-parameter water quality checker (HORIBA U-50) was used.

The BOD was analyzed using the five days incubation period (BOD_5 Manometric Respirometric Method), while the TSS was determined using the standard method of Environment Protection Agency (EPA) with Method No. 160.2. In the analyses of NH_3-N, NO_3-N, NO_2-N, and PO_4^{-3}, Colorimetric Method was used through UV-Visible Spectrophotometer (Shimadzu UV-1800) following the procedure of EPA with Method No's. 350.2, 352.1, 354.1, 365.2, respectively.

Data analysis was performed using the Statistical Package for Social Science (SPSS) Version 20.0. Paired T-Test was then used to examine the significant differences among the parameters during flooding and draining. The significance was set at 95% confidence level (p<0.05).

Levels of BOD and TSS

BOD is the measurement of total dissolved oxygen consumed biologically by the microorganisms to decompose organic matter under aerobic conditions (Bhatnagar and Devi 2013). In the present study (Table 2), BOD mean ranged between 11.15 mg/L and 11.69 mg/L during flooding and between 11.32 mg/L and 13.57 mg/L during draining. These were below the limit proposed by Boyd in 2003 (Table 3). Meanwhile, TSS is the concentration of inorganic and organic matter suspended in the water (Bilota and Brazier 2008). It increases the turbidity of a water column, decreasing light penetration, and impairs photosynthetic activities of aquatic plants, potentially leading to oxygen depletion. It can also result in fish kills through clogging of their gills (Bilotta and Brazier 2008). The present study revealed that it does not pose a threat to the ponds' cultured species as none of the levels exceeded the regulatory limit by the DENR AO (2016). However, it is different from the limit claimed by Boyd in 2003 (Table 3) in which TSS during draining in an extensive and intensive pond exceeded. Furthermore, BOD and TSS during flooding and draining exhibit no significant difference (p>0.05) among fishponds (Table 2).

Table 2. Levels of water quality, mean ±SD in fishponds surrounding Manila Bay

Parameter	Culture System					
	Extensive		Semi-intensive		Intensive	
	Flooding	Draining	Flooding	Draining	Flooding	Draining
BOD (mg/L)	11.15±6.48*	11.32±7.86*	11.20±2.05*	12.60±8.60*	11.69±3.26*	13.57±6.51*
TSS (mg/L)	41.47±33.90*	56.02±53.50*	40.33±31.95*	40.39±20.97*	50.25±28.71*	59.97±22.80*
DO (mg/L)	5.37±1.98**	6.12±2.25**	5.73±1.44*	5.51±2.40*	5.29±1.52*	3.75±0.88*
pH	8.10±0.73*	8.24±0.42*	7.89±0.37*	8.08±0.22*	7.92±1.04**	8.31±0.23**
Salinity (psu)	16.32±11.00*	16.17±10.95*	17.33±9.76*	15.47±8.55*	7.72±5.60*	6.32±2.12*
Temperature (°C)	30.30±2.73*	30.38±2.16*	31.03±1.25*	30.84±2.63*	30.28±1.55*	29.84±3.17*
NH_3-N (mg/L)	1.41±0.69*	1.29±0.71*	1.92±1.21*	2.35±1.57*	0.90±0.17*	1.31±0.87*
NO_3-N (mg/L)	0.07±0.06*	0.08±0.04*	0.12±0.07*	0.16±0.12*	0.06±0.03*	0.06±0.05*
NO_2-N (mg/L)	0.02±0.01*	0.01±0.01*	0.03±0.02*	0.02±0.01*	0.01±0.00*	0.02±0.01*
PO_4^{-3} (mg/L)	1.66±1.32*	1.27±1.01*	1.91±1.42*	2.42±2.28*	1.02±0.76*	1.06±0.58*

*no significant difference between flooding and draining for each culture system and parameter
**with significant (p<0.05) difference between flooding and draining for each culture system and parameters

Levels of DO, pH, Salinity and Temperature

The DO in an extensive pond was significantly lower (*p*<0.05) during flooding (5.37 mg/L) compared to draining (6.12 mg/L, Table 2). This supports Priyadarsani and Abraham's (2016) claim that oxygen dynamics depend on autotrophic and heterotrophic organisms' balanced production inside the pond system since extensive ponds contained both organisms. Nevertheless, DO in both flooding and draining were acceptable as it is above the minimum level (DENR AO 2016; Boyd 2003). The presence of DO is essential to maintain the higher forms of biological life and balance the pollution resulting in a healthy water body (Dixit et al. 2015). DO is critical for fish growth and production. Low DO is an underestimated cause of fish losses, mainly because of its synergistic effects with other toxins like ammonia (Wurts 2013). On the other hand, DO during flooding and draining in the semi-intensive and intensive ponds do not vary (*p*>0.05). However, minimum DO (3.75 mg/L) was found during the draining of an intensive pond, and it is below the recommended level (DENR AO 2016; Boyd 2003).

The pH levels in flooding and draining of both extensive and semi-intensive ponds do not vary (*p*>0.05). Mean levels ranged from 7.89 to 8.10 (Table 2) during flooding and 8.08 to 8.31 during draining. In an intensive pond, pH level was significantly higher (*p*<0.05) during draining (8.31) than flooding (7.92). Tucker and D'Abramo (2008) reported that the rise or fall of pH is due to the relative rate of respiration and photosynthesis within the pond system. All reported mean levels of pH in the study were within the range suggested by DENR AO (2016) and Ekubo and Abowie (2011).

Salinity is a major driving factor that affects the density and growth of aquatic organisms' population (Jamabo and Chinda 2010). Salinity in the fishponds ranged from 7.72 psu to 17.33 psu during flooding and from 6.32 psu to 16.17 psu during draining (Table 2). The intensive pond encompasses the minimum salinity during flooding and draining. However, levels during draining and flooding do not vary (*p*>0.05) in the three pond systems. The salinity requirement is dependable on the cultured species. Milkfish, tilapia, shrimp, and crab are the species being cultured in the fishponds around the bay that requires the salinity of <7.00 psu, <25.00 psu, 10 ~ 25.00 psu, and 5 ~ 25 psu, respectively (Shelly and Lovatelli 2011; Barman et al. 2012; Bhujel 2013; Opinion and Rana 2016; Reddy and Mounika 2018).

As for temperature, season, and geographic location are among the huge factors. When temperature increases, it is more difficult for aquatic life to get sufficient oxygen (Shukla et al. 2013). Higher temperature increases the rate of the micro biota's bio-chemical activity, plant respiratory rate, and so increases the oxygen demand. It further causes decreased oxygen's solubility and increased ammonia level in the water (Bhatnagar and Devi 2013). Moreover, temperature tends to affect the levels of other parameters (Dauda and Olusegun 2014). In this study, the temperature during flooding and draining in the pond system do not exhibit significant differences (*p*>0.05). The temperature ranged from 29.84°C to 31.03°C (Table 2) among ponds during flooding and draining. These are within the safe levels, according to DENR AO (2016) and Bhatnagar and Devi (2013) (Table 3). Bhatnagar et al. (2004) also suggested that temperature less than 20°C is sub-lethal for the growth and survival of fishes, while temperature more than 35°C is lethal to the maximum number of fish species.

Levels of NH_3-N, NO_3-N, NO_2-N and PO_4^{-3}

NH_3-N is toxic to fish if allowed to accumulate in fish production systems. When NH_3-N accumulates to toxic levels, fish cannot extract energy from feed efficiently, and the fish will become lethargic and eventually die (Hargreaves and Tucker 2004). In this study, NH_3-N mean levels (Table 2) ranged between 0.90 mg/L and 1.92 mg/L during flooding and between 1.29 mg/L and 2.35 mg/L during draining. All these levels exceeded the regulatory limit (DENR AO 2016; Bhatnagar and Devi 2013) (Table 3). This implied that NH_3-N levels were not suitable for the culture and imposed a threat to the fish. The primary source of nearly all the NH_3-N in fish ponds is the protein in feed. When feed protein is completely broken down or metabolized, NH_3-N is produced within the fish and excreted through the gills into pond water. Therefore, it seems reasonable to conclude that NH_3-N levels in ponds can be controlled by manipulating the feeding rate or feed protein level (Hargreaves and Tucker 2004). However, levels of NH_3-N during flooding and draining among pond systems do not exhibit significant differences (*p*>0.05). This further implied that water sources were already in high levels of NH_3-N before entering the pond system, which is similar to Opinion et al.'s (2016) claim.

Levels of NO_3-N (Table 2) do not vary during flooding and draining among pond systems (*p*>0.05). However, unlike NH_3-N, NO_3-N is a harmless nutrient,

Table 3. Comparative levels of water quality in fishponds and bay waters, and the regulatory limit set by the various literature

Parameter	Levels of Water Quality				Regulatory Limits		
	Fishpond (Opinion et al. 2016)	Fishpond Present Study*	Bay waters** (Furio et al. 2019)	DENR AO Class SC (2016)	Boyd (2003)	Ekubo and Abowei (2011)	Bhatnagar and Devi (2013)
BOD (mg/L)	----	11.15 ~13.57	----	n/a	30.00	----	----
TSS (mg/L)	----	40.33 ~59.97	----	80.00	≤ 50.00	----	----
DO (mg/L)	----	3.75 ~ 6.12	----	≥ 5.00	≥ 5.00	----	----
pH	----	7.89 ~ 8.31	----	6.50 ~ 8.50		7.00 ~ 8.50	----
Salinity (psu)	----	6.32 ~ 17.33	22.48 ~29.84	----	----	----	----
Temperature(°C)	----	29.84 ~31.03	22.05 ~30.41	25.00 ~ 31.00	----	----	15.00 ~ 35.00
NH_3-N (mg/L)	0.39 ~3.75	0.90 ~ 2.35	----	0.05	----	----	0.05
NO_3-N (mg/L)	0.02 ~ 0.45	0.06 ~ 0.16	0.07 ~ 0.54	10.00	----	----	0.00 ~ 100.00
NO_2-N (mg/L)	0.00 ~ 0.13	0.01 ~ 0.03	0.53 ~ 1.73	n/a	----	----	0.02 ~ 2.00
PO_4^{-3} (mg/L)	0.08 ~ 6.17	1.02 ~ 2.42	0.00 ~ 0.23	0.50	----	----	----

n/a – Not applicable
---- Not indicated.
* Range of the mean values during water exchanges among aquaculture system
**Range of surfaces' mean values throughout the year

except in high levels, produced by *Nitrobacter* bacteria from the combined oxygen and NO_2-N (Bhatnagar and Devi 2013). In this study, levels ranged from 0.06 mg/L to 0.12 mg/L during flooding and from 0.06 mg/L to 0.16 mg/L during draining. Maximum levels were found during flooding and draining in a semi-intensive pond. However, all these levels are within the regulatory limit established by the DENR AO (2016) and Bhatnagar and Devi (2013). If compared to the study of Opinion et al. 2016, NO_3-N in the present study is lower.

The levels of NO_2-N and PO_4^{-3} in fishponds were shown in Table 2. The NO_2-N levels ranged from 0.01 mg/L to 0.03 mg/L during flooding and from 0.01 mg/L to 0.02 mg/L during draining. During flooding and draining among the pond system, the levels show no significant difference (p>0.05). NO_2-N is an intermediate in the oxidation of NH_3-N to NO_3-N. It is a well-known toxicant for fish and a disrupter of multiple physiological functions, including ion regulatory, respiratory, cardiovascular, endocrine, and excretory processes, and turns the blood and gills to brown (Kroupova et al. 2005; Bhatnagar and Devi 2013). Levels of NO_2-N throughout the culture in an extensive pond and the water source of an intensive pond are beyond the safe levels (Table 3, Bhatnagar and Devi 2013). Furthermore, PO_4^{-3} levels (Table 2) ranged between 1.02 mg/L and 1.91 mg/L during flooding and between 1.06 mg/L and 2.42 mg/L during draining. Maximum PO_4^{-3} levels during flooding and draining were found in the semi-intensive pond. Flooding and draining among the pond system does not exhibit a significant difference (p>0.05). The present maximum PO_4^{-3} level was lower than the maximum level published by Opinion et al. 2016 (Table 3). However, all PO_4^{-3} levels exceeded the regulatory limit (DENR AO 2016).

Comparison of the water quality in fishponds and Manila bay waters

The highest level of NO_3-N during draining in fishponds was relatively three times lower than the highest range level observed in Manila bay waters (Table 3). Also, the highest level of NO_2-N during draining in fishponds was almost 86 times lower than the level in the bay water. Urban activities of humans and industries are the major sources of nutrient load that contribute to the bay's worsening status (Sotto et al. 2015). Pedde et al. (2017) also added that agriculture, specifically, crops and livestock, as well as atmospheric deposition, also contribute to the deterioration of the bay. Meanwhile, the highest level of PO_4^{-3} in fishponds during draining is almost ten times higher than the PO_4^{-3} found in the bay (Table 3). In the study of Pedde et al. (2017), decreasing river export of P to the bay is possible due to increased nutrient retention in rivers due to damming and consumptive water use, which further resulted in less transported nutrients to coastal areas. Furthermore, the temperature in fishponds during draining was almost similar to the bay water.

Pond water quality needs to be well-managed and balance for the cultured species to survive (Yeo et al. 2004). Even though there was no incidence of fish kills recently reported in the aquaculture farms around Manila Bay despite the high level of NH_3-N and PO_4^{-3}, there should still be regular monitoring of the water quality of fishponds around the bay. In the Code of Good Aquaculture Practices (GAqP), it was indicated that the water used in the farm should be far from all pollution sources, sufficient and suitable throughout the year (Philippine National Standard 2014). However, the ponds located downstream lose stock through the contaminated irrigation draining from the upstream (Little et al. 2013). Furthermore, the practice of intensive and semi-intensive culture systems may still result in overfeeding or excessive food left, pollution of the water from uneaten food waste, and waste products of cultured organisms (Reddy and Mounika 2018; New 2002).

To conclude, levels of NH_3-N and PO_4^{-3} in Manila bay fishponds were not suitable for fish propagation. Still, other physico-chemical such as NO_3-N, NO_2-N BOD, TSS, DO, pH, and temperature were within the safe levels based on the regulatory limits. Excess amounts of NH_3-N and PO_4^{-3} may pose adverse health effects to the cultured species. However, there was no incidence of fish kills reported throughout the culture despite the high level of NH_3-N and PO_4^{-3}. In addition, DO was lower while pH was higher during draining in an intensive pond while salinity ranged from 6.32 psu to 17.33 psu. Furthermore, the maximum level of NH_3-N, NO_3-N, and PO_4^{-3} in the study were lower than the maximum levels reported by Opinion et al. (2016).

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