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FULL PAPER

Estimation of Nutrient Load from Aquaculture Farms in Manila Bay, Philippines

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ABSTRACT

Waste from aquaculture is considered as one of the possible causes of water quality deterioration in Manila Bay. Aquaculture in the area accounts for almost 30% of the total production in the Philippines. This high production entails intensified application of inputs that could possibly contribute to the nutrient (nitrogen, N and phosphorus, P) load in the bay. Thus, estimation of the N, P and SO_4 loaded from aquaculture farms is necessary to develop more responsive intervention to reduce nutrient load in Manila Bay. Water samples were collected throughout the rearing period from different aquaculture systems in Cavite, Bulacan, Pampanga, and Bataan. The annual estimated N and P loaded from aquaculture farms were 12, 696.66 MT and 2, 363.01 MT, respectively. Fish pens/cages recorded the highest contribution accounting for 88% N and 86% P of the total load. It can be attributed to the direct release of uneaten feeds into the bodies of water. Roughly, 12% N and 14% P were obtained from the fishponds. Furthermore, the annual SO_4 loaded from fishponds was estimated at 36,917.54 MT. Results of the study suggested that there should be an extensive monitoring of the environmental impacts and annual load of aquaculture farms for the sustainable regulations and management of aquaculture activities to reduce nutrient load and improve the aquaculture production as well. Finally, strict compliance to the regulatory guidelines and ordinances must be imposed to achieve the effluent quality standards.

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1. INTRODUCTION

Aquaculture surrounding provinces of Manila Bay is considered as one of the most productive, which accounts for almost 30% of the total aquaculture production in the Philippines. Pampanga is one of the top producing provinces having a 6.82% share to the aquaculture production in the country (PSA 2018). High productions entail intensified involvement of feeds, fertilizers, disinfectants, as well as other chemicals during pond fertilization and feeding, which may result to the discharged of nutrients, organic matter, and suspended solids (Boyd 2001; Boyd 2003; Bhavsar et al. 2016). However, inputs and practices of farmers that may results to these discharges vary depending on the classification of aquaculture systems. Culture systems can be classified as extensive, semi-intensive, and intensive, depending on the stocking density, level of inputs, degree of management, and production. Extensive system depends solely on the natural food present in the system, thus may require pond fertilization to stimulate growth and production of natural food. Stocking densities in semi-intensive systems are higher than extensive system, hence entailing the use of supplementary feeds to augment the natural food in the system. In contrast, intensive system is largely dependent on formulated feeds due to very high densities of cultured species (FAO 1998) Howerton 2001; BFAR 2007; Boyd et al. 2007).

According to the previous study conducted by Opinion and Raña (2016), pond preparation and feeding management activities were commonly practiced in aquaculture farms around Manila Bay. Farmers often apply fertilizers such as urea, chicken manure, complete and ammonium phosphate during pond fertilization while commercial feeds, lablab, and lumot were extensively used for feeding. Nonetheless, majority of the farmers in the area do not observe the guidelines of good aquaculture practices (Opinion and Raña 2016). This suggests that incidence of overfeeding and excessive use of fertilizer were apparent which could lead to high nutrient levels that loads from aquaculture farms (USAID 2013). Levels of nutrients in aquaculture farms in Manila Bay varied widely among fishponds, river tributaries, and coastal area (Opinion et al. 2016). This signifies that there is a variation in waste load among different aquaculture systems. To date, there has been no detailed study on the estimation of nutrients from aquaculture farms surrounding the bay. Hence, crafting of more responsive approach to maintain or reduce the levels of nutrient load as support to the rehabilitation and restoration of Manila Bay remains a challenge.

The present study focused on the quantitative approach of assessing the potential of an aquaculture to pollute the bay. The main objective was to estimate the amount of nitrogen (N), phosphorus (P) and sulfate (SO_4) being loaded by aquaculture farms (fishponds and pens/cages) to Manila Bay. Factors such as N and P from the inputs of feeds and fertilizers and flooding of fishponds were considered. Boyd et al. (2007) described that this indicator is a better reference for policy formulation and better management practices.

2. MATERIALS AND METHODS

2.1 Study Area and Culture Practices

Forty-one (41) aquaculture farms from the surrounding provinces such as Bulacan, Bataan, Pampanga, and Cavite were considered in the study. Twenty five (25) of these were fishponds and sixteen (16) were fish pens/cages (Figure 1). Fishponds were classified according to the type of food used for the cultured species. Actual area, culture duration, and inputs (e.g. feeds and fertilizers) per culture system were presented in Table 1. Total area of fishponds and pens/cages were 73.08 ha and 332.50 ha, respectively. In fishponds, extensive had the prime sampled area, which constitutes 50.60% of the total followed by intensive (36.94%) and semi intensive (12.45%). Culture duration varied from three (3) months to nine (9) months. Extensive system used natural food throughout the culture period; semi-intensive used both natural food and commercial feeds, while the intensive relied only on commercial feeds.

2.2 Estimation of N and P in Farm Inputs

Data on the physical area of the fishponds surrounding the bay according to Bureau of Fisheries and Aquatic Resources (BFAR) and Bureau of Agricultural Statistics (BAS) (BFAR and BAS 2003) now Philippine Statistics Authority (PSA) (Table 1) was used to calculate the total nitrogen (N) and phosphorus (P) input from the commercial feeds and fertilizers. To subdivide the total area for each culture system, percent of extensive (21.10%), semi-intensive (57.80%), and intensive (21.10%) around Manila Bay stated by Opinion and Raña (2016) was adopted.

(Equation 1) $$Total\ inputs\ (kg) = \frac{SFA}{SSA}\ x\ TFM$$

SFA is the sum of feeds/fertilizer in the actual study (kg), SSA is the sum of farm area in the actual study (ha), and TMF is the total farm area around Manila Bay.

2.3 Estimation of N, P, and SO_4 during Flooding and Loading

Collection of water samples was conducted from April 2018 targeting the start of rearing period. Water samples were collected once during the initial flooding. Flooding represents the water from the source such as river that enters the pond system. Approximately five liters of water sample were collected from one feet below the surface of the pond using a fabricated water sampler. Water samples were collected near the gate, mid gate, and in the opposite side of the gate. It was then transferred to polyethylene containers, and placed in an ice chest with temperature not exceeding 6°C during transport. Sample for nitrogen analysis was preserved with 2 mL concentrated (98%) sulfuric acid per liter (EPA 2007).

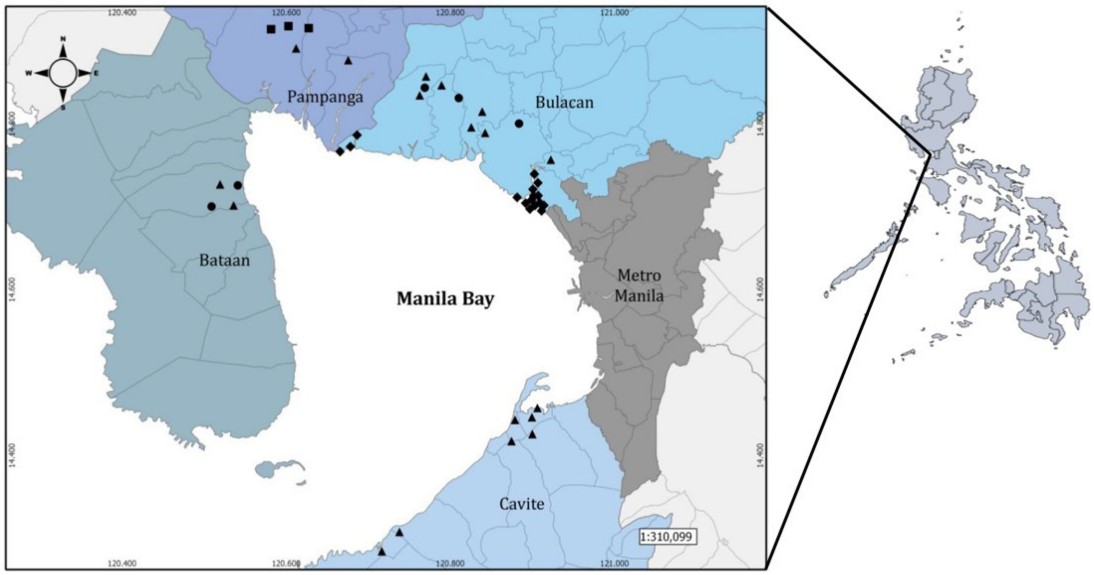

Figure 1. Sampling locations of extensive (▲), semi-intensive (●), and intensive (■) fishponds and pens/cages (♦).

Nitrate (NO_3-N), nitrite (NO_2-N), ammonia (NH_3-N), and phosphate (PO_4) were determined in the laboratory by Colorimetric Method using UV-Visible Spectrophotometer (Shimadzu UV-1800). The standard method of Environmental Protection Agency (EPA) were adopted for the aforementioned analyses with method numbers: 352.1, 354.1, 350.2, and 365.2, respectively. Total Kjeldahl Nitrogen (TKN) was determined following the EPA method number 351.2. Organic nitrogen content was derived by subtracting NH_3-N concentration from TKN. Conversion factor was used to determine the P concentration from PO_4. Total N was represented by the sum of inorganic nitrogen (NO_3-N, NO_2-N, and NH_3-N) and organic nitrogen (Org.N). Analysis of sulfate followed the turbidimetric method of EPA number 375.4.

The amount of N, P, and SO_4 during flooding were determined as the negative value derived from equation 2. The N, P, and SO_4 (kg/MT) were multiplied by the production of fishponds around the tbay then converted to MT.

After three to nine months of culture period (Table 1), water sampling was conducted again until December 2018 before harvest or loading of the ponds. Loading corresponds to the water from the pond systems to the river or coastal areas, which already includes the inputs of the farmers. Collection and analyses of water samples for nutrients were conducted following the procedure on the latter.

2.4. Estimation of Nutrients loaded from Aquaculture Farms to Manila Bay

2.4.1 Fishponds

The method for estimation of nutrient load per metric ton (MT) of production from pond with embankments and performed water exchange was derived from the equation according to Boyd et al. (2007):

(Equation 2)

$$Load\ X\left(\frac{kg}{MT}\right) = \frac{Q_L CX_L\ 10^{-3} - Q_F CX_F 10^{-3}}{Annual\ Production, MT}$$

Where Q_L is the volume of water loaded from the fishpond (m^3/year), CX_L is the concentration of variable X in the loaded water (g/m^3), and 10^{-3} is the factor (kg/g). Q_F is the volume of water flooded in the fishpond (m^3/year) and CX_F is the concentration of variable X in the flooded water (g/m^3).

The N, P, and SO_4 in the result of analyses were expressed as ppm or g/m^3. The volume flooded in and drained from the fishponds were determined using the following assumptions: (1) the volume of the water flooded is equal to the volume of water drained from the fishponds, (2) the whole area of fishpond is filled with water, and (3) the volume of the water

Table 1. Profile of the sampled aquaculture farms provided by the fishpond and pen/cage operators.
Dash lines indicate no fertilizer and/or feed used.

Aquaculture System	Type of Culture	Total Area (ha) (BFAR and BAS 2003)	Sampling Location	Station No.	Area (ha)	Culture period (mos)	Inputs	
							Fertilizer (kg)	Feeds (kg/ day)
Fish ponds	Extensive	7,817.69	Bulakan (Bulacan)	1	3.00	6.00	---	---
				2	1.70	4.00	25.00	---
				3	3.00	4.00	150.00	---
			Meycuayan	4	2.00	6.00	100.00	---
			Paombong	5	0.50	4.00	---	---
				6	0.50	6.00	---	---
			Abucay (Bataan)	7	0.70	4.00	50.00	---
				8	2.00	4.00	---	---
			Kawit (Cavite)	9	0.50	4.00	---	---
				10	0.08	4.00	---	---
			Noveleta	11	3.00	6.00	---	---
				12	5.00	6.00	---	---
				13	5.00	9.00	---	---
				14	3.00	6.00	---	---
			Ternate	15	0.50	6.00	---	---
			Sasmuan (Pampanga)	16	3.00	6.00	120.00	---
				17	1.50	9.00	---	---
			Masantol	18	2.00	6.00	25.00	---
				Total	36.98		470.00	---
	Semi-Intensive	21,415.30	Bulakan, (Bulacan)	19	0.80	4.00	30.00	8.00
			Malolos	20	1.50	6.00	120.00	2.00
			Paombong	21	0.80	4.00	---	1.00
			Abucay (Bataan)	22	6.00	4.00	125.00	2.00
				Total	9.10		275.00	13.00
	Intensive	7,817.69	Sasmuan (Pampanga)	23	12.00	3.00	---	139.00
				24	8.00	3.00	---	113.00
				25	7.00	3.00	---	160.00
				Total	27.00		---	412.00
Fish pens/cages	Intensive	549.00	Obando (Bulacan)	26	20.00	4.00	---	2,563.00
				27	16.00	4.00	---	5,313.00
				28	9.00	6.00	---	131.00
				29	7.00	6.00	---	1,111.00
				30	4.00	4.00	---	246.00
				31	1.50	6.00	---	83.00
				32	5.00	4.00	---	313.00
				33	14.00	4.00	---	344.00
				34	5.00	6.00	--	278.00
				35	9.00	6.00	---	278.00
				36	12.00	6.00	---	417.00
				37	20.00	6.00	---	8.00
				38	14.00	6.00	---	361.00
			Hagonoy	39	40.00	6.00	---	233.00
				40	95.00	6.00	---	2,106.00
				41	61.00	4.00	---	38,125.00
				Total	332.50		---	51,910.00

is equal to the product of length (m), width (m), and depth (m) in which area (ha) was the factor to determine the width and length while the depth was given by the fishpond operators.

2.4.2 Fish pens/cages

The estimation of nutrient load per MT of production from fish pens/cages was also derived from Boyd et al. (2007):

(Equation 3)

$$Load\ X\ \left(\frac{kg}{MT}\right) = \frac{\mathrm{FCX_F} - \mathrm{BCX_B}}{Annual\ Production,\ MT}$$

Where F is the total annual feed used (kg), CX_F is the concentration of nutrient X in feed (decimal fraction), B is the biomass (kg), and CX_B is the concentration of nutrient X in biomass (decimal fraction). The N and P in feeds were determined according to the guaranteed proximate analysis of the commercial brand and the practical diet formulation cited by Alava (2002), respectively. Nitrogen in feeds was derived from the protein content where 6.25 factor was used. Nutrients (N and P) in the cultured species were based on the food composition tables set by the DOST-FNRI (1997).

2.4.3 Total Load

The method for estimation of total nutrient load from fishponds and fish pens/cages was derived from Zhang et al. (2015):

(Equation 4) $NL_{MT} = NL \times H \times 10^{-3}$

Where NL_{MT} is the total load in MT for each nutrient, NL is the nutrient loaded in kg/MT, H is the aquaculture production (harvest) in MT annually, and 10^{-3} is the factor (MT/kg).

The production on freshwater and brackishwater fishpond in Bulacan, Pampanga, Bataan, and Cavite from PSA (2018) was used to determine the total nutrient load from fishponds. In fish pens/cages, total production was based on the actual interview and information provided by the Local Government Unit of Bulacan. Total load from aquaculture system was represented by the sum of total load from fishponds and fish pens/cages.

3. RESULTS AND DISCUSSION

3.1 N and P Inputs

Aquaculture is considered as one of the possible contributors to the water quality deterioration in Manila Bay, mainly due to the nutrient discharges. Major source of these discharges is the excessive inputs of feeds and fertilizers (Dabi and Dzorvakpor 2015; Mateo-Sagasta et al. 2017). Chatvijitkul et al. (2017) cited that 60-80% of nitrogen and phosphorus in feeds enter the culture system as wastes. These may lead to the buildup of organic wastes and dissolved nutrients in the water column, thereby polluting adjacent bodies of water (BFAR 2007). However, quality and quantity of the effluent still vary in response to several factors including production system, and physical and nutritional characteristics of the feeds used (Shipton and Hecht 2013).

The provinces surrounding the bay constitute high aquaculture production in the country (PSA 2018). This significantly contributes in meeting the countries fish supply and demand security yearly. However, such level of production includes several inputs, which considered as the basic needs of an aquaculture system (FAO 2007). Table 2 showed

Table 2. Annual input of N and P from fertilizer and feeds applied in fishponds and fish pen/cages.

Aquaculture Systems	Inputs(MT)			
	Commercial Feeds		Commercial Fertilizer	
	N[a]	P[b]	N	P
Extensive Fishponds	--	--	38.34	1.91
Semi-intensive Fishponds	244.28	35.47	27.77	14.12
Intensive Fishponds	532.81	97.58	--	--
Fish pens/cages	32,530.62	5,955.66	--	--
Total	33,307.71	6,088.71	66.11	16.03

[a]Nitrogen content was obtained from the protein composition of the commercial feeds used
[b]Phosphorus content was acquired using the diet formulation cited by Alava (2002).

the annual nutrient input of commercial feeds and fertilizers applied by the farmers. Fish pens/cages had the highest N and P input, which were mainly due to the application of commercial feeds. It constituted 98% of the total annual input of both N and from feeds. This entails that fish pens/cages completely rely on feeds as food for the cultured species. According to Vista et al. (2006), feed costs constitute the largest share of production expense in aquaculture farms. FAO (2007) also added that feeds will continue to dominate aquaculture needs. On the other hand, farmers in semi-intensive and extensive fishponds have lesser inputs (Mondal et al. 2012). Approximately 0.73% N and 0.58% P from the annual feed input were recorded in semi-intensive fishponds. The latter also accounted 42% N and 88% P inputs from fertilizer. Extensive culture system contributed 58% N and 12% P, which is mainly from fertilizers. Anras et al. (2010) and Boyd et al. (2007) stated that both extensive and semi-intensive systems contribute to the preservation of natural wetlands in coastal areas. In terms of nutrient efficiency, semi-intensive is slightly superior compared to intensive system.

3.2 Estimated inputs of N, P, and SO_4 during flooding and loading

Levels of nutrients in fishponds can also be attributed to the river tributaries containing wastes that essentially doubled the amount of nitrogen in the river (Aloe et al. 2014; Sotto et al. 2015). Such wastes were generated from the anthropogenic activities such as sewage, garbage disposal, industry, and agriculture (croplands, livestock and poultry, and aquaculture) (BSWM 2012; Aloe et al. 2014; Sotto et al. 2015; Opinion and Raña 2016). Major contribution was from the point sources such as domestic wastes (Morée et al. 2013; Boyd et al. 2007). This supports the result of an estimated N that was flooded in the fishponds, which is four times higher than the N during loading (Table 3). Hypothetically, the amount of N and P during loading in fishponds should be comparable to flooding assuming 100% utilization of inputs, such as fertilizers and feeds. On the other hand, excessive application of inputs and/or poor utilization by cultured species could lead to elevated levels of N and P during loading. Thus, the reduction of N during loading, as shown in Figure 2, signifies that N from feeds and fertilizers was efficiently converted to fish biomass, leached to sediments or consumed by the algae rather than excreted as waste. However, amount of P loaded from the fishponds had increased by 35.00% (Figure 2). Lazzari and Baldisserotto (2008) mentioned that 69%-86% of the dietary P in commercial feed is excreted in the effluents and the dietary composition affects P retention in cultured

Table 3. Annual amount of nutrients: flooded in fishponds (A), loaded from fishponds (B), and loaded from fish pens/cages (C)

Sources	Nutrients	Nutrient Load kg/MT	Total Nutrient Load (MT)
A	NH_3-N	3.65 ± 3.52	(total N) 6,318.39
	NO_3-N	2.09 ± 2.68	
	NO_2-N	0.13 ± 0.20	
	Org.N	25.92 ± 35.35	
	P	0.45 ± 0.62	88.47
	SO_4	10,957.52 ± 14,181.89	2,177,467.00
B	NH_3-N	3.78 ± 3.75	(total N) 1,578.33
	NO_3-N	0	
	NO_2-N	0.37 ± 0.31	
	Org.N	3.80 ± 3.43	
	P	1.62 ± 1.88	321.73
	SO_4	185.78 ± 132.89	36,917.54
C	N	4308.63	11,118.33
	P	791.05	2,041.28
Total N and P load (B + C)	N		**12,696.66**
	P		**2,363.01**

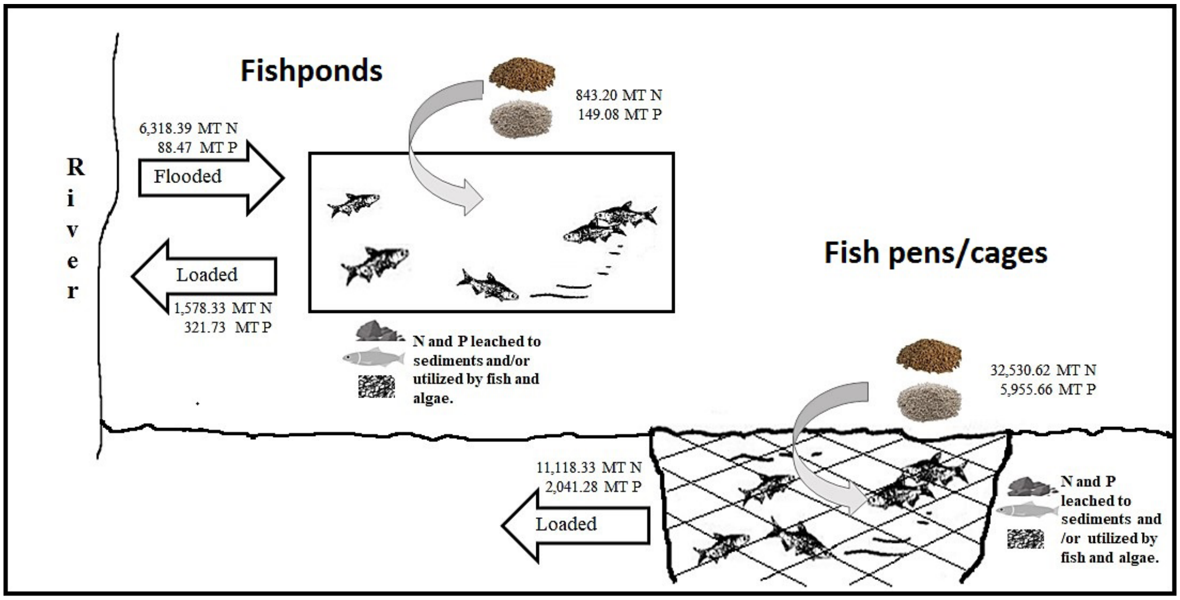

Figure 2. Summary of the annual estimation of N and P inputs flooded in and loaded from fishponds and pens/cages surrounding Manila Bay.

species. The P excretion of fish is unavoidable and occurred even at zero intake of P (Rodehutscord et al. 2000). Moreover, Opinion et al. (2016) claimed that P from uneaten feeds and metabolic wastes of cultured species deposited into sediments possibly contributes to the increase of P discharge during draining from the fishponds. On the other hand, level of sulfates during loading was reduced by 98% compared to flooding (Table 3). This can be attributed to semi-intensive and extensive fishponds surrounding the bay as Bergheim and Brinker (2003) and Turcios and Papenbrock (2014) claimed that combination of fish and photosynthetic species in a culture facility significantly reduced the nutrients or pollution. Metaxa et al. (2006) also mentioned that using high rate algal ponds can improve effluent quality.

Conversely, N and P loaded from fish pens/cages were higher by seven and six times, respectively, than that of the fishponds (Table 3). This result was supported by the claim of Islam (2005) and Boyd et al. (2007) that open culture system has greater potential for causing pollution than pond system. It can be due to the direct release of uneaten feeds into the bodies of water (Boyd 2001). Reduction of effluents relies almost entirely on developing improved feeds and feeding practices (Boyd et al. 2007).

3.3 Total Nutrient Load from Fishponds and Fish Pens/Cages

The annual estimated N and P loaded from aquaculture farms were 12,696.66 MT and 2,363.01 MT, respectively (Table 3). Fish pens/cages recorded the highest contribution accounting for 88% N and 86% P of the total load. Moreover, fishponds only contributed 12% N and 14% P of the total load.

Aquaculture has less relative contribution of nutrients compared to crops and livestock (Mateo-Sagasta et al. 2017). The results of this study substantiated the claim since the total N loading from the crops surrounding the bay was estimated at 26,491.00 MT (BSWM 2012). It was 109% higher compared to the 12,696.66 MT N (Table 3) loaded from the aquaculture farms to the bay. Similar result was obtained by Zhang et al. (2015), wherein total N loaded from aquaculture was lower than the N discharged from croplands in China. The latter is one of the few available studies of nutrient loading from aquaculture farms in Asia where nutrient discharge was defined as per unit of aquaculture production. The total N from fishponds estimated at 7.95 kg/MT (Table 3) was within the range of nitrogen discharge rate (5.40 kg/MT-35.70 kg/MT) from fishponds as per Zhang et al. (2015). De Silva et al. (2010) also cited that N load ranges from 30.90 kg/MT to 160 kg/MT. It is higher than the actual load of nitrogen on this study, but Verdegem (2013) indicated that nutrient loading from ponds differ by a factor up to 10 depending on the production systems. Furthermore, the total N loaded from fishponds is three folds lesser than the nutrients from domestic (46,700 MT) estimated by Sotto et al. (2015). The estimation of the latter was based on the density of the population in the surrounding provinces in Manila Bay.

4. CONCLUSION

The estimated annual N and P loading from aquaculture farms surrounding Manila Bay were 12,696.66 MT and 2,363.01 MT, respectively. Highest nutrient load was recorded in fish pens/cages accounting for 88% N and 86% P of the total load. It can be attributed to the direct release of uneaten feeds to the bodies of water. Roughly 12% N and 14% P were discharged from fishponds. Furthermore, the annual SO_4 loading from fishponds was estimated at 36,917.54 MT. This study, however, does not address the fate of N and P after they were loaded from the aquaculture system. Extensive monitoring of the environmental impacts and annual loading is recommended for crafting of appropriate policies and management practices to reduce nutrient load and improve the aquaculture production as well.

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