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EFFECTS OF FISH FARMING ON SEDIMENT, WATER QUALITY AND PLANKTON COMMUNITIES IN BAROBO COASTAL WATERS IN LIANGA BAY, SURIGAO DEL SUR, PHILIPPINES

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Abstract: The study was conducted to establish the effect of fish farming on plankton communities, water quality and sediment in Barobo Coastal Waters in Lianga Bay Philippines. Plankton, water, and sediment samples were collected during northeast monsoon period (November, December, and February) within the fish farms; transition zone (in-between fish farm and outside) and outside the mariculture zone. Two stations were established per zone. Results showed that a total of 245 taxa, 66 genera and 90,532 individuals of phytoplankton, while zooplankton had 306 taxa, 192 genera and 10,984 individuals were recorded across sampling stations for the entire sampling periods. There were no significant differences except for abundance/richness noted on the diversity of both phytoplankton and zooplankton communities between stations indicating that mariculture activities have no effects on the plankton communities. For the water quality parameters, water temperature, salinity, ammoniacalN, dissolved organic phosphorous and potassium did not vary significantly ($p>0.05$) while pH, transparency, velocity, DO and TSS vary significantly ($p<0.05$) between the stations. For the sediments, only N2 ($p=0.051$) showed no significant difference while the rest of the parameters such as pH ($p<0.000$), texture ($p<0.000$), Organic Matter % ($p<0.000$), available P ($p<0.000$) and extractable K ($p<0.000$) showed significant differences between stations. Most of the physicochemical parameters of water and sediments were significantly higher than the transition and outside mariculture zones which indicates that the water and sediment quality measured within the fish farm area were deteriorating. This finding may also imply that transition and outside mariculture zone has not yet affected by the fish farming activities. Despite the low degree of impact detected within the mariculture zone, the organic matter carrying capacity should be carefully determined to avoid environmental drawbacks, thus regular monitoring on the sediment and water quality is recommended.

Keywords: fish farms, mariculture, physicochemical parameters, plankton

Introduction

With available land and freshwater becoming scarce, marine aquaculture (finfish, shellfish, and seaweeds) will be an increasingly important contributor to the world's future seafoods supply (FAO 2012; World Bank 2013). In the Philippines particularly in Surigao del Sur, Barobo Lianga Bay is one of an important coastal zones in the Caraga region contributing 1.2% to the country's Milkfish production (PSA 2020). For the last 12 years, Milkfish were the main fish species cultured in fish cages and fish pens in the area. Recently, Jackfish species or commonly known as jacks, trevallies and

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kingfishes have been cultured alternately with and adjacent to milkfish fixed offshore fish cages and fish pens in a 160-hectare mariculture zone in the coastal waters of Barobo Lianga Bay. Milkfish are fed with commercial feeds, while Jackfish are fed with trash fish sourced from local markets. The Barobo Coastal Waters is a semi-enclosed embayment where fish farming activities are apparent and continually expanding since it started in 2010. While marine aquaculture has grown rapidly, so have concerns regarding the environmental impacts caused by the industry. It is well known that fish farming releases a substantial amount of nutrients into the marine environment in the forms of excess feeds, fish feces and sewage (Holby and Hall 1991; Nash 2001; Pawar, et al. 2002; Hall, et al. 2008). Continued inputs of nutrients from fish farming activities usually result environmental changes that significantly alter planktonic and benthic communities (Wu 1995; Fernandes, et al. 2001; Katranidis, et al. 2003). Fish farming wastes contribute to dissolved N and P but not to silica, thereby creating conditions favoring the growth of certain phytoplankton groups, such as flagellates or cyanobacteria (Villa, et al. 2008; San Diego-McGlone, et al. 2008; Matijevic, et al. 2008; Yucel-Gier, et al. 2008; Wang, et al. 2009; SkejicŁ, et al. 2011) instead of the silicon (Si)-limited diatoms which form part of the classical food web, channeling energy towards higher trophic levels (including fish). Where several fish farms are situated in close proximity, the increased nutrient levels may lead to algal blooms and the depletion of oxygen (Pillay 1992). The study will determine the impact of aquaculture particularly fish farming in Barobo Coastal Waters in Lianga Bay. Presently, there is a scarce documentation and no regular monitoring as to the status of plankton communities and quality of water and sediment in the area, hence this study is conducted in order to contribute towards a better understanding of the impacts of fish farming to plankton abundance and the physical and chemical parameters of the water and sediment in typical mariculture areas of Barobo coastal waters. With the expanding mariculture zone particularly fish pens at the coastal areas of Barobo, accumulation of residues from fish feeds and fish feces and wastes generated from related fish farming activities will be apparent particularly at the sediment. Results of this study will also contribute to the future assessment and determination on the level of wastes accumulated at the sediment that can be assimilated without causing significant impact to the water parameters and planktonic abundance which in turn cause algal blooms that can likewise affect metabolic and respiratory processes of farmed fish (e.g. reduction of oxygen and elevated water surface temperature).

Methods

The sampling areas were divided in to three (3) sites. Experimental Site which is composed of two stations E1-1 under 4 cages with Milkfish and E1-2 under 4 cages with Jackfish; between Experimental and Reference Sites which more than one km. southeast from Experimental Site and around 3 km. northeast to Reference site with stations B1-3 and B2-4; and Reference Site under reference stations of R1-5 and R2-6 around 4 km. eastward from the mariculture zone which is distant and outside fish farming activities. Measurements and samplings of physicochemical and biological parameters was conducted in once a month in November 2020 and February 2021 at both fish pens of Milkfish and Jackfish.

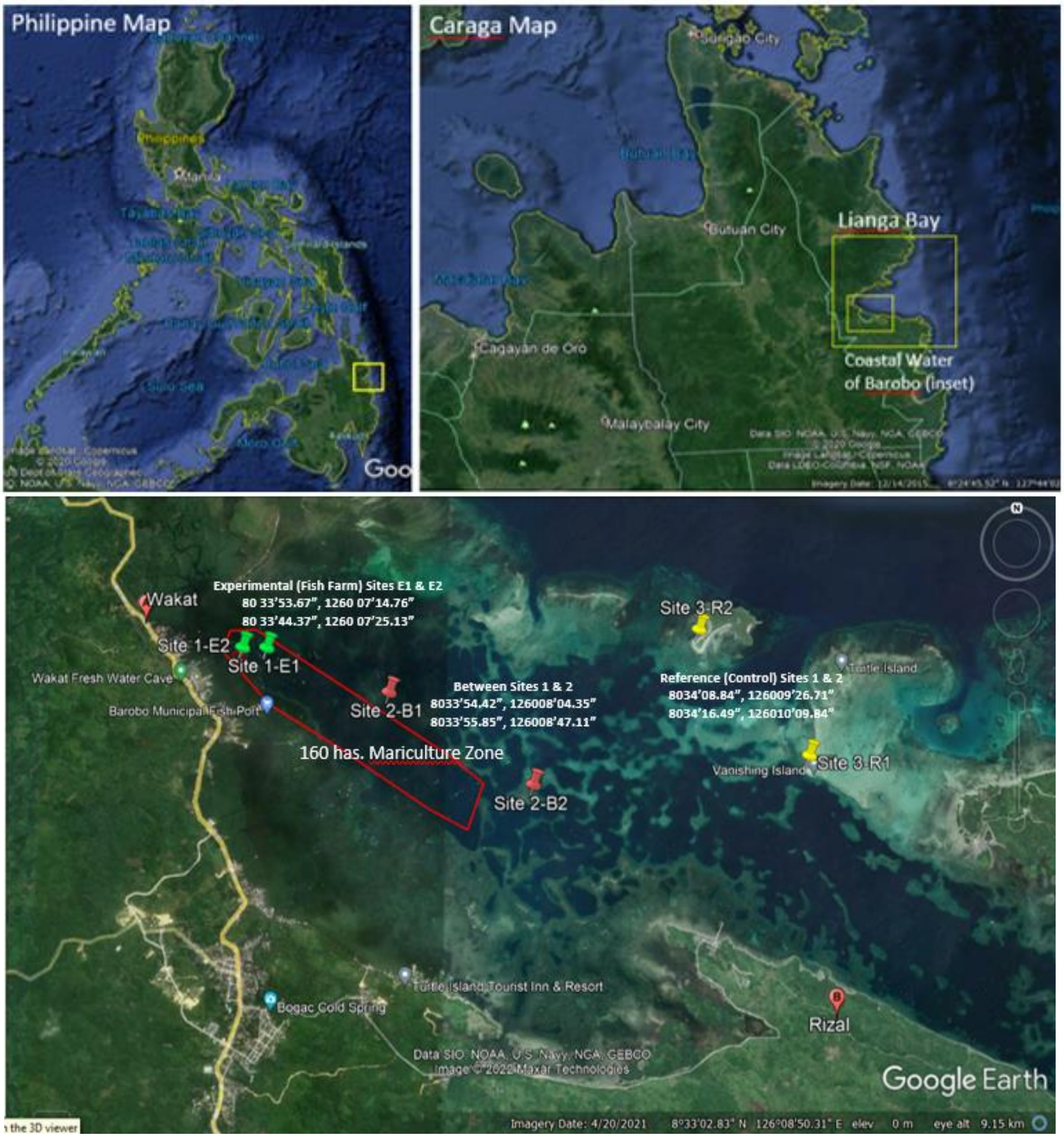

Figure 1. Map of Lianga Bay showing the study area.

Measurements of Physicochemical Parameters of Water

Physicochemical parameters were determined by the specific instruments to provide necessary readings. Water temperature, salinity, Dissolved Oxygen (DO) and pH were measured in-situ using multi-parameter water tester. Water transparency was determined using a Secchi disc. Total Suspended Solids (TSS) was measured using the gravitational filtration set-up. Surface water movement (based on current speed and direction) was measured using an improvised weighted current drogue. Drifting detritus (seaweed, wood chips, etc.) in the water were examined to determine the direction of the flow of the surface current. This direction was measured with the marine compass.

Water Nutrient Analysis

Water samples for the analysis of nutrients (AmmoniacalN, Dissolved Organic Phosphorus and Potassium) were taken on monthly basis for 3 months using a water sampler. Samples were collected for surface, mid, and bottom (about 0.4 m above, bottom and below the surface water) and mixed over the water column to make a composite sample per each sampling location. Samples were preserved on ice in an insulated container prior to analysis in the laboratory. Standard methods used to analyze key nutrients; Dissolved Organic Phosphorus (DOP) was analyzed by Vanadomolybdate method, ammoniacalN (NH3-N) by steam distillation method and Potassium (K) by visible spectrophotometer method. Concentrations of these nutrients were determined by spectrophotometry.

Biological Parameters

Water samples for biological parameters were collected at daytime (7 am to 5 pm) observing vertical sampling method in each replicate of the study area. A conical plankton net (length: 0.45 m; mouth diameter: 0.21 m; mesh was used to collect samples at the cod-end and transferred into a 250 ml. labelled plastic sampling bottle. A few drops (5 mL) of 70% ethyl alcohol were added to preserve the samples. Four (4) replicate samples were collected in each sampling station. Prior to laboratory analysis, all collected samples were stored in a cool environment (4 °C) to preserve the specimen.

Sediment Collection and Physicochemical Analysis

Nutrient quality parameters of sediments were measured based on FAO 2012 standard. Sediment samples were collected by experienced divers using plastic tubes which were inserted into the sediment to preserve an undisturbed core. Plastic rubber stoppers were used to close the top and the bottom of each sample. Samples were preserved in ice and placed in an insulated container upon transport to the laboratory for analysus. pH was determined using pH/EC meter using 1:1 soil: water (weight by volume). Available phosphorus concentrations were measured through Olsen method, potassium through Cold Sulfuric Acid Method and texture through Feel Method. Sediment organic carbon/matter was determined using Walkley-Black Method and total nitrogen contents were determined colorimetrically on an AutoAnalyzer-3 according to Regular Kjeldahl Method (SSSA 1996) of Integrated Laboratory, Department of Agriculture-Caraga.

Phytoplankton Analysis

A calibrated pipette was used to obtain one (1) ml subsample from the 50 ml sample volume and placed into the Sedgewick rafter counting cell (depth: 1 mm: length: 50 mm; width: 20 mm; area: 1000 mm; volume: 1 ml). Phytoplankton individuals or species encountered were examined under the inverted microscope (ULWCD 0.30, Olympus CK2) and identified and counted. Three (3) 1-ml subsamples were analyzed and then the average is computed. The cell abundance of each phytoplankton species are calculated using the formula of (Sournia 1978; Carmelo 1997; Parsons, et al. 1984; Gonzalez, et al. 2004; Moncheva 2010). Phytoplankton were identified up to the species level (Verlecar and Desai 2004). Abundance in cells per ml. is the number of cells per ml divided by the number of subsamples.

Zooplankton Analysis

Zooplankton samples were collected in monthly intervals for three months in the identified sampling sites. The zooplankton samples were collected at daylight hours (10.00 hours to 14.00 hours by towing a 55 millimeter mesh Hydrobios plankton net. Collected samples were immediately transferred each time to a 250 ml labelled plastic container with screw cap. Ten samples were collected from the site and then preserved with 70% ethyl alcohol prior to microscopic analysis (Yigit, et al. 2006; Kolo, et al. 2010) at different magnifications (50, 100 and 400). Appropriate guide (ALPHA 1998) were used to aid species identification. The isolated zooplanktons were subjected to species composition and population density. Zooplankton were initially sorted into broad taxonomic groupings following Castellani and Edwards (2017).

Statistical Analyses

Difference on the physicochemical parameters of water and plankton abundance between the two fish cages and between fish farm areas (experimental sites) and areas distant/outside farming activities (between control and experimental sites and reference sites) were determined using one-way ANOVA. Statistical analysis was performed using SSP software in the determination of significant difference of the variables using a significant level of 5%. Diversity indices of phytoplankton and zooplankton were computed for each sampling station using Paleontological Statistics PAST software in order to determine changes in the plankton composition. Seriation was also used to determine the graphical structure of the communities of phytoplankton in 6 sampling stations.

Results

Physicochemical Parameters of Water

Presented in Table 1 are the mean results of the physicochemical parameters of water from the 6 sampling stations. Ten (10) water quality parameters were summarized as mean values of the three sampling months.

Table 1. Mean results of water physicochemical parameters

	Water Physicochemical Parameters									
Station Code/Label	**Temperature (^{0}C)**	**pH**	**Salinity (mgL^{-1})**	**Transparency (m)**	**Velocity (ms^{-1})**	**DO (mgL^{-1})**	**TSS (mgL^{-1})**	**NH_3-N (mgL^{-1})**	**DOP (mgL^{-1})**	**K (mgL^{-1})**
S1-E1-1/Milkfishcage	30.78[a]	8.08[c]	32.58[a]	8.00[a]	0.07[c]	6.99[d]	53.31[a]	2.77[a]	0.02[a]	374.67[a]
S2- E2-2/*Jack*fishcage	31.00[a]	8.10[b]	32.96[a]	1.83[bc]	0.08[b]	7.11[d]	52.93[a]	3.08[a]	0.01[a]	457.67[a]
S3- B1-3	30.33[a]	8.09[bc]	32.78[a]	1.00[c]	0.15[a]	7.30[c]	39.14[b]	.	0.13[a]	382.33[a]
S4- B2-4	30.11[a]	8.08[c]	32.83[a]	3.00[b]	0.06[c]	7.32[c]	37.34[b]	.	0.13[a]	384.33[a]
S5-R1-5	30.28[a]	8.05[d]	32.83[a]	0.97[c]	0.13[ab]	8.23[a]	38.52[b]	.	0.13[a]	318.33[a]
S6- R2-6	30.06[a]	8.13[a]	32.72[a]	2.97[b]	0.07[b]	7.94[b]	38.67[b]	1.69[a]	.[b]	399.00[a]

Note: Numbers in a column with different letters denote significant difference

The mean for three months sampling for water temperature, salinity, ammonia-nitrogen, DOP and K did not vary significantly ($p>0.05$) while pH, transparency, velocity, DO and TSS showed significant variations ($p<0.05$) between the 6 stations (Table 1). The temporal (every month between the 6 stations) and spatial (per station between months) variations in the physicochemical water quality parameters are presented in Figure 2.

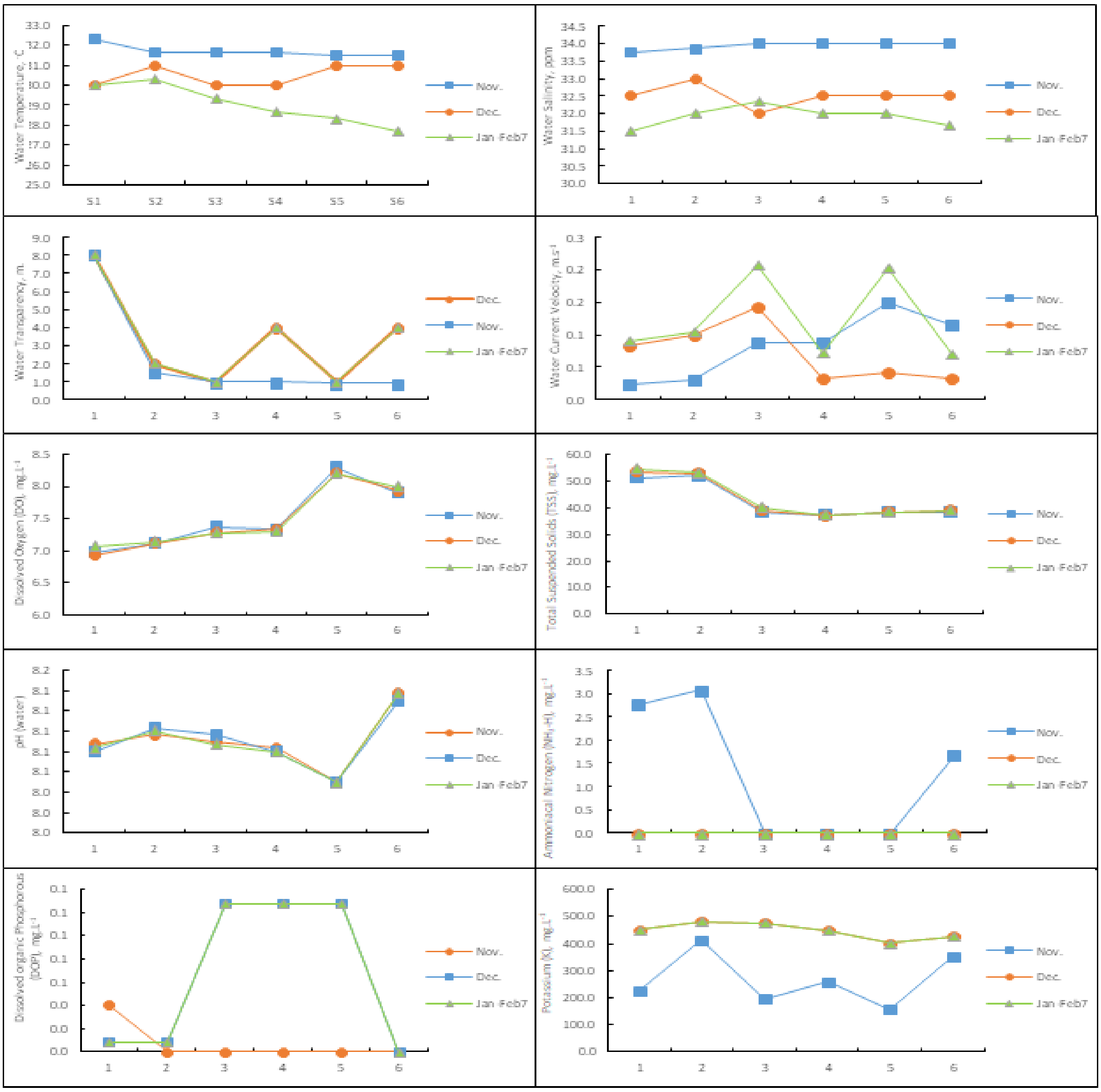

Figure 2. Spatial and temporal variations of the physicochemical parameters of water in three months sampling period

The temperature reading showed a narrow variation in the month of December with a range from 30.0 ºC to 31.0 ºC with no significant difference between stations. The lowest recorded temperature was in the month of February that ranged from 27.67 ºC to 30.33 ºC with significant difference between stations. Recorded temperature in every station also showed significant difference between months (temporal) except Station 2 (E2-2) in Jack fish pens sites. While in monthly basis (Nov. 2020 to February 2021), only in February that temperature showed significant variations between the 6 stations (spatial) (Figure 2). The means of the temperature in three months' period also showed no significant difference between the 6 stations (Table 1).

Salinity shows very little variability throughout the sampling campaigns, varying from a minimum station average of 32.58mg L^{-1} to a maximum of only 32.96mg L^{-1}. Mean results of salinity also showed no significant difference between the 6 sampling stations. Temporally, salinity showed significant variations ($p<0.05$) between months in each of the 6 sampling stations. In spatial basis, only in the month of February showed no significant difference ($p>0.05$) between stations.

Water transparency in Station 1 (E1-1-Milkfish fish pen) showed significant difference with the rest of the stations while Station 2 (E2-2 (Jack fish pen), Station 4 (B2-4), one station in between experimental site and reference site and Station 6 (R2-6) - one station in Reference site also differs with Stations 3 (B1-3) and Station 5 (R1-5). Hence, water transparency in two stations in each of the three sampling sites significantly differs with one another. Station 1 (E1-1/Milkfish fish pen) showed to have the highest water transparency of 8 meters which is also observed to be the entire water depth/column of the station (Table 1). Water transparency has significant variations between months in sampling stations 4 and 6 while the water transparency for the rest of the stations have no significant difference between the three months sampling periods.

Water Velocity in 6 sampling stations showed the highest (0.14 m s^{-1}) in sampling Station 3 (B1-3), which showed significant difference with the rest of the stations except Station 5 (R1-5) which is also noted to have the next highest water velocity of 0.13 m s^{-1}. Likewise, Station 5 (R1-5) showed significant difference with the rest of the stations except Station 2 (E2-2) and Station 6 (R2-6). This means that higher water velocity is reported outside the experimental (Milkfish and Jack fish pens) sites (Table 1 and Figure 2).

Dissolved Oxygen (DO) of 8.23 mg L^{-1} and 7.94mg L^{-1} among the sampling stations is noted in Reference sites in Station 5 (R1-5) and Station 6 (R2-6), respectively which showed significant difference with the rest of the stations. Experimental site, Station 1 (E1-1) and Station 2 (E2-2) also showed significant difference with stations between Station 3 (B1-3) and Station 4 (B2-4) - experimental and reference sites with the latter noted to have the lowest two DO of 6.99 mg L^{-1} and 7.11 mg L^{-1}, respectively (Table 1). DO in every station have no significant variations between months but have significant difference between stations in monthly basis. The highest DO was noted in the month of November in Station 5 and lowest in the month of December in Station 1 (Figure 2).

Total suspended solids (TSS) in Station 1 (E1-1) and Station 2-E2-2 showed significant difference with the rest of the stations in between (B1-3 and B2-4) and Reference sites (R1-5 and R2-6). Experimental sites (E1-1 and E2-2) showed to have the highest TSS at 53.31 mg L^{-1} and 52.93 mg L^{-1}, respectively while the rest of the stations noted to have lower results of over 30mgL- TSS in each station (Table 1). TSS in every station had no significant variation between months where February had the highest reading in Station 1 and also the lowest in Station 6 (Figure 2).

pH mean results showed the highest in the Reference site R2-6 (8.13) and significantly differed with the rest of the stations. The results are slightly basic or above neutral (pH 7) as all of the results is more than pH of 8. Both stations in Reference site R2-6 and R1-5 have the highest and lowest pH of 8.13>8.05, respectively. Second highest pH is reported at E2-2/Jack fish pen station of 8.10 which showed significant difference with E1-1/Milkfish fish pen and B2-4 except with site B1-3. The lowest reading was in Station 5 (R1-5) of 8.05 (Table 1). There was no significant difference of pH between months in each of the 6 stations (Figure 2).

AmmoniaCal nitrogen (NH3-N) is noted the highest at E2-2/Jack fish pen (3.08mgL^{-1}) followed by E1-1/Milkfish fish pen (2.77mgL^{-1}) and Reference site station, R2-6 (1.6mgL^{-1}) while the rest of the stations showed a Below Detection Limit (BDL) results with no significant difference between stations (Table 1). Only in the month of November where reading of NH3-N was observed in Stations 1, 2 and 6 while BDL in the months of December and February in Stations 3, 4 and 5 (Figure 2).

Dissolved Organic Phosphorous (DOP) showed the highest in Experimental site E1-1 (0.0187mgL^{-1}) while Below Detection Level (BDL) in Reference site station R2-6, which showed significant difference with the rest of the stations. DOP reading in Experimental site E1-1 showed no significant difference with Stations 2,3,4,5 (E2-2, B1-3, B2-4, R1-5) which showed to have uniform trace amount of DOP at -332.99 mgL^{-1} (Table 1). DOP concentrations were not significantly different between months among stations (Figure 2). The highest reading of DOP reported at E1-1/Milkfish fish pen (0.0187 mgL^{-1}).

Potassium (K) showed the highest mean reading in all sampling periods in E2-2/Jack fish pen of 457.67 mgL^{-1} and lowest (318.33 mgL^{-1}) at Reference site R1-5 with no significant difference between the 6 sampling stations (Table 1). In monthly bases, K concentration showed the highest in the month of December and February with no significant difference between these months, while lowest in the month of November with significant difference compared to the latter months (Figure 2).

Physicochemical Parameters of Sediment

The means of the physicochemical parameters of sediments collected in 3 months' period are presented in Table 5. Results show that the highest in terms of the pH of sediment is noted in Station 6 (8.80), while texture (2.0), Organic Matter (OM) (5.98%), nitrogen (N_2) (0.32%), available P (39.11ppm), and extractable K (733.67ppm) are all observed in Station 2. Of all the mean values of these physicochemical parameters of sediments, only N_2 had no significant difference ($p>0.05$) between stations (Table 5).

Table 2. Mean results of sediment physicochemical parameters

Sampling Sites	pH	Texture	%OM	Total N_2 %	Available P (ppm)	Extractable K (ppm)
S1- E1-Milkfish fish pen	7.76^{c}	2.00^{a}	4.62^{a}	0.28^{a}	28.67^{a}	414.56^{b}
S2- E2-*Jack* fish pen	7.73^{c}	1.89^{a}	5.98^{a}	0.32^{a}	39.11^{a}	733.67^{a}
S3- B1-past Gusoan	8.43^{b}	1.00^{b}	0.53^{b}	0.03^{a}	28.89^{a}	241.56^{bc}
S4- B2-/near Sanctuary	8.68^{ab}	1.00^{b}	0.34^{b}	0.11^{a}	12.89^{b}	154.78^{c}
S5- R1-/near Vanishing	8.69^{ab}	1.00^{b}	0.36^{b}	0.02^{a}	12.22^{b}	137.33^{c}
S6- R2-/near Cabgan	8.80^{a}	1.00^{b}	0.31^{b}	0.01^{a}	10.11^{b}	148.44^{c}

Note: Numbers in a column with different letters denote significant difference

The spatial and temporal comparisons of the physicochemical parameters of sediments are presented in Figures 3 to 8.

pH in sediments for the month of November had significant difference between stations, where the highest (8.80) was recorded in Station 6 and the lowest (7.50) was in Station 2. In December, the highest pH (8.86) was observed in Station 6 and the lowest (7.61) in Station 2 with significant variations between stations. pH varied significantly in the month of February where the highest (8.67) was noted in Station 4 and the lowest (7.60) in Station 2 (Figure 3). Generally, pH values showed an increasing trend with distance from the fish farm (Stations 1 to Station 6) ranging from 7.5 to 8.97 and a decreasing trend from November to February ranging from 8.42 to 8.25 (Figure 3).

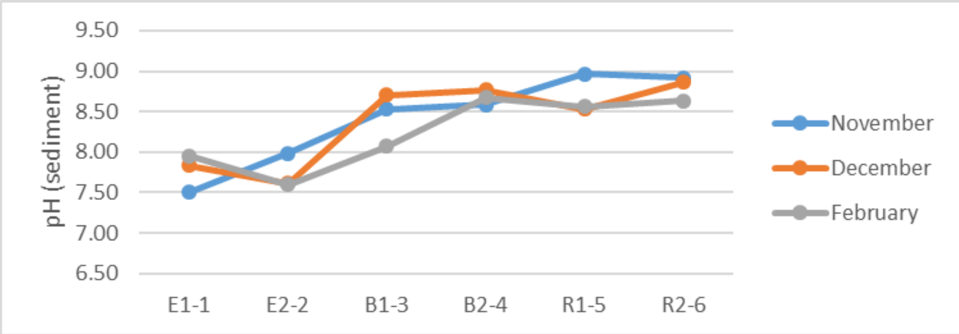

Figure 3. Spatial and Temporal pH readings in sediments.

Sediment texture in Experimental site (Stations 1 and 2) have relatively homogenous mean results of 2.00 and 1.8, categorized as medium respectively, but showed significant difference with the rest of the stations which have uniform texture of 1.00 qualitatively described as light texture. In terms of qualitative description of the sediment texture, number 3 denotes heavy texture, 2, medium texture and 1, light texture. Results in Figure 4 show a decreasing trend of the textures of sediments in relation to the distance from fish farms. Temporally, the trend of the textures in fish farm station 1 was decreasing but the trend in fish farm station 2 was generally increasing while the rest of the stations remained the same (Figure 4).

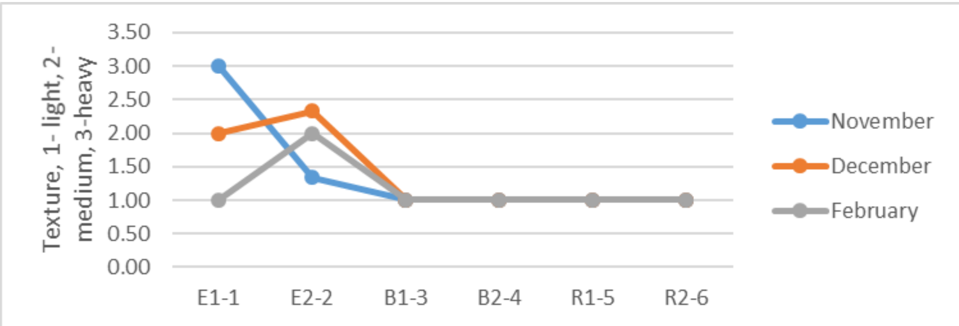

Figure 4. Spatial and Temporal texture readings in sediments.

Percent Organic Matter (%OM) in sediment also showed similar pattern with the sediment texture (Figure 5). Experimental site S1 and S2 showed to have the highest %OM with the mean results of 4.62 and 5.98, respectively and significantly differs with the rest of the stations. Spatially, the trends of the percent organic matter of the 6 sampling stations have S2>S1>S3>S5>S4>S6. Temporally, it is noted in the results that the trends are increasing in Station 2 and decreasing in Station 1, while no observed changes in the trends in Stations 3, 4, 5 and 6. The reference and in between stations had a consistent trends of OM content compared to the varied trends in experimental of fish farming stations (Figure 5). The highest OM content was in February (7.5%) in Station 2 and the lowest (0.30%) in November, December and February in Stations 4, 5 and 6 (Figure 5).

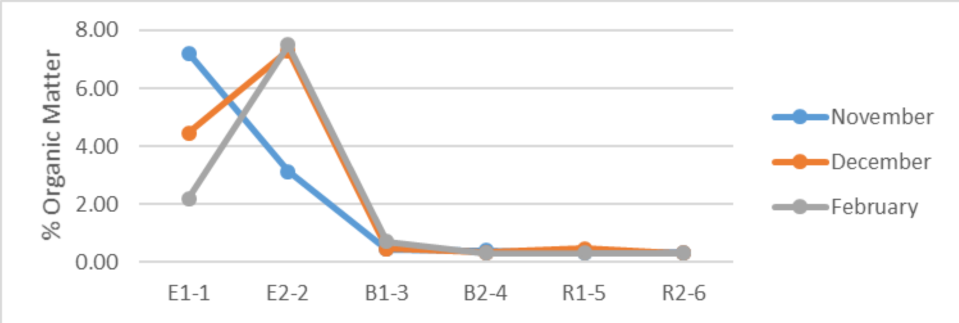

Figure 5. Spatial and Temporal % Organic Matter readings in sediments.

On the other hand, total nitrogen (%) in the sediments showed varied trends spatially and temporally. Results in Figure 7 show the highest temporal dynamics of OM content was recorded in the month of December. The highest OM content (0.44%) was recorded in both Stations 1 and 2 under the fish farms in the experimental site, while the lowest was in February (0.00%) in Stations 4, 5 and 6, all from the reference and in between sites from the fish farms. Station 3 showed a decreasing trend in % nitrogen from the month of November to the month of February.

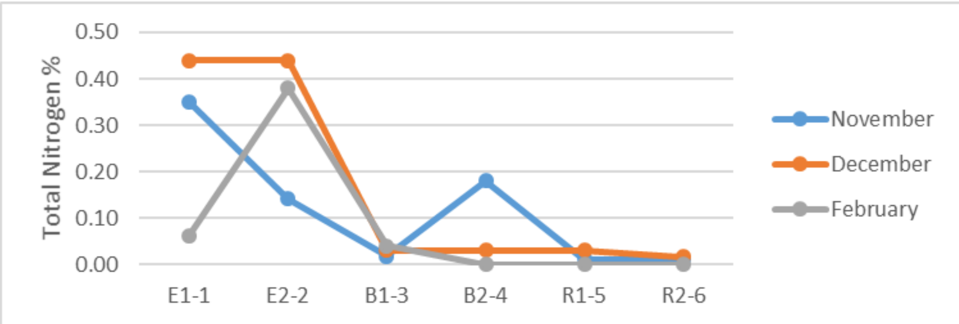

Figure 6. Spatial and Temporal % Nitrogen readings in sediments.

For the Available Phosphorous in sediments, the highest reading was noted at Jackfish fish pen (S2) with a mean result of 39.11 ppm and the lowest in Station 6 with 10.11 ppm available phosphorous. The result also for the available P in the sediments in the station 2 showed to have significant difference with the rest of the stations 4, 5 and 6 while no significant differences in Stations 1 and 3 (Table 5). Spatially, the trend of available P in sediments is S2>S3>S2>S4>S5>S6. A temporal variation of available P concentration in sediments was highest (59.33ppm) in the month of November in Station 2 and lowest (3.00 ppm) of same month in Station 5 (Figure 7).

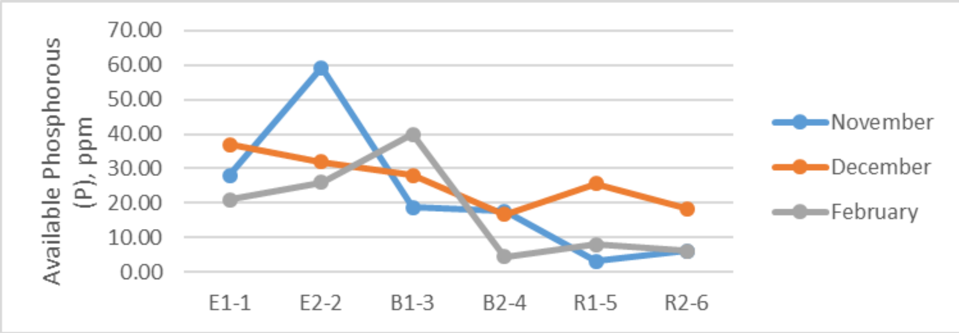

Figure 7. Spatial and Temporal Available Phosphorous readings in sediments.

Available P content in sediments of Stations 4, 5 and 6 were significantly differed with Stations 1, 2 and 3.

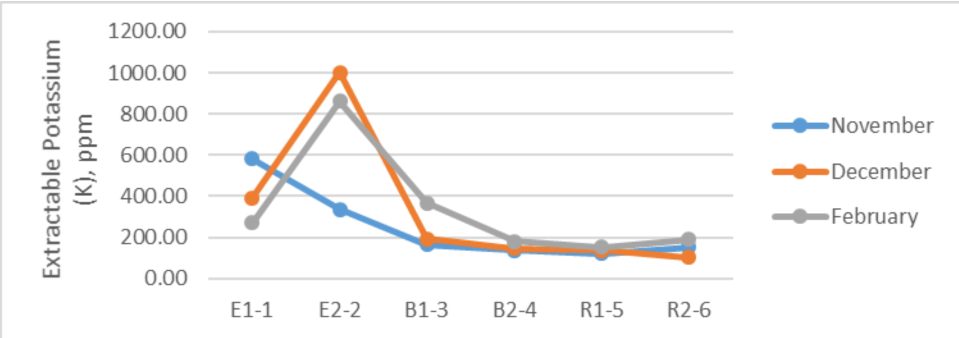

Figure 8. Spatial and Temporal Extractable Potassium readings in sediments.

Meanwhile, the highest mean results of extractable potassium in sediments among the stations is at Station 2 with 733.67 ppm reading followed by Station 1 (414.56ppm) and Station 3 (241.56ppm) (Table 5). The mean extractable K contents in fish farm stations (Stations 1and 2) had no significant difference and observed to have significant difference with Stations 3 (241.56 ppm), Station 4 (154. 78ppm), Station 6 (148.44ppm) and Station 5 (137.33 ppm). Spatially, there is a decreasing trend of the extractable K contents in sediments with the distance from fish farming activities. The trend in Station 1 was decreasing while Station 2 was increasing temporally (Figure 9).

Plankton Communities

The mean results of the phytoplankton and zooplankton counts in the 6 sampling stations from the 3 months sampling are presented in Table 3. Results showed that the highest mean in the phytoplankton counts (3,292 cells/mL) was observed in Station 4 (between the experimental and reference sites) and the lowest count (1,720 cell/mL) was in Station 4. No significant differences in the means of the phytoplankton counts in Stations 2, 5 and 6 but has significant difference in Stations 1 and 4 with both have p values of less than 0.050 (p=0.000).

Table 3. Mean results of phytoplankton and zooplankton counts in six sampling stations in three months period.

Sampling Sites	Station Code and Label	Phytoplankton (cells/mL)	Zooplankton (ind/L)
Experimental (Fish Farms) Site	**S1-E1-** Milkfish cage	1,924[c]	361[a]
	S2-E2- *Jack*fish cage	2,829[ab]	376[a]
Between Sites	**S3-B1**	3,292[a]	367[a]
	S4-B2	1,720[c]	230[b]
Reference Site (distant/far from fish farming activities)	**S5-R1**	2,737[ab]	244[b]
	S6-R2	2,586[ab]	254[b]

Note: Numbers in a column with different letters denote significant difference

On the other hand, the mean of the zooplankton counts in ind. L-1 did not go with the trend of the means of phytoplankton counts. Results in Table 3 on the means of zooplankton counts show that Station 2 has the highest mean (367ind. L^{-1}) and the lowest is in Station 5 (244 ind. L^{-1}). No significant differences were noted in the means of the zooplankton counts between Stations 1, 2 and 3 and between Stations 4, 5 and 6. However, significant differences were observed in the later Stations 1, 2 and 3 compared to Stations 4, 5 and 6 (Table 3).

Diversity of Phytoplankton and Zooplankton

Results in Table 4 show the diversity indices of phytoplankton. The highest number of taxa (244) was in Station 4 (Sanctuary) while the lowest (215) was in S1-Milkfish fish pen. Considering the other biodiversity indices such as Shannon_H, Simpson_1-D and evenness, it can be noted that S1 has the lowest value which means that it has the lowest diversity while the highest is at S3-B1-3. The highest diversity was noted in Station 3 with a Shannon_H value of 5.273 and the lowest (4.847) was in Station 1 which is confirmed with the values in Simpson_1-D. This is also true with the Dominance index which is inversely proportional to other diversity indices, where S1-E1-1 has the highest dominance value which means that there is a species or taxa that has the highest number of individuals dominating in the area.

Table 4. Diversity indices of Phytoplankton

Stations and Label	Taxa_S	Individuals	Dominance_D	Shannon_H	Simpson_1-D	Evenness_e^H/S
S1 E 1-1	215	11,541	0.01068	4.847	0.9893	0.5926
S2 E2-2	232	16,972	0.006491	5.19	0.9935	0.7736
S3 B1-3	237	19,760	0.005765	5.273	0.9942	0.8226
S4 B2-4	244	10,324	0.007141	5.167	0.9929	0.7187
S5 R1-5	227	16,419	0.007259	5.103	0.9927	0.7249
S6 R2-6	241	15,516	0.006987	5.154	0.993	0.718

Results in Table 8 show that the fish pens stations 1 and 2 have the highest number of zooplankton taxa in which both have 305, and the lowest is in Station 6 with 302 number of taxa. The highest number of individuals is at Station 2 (2,252) followed by Station 3-near Station 3 (2,203) and Station 1-Milkfish fish pen (2,164), while the lowest number of individuals is noted at Station 4-near Fish sanctuary with 1,379 number of individuals. Stations 3 and 4 have both the lowest and highest dominance index, respectively. Shannon_H and evenness is the highest at Station 3 while the lowest is at Station 1, however it is noted that the diversity of zooplankton based on the Shannon_H values did not differ significantly.

Table 5. Diversity indices of Zooplankton

Stations and Label	Taxa_S	Individuals	Dominance_D	Shannon_H	Simpson_1-D	Evenness_e^H/S
S1 E 1-1	305	2,164	0.005889	5.405	0.9941	0.7292
S2 E2-2	305	2,252	0.005512	5.449	0.9945	0.7623
S3 B1-3	304	2,203	0.005230	5.485	0.9948	0.7928
S4 B2-4	303	1,379	0.006091	5.448	0.9939	0.7663
S5 R1-5	303	1,464	0.005836	5.453	0.9942	0.7704
S6 R2-6	302	1,522	0.005587	5.474	0.9944	0.7897

Discussion

Effects of Fish Farming on Physicochemical Parameters of Water

The temperature noted to have to significant difference in three months sampling period between 6 sampling stations showed that fish farming had no effect to the water temperature during the course of the study. The temperatures in all 6 stations in the present study were sufficient to the optimum temperature for the growth and food conversion of cultured fish that ranged between 26-32 °C (Kungvankij et al., 1984). Milkfish has suitable temperature range of 18 °C-30 °C, while Jack fish suits to a temperature range of 22°C-30 °C (Afonso et al., 2009 and Handeland et al., 2009) of which in the present study, the temperature readings were suitable for the growth of these two fish species. It is also noted that the mean results on temperature (30.43^0C) is slightly higher than the water quality guidelines of Class SB water ($26\text{-}30^0$C) also known as Fishery Water class II – waters suitable for commercial propagation of shellfish and intended as spawning areas for Milkfish and similar species as indicated in the DENR Administrative Order nos. 2016-08 and 2021-19.

Based on results on salinity, fish farming of milkfish and Jack species cultured at present had no effect to the parameter of water in the area. These two fish species Jack fish (Torres and Santos, 2019) and Milkfish (A'yun and Takarina, 2017) reared in the mariculture zone of Lianga Bay belong to the euryhaline group characterized to have a capability to tolerate different saline conditions.

Lowest water transparency observed in Station 5 (R1-5) of 0.97 m. was also above the maximum limit of 0.2-0.4 m (Chackroff, 1978). In the present study, fish farming did not affect the transparency of water where the two fish species were reared. Transparency of water in the 6 sampling stations had no significant difference with the depth of water during the sampling periods. This means that the depth of water in each sampling station is similar to its transparency readings. In addition, transparency of the present study is above the maximum limit which means positive effect to the organisms in the Barobo coastal waters. Transparency enables the sun rays to penetrate to a certain depth enabling photosynthetic flora to perform productive activities, which is very important in the aquatic ecosystem (Kirk, 1994).

Station 3 (B1-3) and Station 5 (R1-5) are relatively shallow stations where white sand substrates which serve as wave buffers were noted during the sampling periods, thus attributed to higher water velocity as compared to the rest of the sampling stations (Table 1 and Figure 2). The experimental sites are located in the cove of Barobo coastal water that limit its exposure to prevailing winds than the transition and reference sites hence, expected to have significant variations in terms of water velocity between stations. Water velocity which were observed towards the direction of the shores during the course of the study is influenced by prevailing wind of the area or wave action and depth of the water (Li and Hewett 2015). While velocity of water influenced the distribution of organic particles in the bodies of water (Furukawa et al., 1996 and Reynolds et al., 2016) hence, the organic particles from the fish farms are expected to have influence only within the experimental stations but have no influence the reference sites.

DO in fish pens showed to have the lowest mean results which is attributed to the density of fish in these stations (Experimental Stations) that requires oxygen for its metabolic processes and so with the decomposition of excess nutrients from fish feeds by phytoplankton and benthic organisms (Bricker et al., 2007 and Breitburg et al., 2009). Though DO in the fish farm stations were lower and have significant difference compared to the other sites, the readings of this parameter in the experimental stations are way above the minimum water quality guidelines for Class SB water of DAO 2016-09 at 6 mg L-1. Thus, DO in the fish pen stations are still suitable for aquaculture activities at fish densities of 2,000 and 1,300 fingerlings of Milkfish and Jack, respectively per 80 m^2 fish pen.

Results of the TSS in the fish farms were around 53mgL^{-1} higher than the 50mgL^{-1} water quality guideline of DENR AO 2016-08 for the same water class. This can be attributed to the cultured fish in the experimental sites as well as excess fish feeds, fish litter and mixing of water that can agitate the bottom sediment. Land based sources such as the soil erosion from the nearby shorelines and the mangrove substrates can also contribute to the TSS level in the experimental site with the exchange of tides. Plankton communities and settling organic substrates also contribute to the TSS of the water column (Chen, et al., 2006; EPA, 2012; Perlman, 2014 and Kim & Kim, 2015).

The pH readings during the sampling periods in the sampling stations were all within the range set by DAO 2016-08. Base on the results, the entire Barobo coastal waters has a pH balance mechanism attributed to the wave action and water mixing mechanism strategic in the area that can help assimilate pollutants in water through increase of dissolved oxygen that can increase pH levels and lessen contribution to ocean acidification (USEPA, 2022).

The high AmmoniaCal nitrogen (NH_3-N) reading in the experimental sites was linked to the increase in fish biomass in the month of November since most of the fish pens in the sampling areas were at harvesting time during this month where large excretion of ammonia over the gills, of feces, and of uneaten feed of farmed fishes were expected, ammonia being the main constituent in the dissolved excretions of fish (Hakanson, Ervik, Makinen & M‹ller, 1988). On the other hand, feed wastage and pollutant loadings are much higher in open-sea cage culture systems where trash fish is used as feed (Wu 1995). While the presence of NH3-N in the Reference site, R2-6 maybe attributed to the tourism activity such as swimming and camping in the nearby tenanted Cabgan Island frequented with tourists. The NH3-N results also showed to be way higher than what is stipulated in DAO 2016-08 of 0.05 mgL-1.

The results denote that fish farming did not affect the Dissolved Organic Phosphorous (DOP) concentrations in water and the highest reading is reported at E1-1/Milkfish fish pen (0.0187 mgL^{-1}) which is still lower than set by DAO 2021-19 for water quality guideline. It can be explained that the fluctuations of DOP in surface water are controlled by the interplay of physical and biological factors (Ruttenberg et al., 2005). Organic phosphorus occurs in a variety of organic compounds. The crudest classification is dissolved organic phosphorus (DOP) and particulate phosphorus (PP). The sum of DOP, PP, and phosphate is total phosphorus (TP). Phosphorus is used in cells for nucleic acids, phospholipids, and other compounds (Dodds, 2002). Phosphorus is found in fish feeds and is broken down into a more useable form (phosphate) through decomposition (Ruttenberg, 1992).

Results on Potassium (K^+) concentration of the present study show that fish farming did not significantly affect the parameter. Potassium is one of the major components in seawater other than chloride, sodium, sulfate, magnesium, calcium and other compounds that make up the saline water. The concentration of K^+ in the typical seawater is 380-450mgL^{-1} (Horiba, n.d.) Its sources include land based run-off from agricultural areas applied with fertilizers, natural decomposition of rocks, bottom sediment of the area and dead plant and animal materials often bounds to clay minerals in soil and tends to settle and consequently ends up in the bottom sediment of the ocean. Potassium is a dietary requirement for nearly any organism including a number of bacteria and phytoplankton, because it plays an important role in nerve functions (Lenntech, 2022).

Effects of Fish Farming on Physicochemical Parameters of Sediment

Sediments from the 6 sampling stations were slightly basic in nature with pH values ranging from 7.5 to 8.97 with significant difference spatially and temporally. The decreasing and increasing trends of pH values in sediments of the sampling stations showed that the basicity is increasing with a distance from fish farms. Though the pH of sediment in fish farm stations are slightly alkaline, the significant difference compared to the pH in the reference and in between stations could still be attributed to the influence of fish farm activities. Some of the known facts that soil pH is affected by the inherent factors that include climate, mineral content, and soil texture (USDA 2021). In the present study, the spatial and temporal variation of soil pH in sediments could be affected by the minerals from the organic inputs from the fish farming activities that could also affect the variation of the texture of sediments.

The decreasing and increasing trends of the texture of sediments in fish farm stations indicated that fish farm activities and the type of feeds used in these fish farms had influence in these variations. These decreasing and increasing temporal trends of the sediment texture in Stations 1 and 2 could be attributed to the organic inputs from the fish feeds and fish feces that settled into the bottom sediments in the sea floor. The observation on the constant trend of sediment in 3 months sampling periods explains that there are no or little sources of organic inputs brought by the fish farming activities from the experimental stations that did not vary the temporal texture quality of sediments in the reference and between stations. The study observed further that the trends of the sediment texture are caused by high pollution loading of feed and fish feces inputs and are being accumulated in the bottom sediments and that the significant impact is normally confined to within less than 1 km from the fish farm.

The observed trends in % OM are similar to the trends noted in the texture of sediments. In this study, the variables observed in the OM content in sediments only presented noticeable changes under the fish farm itself, indicating that the impact was very localized. This implication showed further that there might have overfeeding and inefficient feed conversion that leads to changes in water quality, increased turbidity, and build-up of organic sediment especially at the bottom of the fish pens (BFAR-PHILMINAQ, 2007).

To efflux from the sediment, waste from feeds, feces and direct excretion from cultured fishes may also have contributed to the high concentration of nitrogen at the two fish farming stations. The data showed a clear local effect of the fish (Milkfish and Jackfish) production (Fig. 6). Thus, nitrogen concentrations in sediments below the fish cages were decreasing from 0.44% to 0.00% with the increased distance from the fish cages. Uneaten feed and feces are the major sources of suspended solids in cage culture (Chen et al., 2000). When the feeds used in fish farming are higher in digestibility, it will bring about lesser fecal matter, carbon and nitrogen waste. High quality fish feed has high digestibility around 87-88% while low quality feed has only 25-33% of feed that may eject as feces (Nash, 2001). The general increase of sedimentation rate and total organic carbon and nitrogen of deposited materials is attributed with the increased input of fish feed (Holmer et al., 2002).

Available P content in sediments of Stations 4, 5 and 6 were significantly differed with Stations 1, 2 and 3. The reason could be that fish farming activities could input higher organic material which induced higher organic P concentrations in the sediments (Barić, et al. 2006). Wu (1995) reported that up to 82% of the phosphorus in fish feed was lost to the environment while Pearson & Black (2001) found that 34‒41% of phosphorus in feed was released in dissolved form. Under the Redfield ratio basis, the proportion of phosphorus in the fish feed could be doubled compared to carbon and nitrogen (Sanz-Lazaro et al., 2015).

The high extractable potassium contents of sediments in all the stations is maybe influenced to some extent by fish farming activities however, it is natural that seawater contains about 400 ppm potassium. It contains a natural concentration of about 4.5x10-5 g/L that tend to settle mostly in the bottom sediment (Lenntech, n.d.).

Effects of Fish Farming on Plankton Communities

Highest mean result of phytoplankton count was not observed in the fish farms but in Station 3, (the station between the experimental and reference sites). Station 3 is characterized as seaweed, Eucheuma cottonii farm area fertilized with phosphate. High phytoplankton abundance occur in seaweed cultivation locations which is associated with high phosphate and nitrate (Parakkasi et. al, 2020) According to Effendi (2003), phosphate concentration ranges between 0.051-0.1 mgL^{-1} would indicate fertile waters which causes phytoplankton to grow well. Based on water quality results, Station 3 has highest DOP than the fish pens Station 1 and 2 seaweed, Eucheuma cottonii farm area fertilized with phosphate.

The highest phytoplankton result in Station 3 is the release of nutrients from the fish farms stimulated an increase of pelagic primary production to different distances from the fish farms (Dalsgaard and Krause-Jensen, 2006). Higher phytoplankton and zooplankton count and biodiversity in the Jackfish pen than Milkfish fish is also attributed to the trashfish in which nutrients from fish tissue is directly utilized which could induce algal growth (Yongli Gao, et al., 2014). In addition, assemblages in planktonic communities are highly dynamic that changes rapidly in response to circulation and fertilization patterns and with other favorable physical and environmental factors. Planktonic assemblages might fluctuate at short-time scales with different assemblages characterizing the various phases of an upwelling cycle as evident in coastal upwelling systems (Marañón, 2015).

On the other hand, the mean of the zooplankton counts in ind./L did not go with the trend of the means of phytoplankton counts. Generally, there is a direct relationship of the number of phytoplankton and zooplankton. However, the results in the present study did not follow with the general trend since zooplankton tend to look for an alternative food when there is shortage of food (phytoplankton). (Hu et al., 2015).

Conclusions

Results showed that fish farming activities showed considerable effects on sediments and plankton communities than in the physicochemical parameters of water. Comparing the Milkfish fish and Jackfish pen, the phytoplankton, water pH, transparency, velocity, and extractable potassium of sediment showed significant difference. When comparing the experimental site to areas distant from fish farming, DO, TSS and Ammoniacal nitrogen showed significantly higher in the fish farms (experimental site) than at areas 1 km Between experimental site and reference site and at Reference Site. For physicochemical parameters of sediment, pH showed significantly low at the fish farms than in areas outside the experimental site, heavy sediment texture characterized the fish farms while light to medium at outside fish farms. Organic matter %, and extractable potassium is significantly higher at the fish farms than in areas outside fish farming activities. Total Nitrogen and available phosphorous are also noted to be higher at the fish farms but not statistically significant as compared to other sampling sites. Thus, fish farming activities be it utilizing commercial fish feeds and trashfish really affects plankton communities and the sediments as well as on the physicochemical parameters of water that is directly affected with the nutrient pollution such as DO and TSS. With these findings it is highly recommended to conduct a regular monitoring at the area as to the short term and long term effects of the fish farming activity and to conduct a regular clean-up especially on organic wastes that accumulates overtime at the sediment.

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