SPATIAL AND TEMPORAL DISTRIBUTION OF PLANKTON COMMUNITIES IN LIANGA BAY

[1]Gemma A. Asufre and [1]Roxan G. Eupeña

Abstract

The study on the spatial and temporal distribution of plankton was conducted in Lianga Bay. Water was collected on a monthly basis for 12 months from February 2009 to January 2010 in four established sampling stations. Data on the physico - chemical parameters of the water were also collected to determine the fluctuation of temperature, dissolved oxygen, total suspended solids, water transparency, pH, water movement, bottom depth, salinity, ammonia nitrogen, nitrate; and phosphorous in four sampling stations and in 12 months sampling periods. Results of the study revealed a total of 245 phytoplankton taxa dominated by 42 genera of Chaetoceros and 22 genera of Ceratium were recorded during the month of February 2009 to January 2010. The abundance of phytoplankton was significantly different in sampling months but no significant difference between stations. For the zooplankton, there were 102 species of zooplankton with 35 species of copepods noted in all stations and sampling periods dominated by Calanus glacialis in all stations and sampling months. The significant difference on the abundance of the zooplankton species was only observed between months but not between sampling stations.

Keywords: *plankton, spatial, temporal distribution, copepods*

1.0 Introduction

Plankton communities underpin the marine food web in aquatic ecosystem. Planktons are used as food for the higher trophic animals and indicators of the status of aquatic ecosystem. As floating organisms and affected by the environmental parameters, it is hypothesized that plankton communities are distributed across spatial and temporal scales that influence the flow and food web structure of Lianga Bay Coastal Waters. Assessment on its distribution in Lianga Bay is very essential in understanding the food and environmental parameters for "Tikod Amo" (*Spondylus sp.*) oyster for the generation of its culture technology in this particular marine ecosystem.

According to Berg & Newell (1986), oysters obtain energy resources by filtering particles from seawater and their growth depends upon these particulate matters that include planktons. This assumption is supported by some data such as the study of Paulmier (1972) of which Tintinnids (zooplankton) have been observed in oysters' stomachs; protists retain in filter-feeding bivalves (Sournia et al. 1991); and 6 different species of bivalves were able to selectively clear and digest dinoflagellates (phytoplankton) (Shumway et al. 1985). Plankton communities are affected by the physico-chemical characteristics of the water that is influenced by natural and anthropogenic origins and the interaction

[1]Surigao del Sur State University

between the biotic and abiotic factors (Odum, 1983; Falkowski et al., 1998; Lewis et al., 1999). As stressed by Cetinic et al. (2006), various processes such as nutrient recycling, grazing, particle sinking and food webs influence the composition of phytoplankton. The quality of water and its capacity to sustain life in the higher trophic communities have been successfully assessed through the quality, quantity and seasonal patterns of phytoplankton (Hulyal and Kaliwal, 2009). Since phytoplankton as primary producers is placed at the base of the food web, they first link trophically to zooplankton then to the higher trophic communities including oysters (Abuzer and Okan, 2007).

The elucidation of this link is important in describing the food environment of the culture space of Tikod Amo (TA) oyster. However, there is no available study that describes distribution of plankton communities and physico-chemical parameters in spatial and temporal scales in Lianga Bay.

In the present study, we investigate the abundance and distribution of the plankton communities and some environmental factors in the waters of Lianga Bay to establish its space-time variations necessary for the development of technology on the culture of “Tikod Amo”oyster. The study on the occurrences of different types of species of plankton is fundamental in characterizing the food available for “Tikod Amo” and other organisms in the higher trophic levels in Lianga Bay. Similarly, physico-chemical parameters of the water in Lianga Bay should be determined to characterize the habitat of TA oyster species.

2.0 Materials and Methods

The study area was located in the coastal waters of Lianga Bay in the municipality of Barobo, Surigao del Sur. It is located in the central part of the province lies within a geographical coordinates of 8°34’00” and 8°25’06” latitude and 125°59’00” and 126°22’00” longitude. It is bounded on the north by the Pacific Ocean and the municipality of Lianga; on the south by the municipality of Tagbina; on the east by the municipality of Hinatuan; and on the west by the province of Agusan del Sur (MPDO, Barobo, Surigao del Sur). Using the Global Positioning System (GPS), four sampling stations were established in Lianga Bay within the Barobo Coastal Waters (fig. 1).

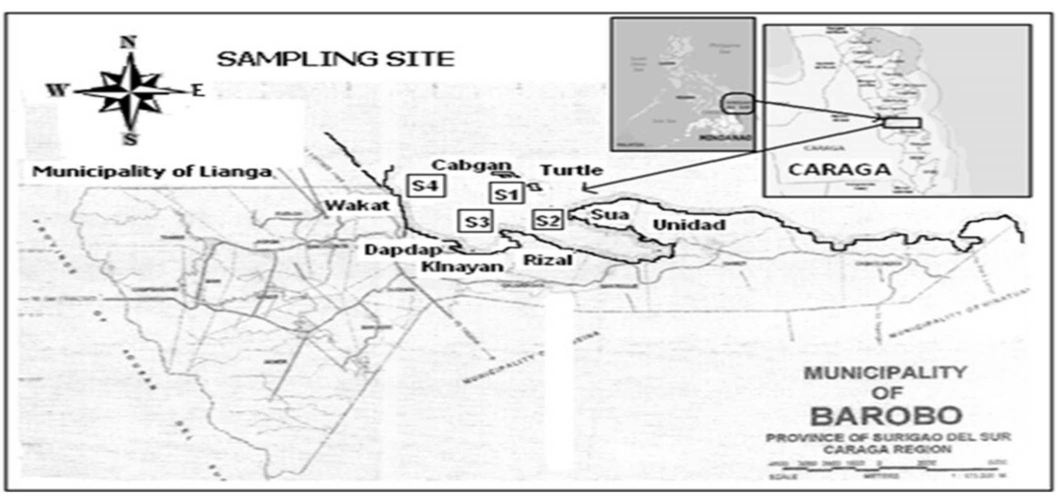

Figure 1. Map of Lianga Bay showing the four sampling stations. Inset is the map of Mindanao with Lianga Bay enclosed in a rectangle

The four (4) sampling stations were located in the following grid coordinates: Station 1(S_1) was positioned in between 8˚33'08.3" North latitude and 126˚08'53.3" East longitude; Station 2 (S_2) (8˚33'01.8" North latitude and 126˚08'46.8" East longitude); Station 3 (S_3) ($8^0$33'42.9" North latitude and 126˚07'24.9" East longitude); and Station 4 (S_4) ($8^0$34'07.7" North latitude and 126˚07'14.3" East longitude.

Sampling was conducted once a month for a period of one (1) year that started from the month of February 2009 to January 2010. Data collection for the physico-chemical parameters was done once a month for a period of 1 year to cover the dry (March-June) and wet seasons (July-February). Collection of samples was daytime (7 am to 5pm) in four (4) identified sampling stations. The following physico-chemical characteristics were determined:

Temperature. Water temperature was determined in situ using a field thermometer.

Dissolved Oxygen (DO). The dissolved oxygen was determined using Winkler Analysis.

Total Suspended Solids (TSS). The total suspended solids were measured using the gravitational filtration set-up. One-liter of water samples were filtered using the pre-weighed Whatman filter paper (# 41). The filter paper was then oven dried at 100^0C for twenty-four (24') hours and re-weighed. The weight difference of the filter paper before and after oven drying represents the total suspended solids expressed in mg/l.

Water Transparency. Water transparency was determined using a Secchi disc, an 8 inches in diameter metal painted in alternate black and white quadrants. The disc was lowered slowly into the water until the white portion could no longer be seen, then the disc was raised slowly toward the surface until the disc reappeared. The depth in meter of the water during the reappearance of the disc was considered the vertical visibility or water transparency.

pH. Determination of the pH of the water was done using a portable pH (Multiline F/ SET-3) meter.

Water Movement. Surface water movement (based on current speed and direction) was measured at three (3) hour interval from 0400 t0 1600 hour during low and high tides using an improvised weighted current drogue made from heavy duty vinyl coated material (size: 48 inches; weight: 3 lbs.; stowed dimensions: 12" x 6" x 4"), which has enough buoyancy to float, but stays below the water surface out of the wind drag. The drifting detritus (seaweed, wood chips, etc.) in the water were examined to determine the direction of the flowing of the surface current. This direction was measured with the marine compass. A fixed length (5 meters) along the side of the boat was measured using meter stick, then the drogue was released and, the drogue's rate of movement in centimeters/second was measured using stop watch. The measurement was the surface current velocity. The drogue was recovered with a dip net and the measurement was repeated four times.

2.1 Determination of the Bottom Depth and Type

Bottom type of the sampling sites was determined through direct observation by diving into the bottom during high and low tides. The depth was measured using a rope that will be towed into the bottom.

Salinity. Water salinity was determined in situ using a refractometer (ATAGO).

Ammonia Nitrogen. Total ammonia nitrogen ($NH\text{-}3 + NH_4$) was determined through colorimeter by formation of indophenols blue.

Nitrate. Nitrate was measured using the colorimetric method with sulfanilamide; nitrate (reduction method with cadmium).

Phosphorous. Dissolved reactive phosphorous was determined through colorimetric method based on the formation of molibdate.

2.2 Plankton Samples Collection and Analysis

Phytoplankton and zooplankton samples were collected in all sampling stations once a month for one (1) year period to cover the dry and wet seasons.

2.3 Collection of Phytoplankton samples

Daytime (7 am to 5 pm) vertical and horizontal sampling was conducted in each established sampling stations. Conical plankton net (length: 0.45m; mouth diameter: 0.21 m; mesh size opening: 50 µm) was lowered to a depth of five (5) meters and the samples collected at the cod-end was transferred into the plastic sampling bottle. A few drops of Lugol's solution were added in order to preserve the samples. Four replicate samples were collected in each sampling stations. All collected samples were stored in a cool environment (at normal room temperature) prior to laboratory analysis.

For laboratory analysis of the phytoplankton samples, a calibrated pipette was used to obtain one (1) ml subsample from the 50 ml sample volume and then placed into the Sedgewick rafter counting cell (deep: 1 mm: length: 50 mm; width:20 mm; area: 1000 m^2; volume: 1 ml). Each phytoplankton individuals or species encountered under the inverted microscope (ULWCD 0.30, Olympus CK2) was identified, counted and tallied into the designated tally sheet. Four (4) 1-ml subsamples from each of the collected samples were analyzed and then the average was taken. The abundance of each phytoplankton species was calculated using the formula of Newell (1963):

$$Abundance\left(\frac{cells}{ml}\right) = \frac{no.\ of\ cells\ counted/ml}{no.\ of\ subsamples}$$

Phytoplankton samples were identified up to the species level using the references of Yamaji (1982).

2.4 Collection of Zooplankton Samples

Zooplankton samples were collected using conical plankton net (length: 1.8 m; diameter: 0.45 m; mesh size opening: 300 mm) with a flow meter (Rigosha and Co., Ltd No. 1687) attached to the center of the mouth of the net. The flowmeter, with a propeller that rotates with the flow of the water and records the number of revolutions were used to measure the quantity of water filtered by the net. Prior to zooplankton sampling, the flowmeter was first calibrated following the standard procedure described by Omori and Ikeda (1984). During the field collection, the plankton net, with the attached calibrated flowmeter, was lowered to a depth of 5m-15 m and then the net was hauled back to the surface. Zooplankton samples will be collected at the cod-end of the net was drained into a properly labeled polyethylene bottle. Four replicate samples were collected in each sampling stations. Immediately after each zooplankton collection, the sample was fixed with buffered formalin.

For laboratory analysis of the zooplanktons, zooplankters encountered in the samples were identified to the nearest taxa using the guide illustrations of Yamaji (1982), Todd and Laverack (1991) and

Boltovsky (1999). Prior to counting, the total volume of the zooplankton sample was measured and recorded. Then, the entire sample was placed in a large culture dish and larger zooplankton (visible to the naked eye), megaloplankton and micronekton were sorted and identified to the nearest taxa possible. Each large identified organism was counted, removed and transferred into a properly labeled vial filled with 70% ethyl alcohol. For the abundance of the smaller zooplankton individuals, a 1-ml subsample was taken from the entire zooplankton sample using an improvised wide mouth pipette (1.0 ml). The subsample was then placed into a sedgewick-rafter counting chamber cell (deep: 1 mm; length: 50 mm; width: 20 mm; area: 1000mm^2; volume: 1 ml) and was covered with a coverslip (no. 1 ½) in a manner where no bubbles could occur. Each zooplankton individuals encountered in the entire counting chamber was identified and counted using a dissecting microscope (Carton TB-20). The counting was repeated several times until each major zooplankton representative reaches 300 individuals. The abundance of each zooplankton individuals or groups was expressed as individuals per m^3 following ICES Zooplankton Methodology Manual (2000):

$$\textit{individuals } m^3 = \frac{(n)(K)}{m^3}$$

where:

n = total number of individuals per cubic meter (m^3)

K = part of the sample counted, i.e. the proportion of total volume to Subsample volumes

K = B x M x C

B = actual flowmeter reading

M = area of the mouth of net

C = depth of net hauled over calibration constant of the flow meter

m^3 = volume of water filtered by the net

For statistical analysis of plankton samples, biological data for plankton was analyzed using quantitative indices to determine the relative abundance and diversity of species and groups using PAST software. Significant differences of the physico-chemical parameters and plankton abundance between stations and between months were determined using Analysis of Variance.

3.0 Results and Discussion

3.*1 Spatial and Temporal Physico-chemical parameters in Lianga Bay*

The physico-chemical parameters of the seawater in the area were observed to have annual average temperature of 27.7°C, DO (9.0mg/L), TSS (26.0mg/L), water transparency (5.7m), pH (8.2), water movement (4cm/s), bottom depth (6.6 m), salinity (31.9 ppt), ammonia nitrogen (0.46 mg/L), nitrate (0.22 mg/L) and phosphorous (0.39 mg/L) which are favorable for shellfish culture (Angell and Tetelepta, 1982; Angell, 1986; Brown and Hartwick 1988a; Brown and Hartwick 1988b; Appukuttan et al., 1998).

The fluctuations of the average physico-chemical parameters of seawater in each station for 12 months and the average monthly variations of these water qualities are shown in figs. 2 and 3, respectively.

Among the physico-chemical parameters, only temperature, TSS and salinity had no significant difference between stations. DO, water transparency, bottom depth, concentration of ammonia nitrogen, nitrate and phosphorous had high significant difference between stations while pH and water movement were significant at

0.05 levels. Spatially, variations of the phyiso-chemical parameters were observed on the DO, water transparency, bottom depth, concentration of ammonia nitrogen, nitrate, phosphorous, pH and water movement (fig. 2).

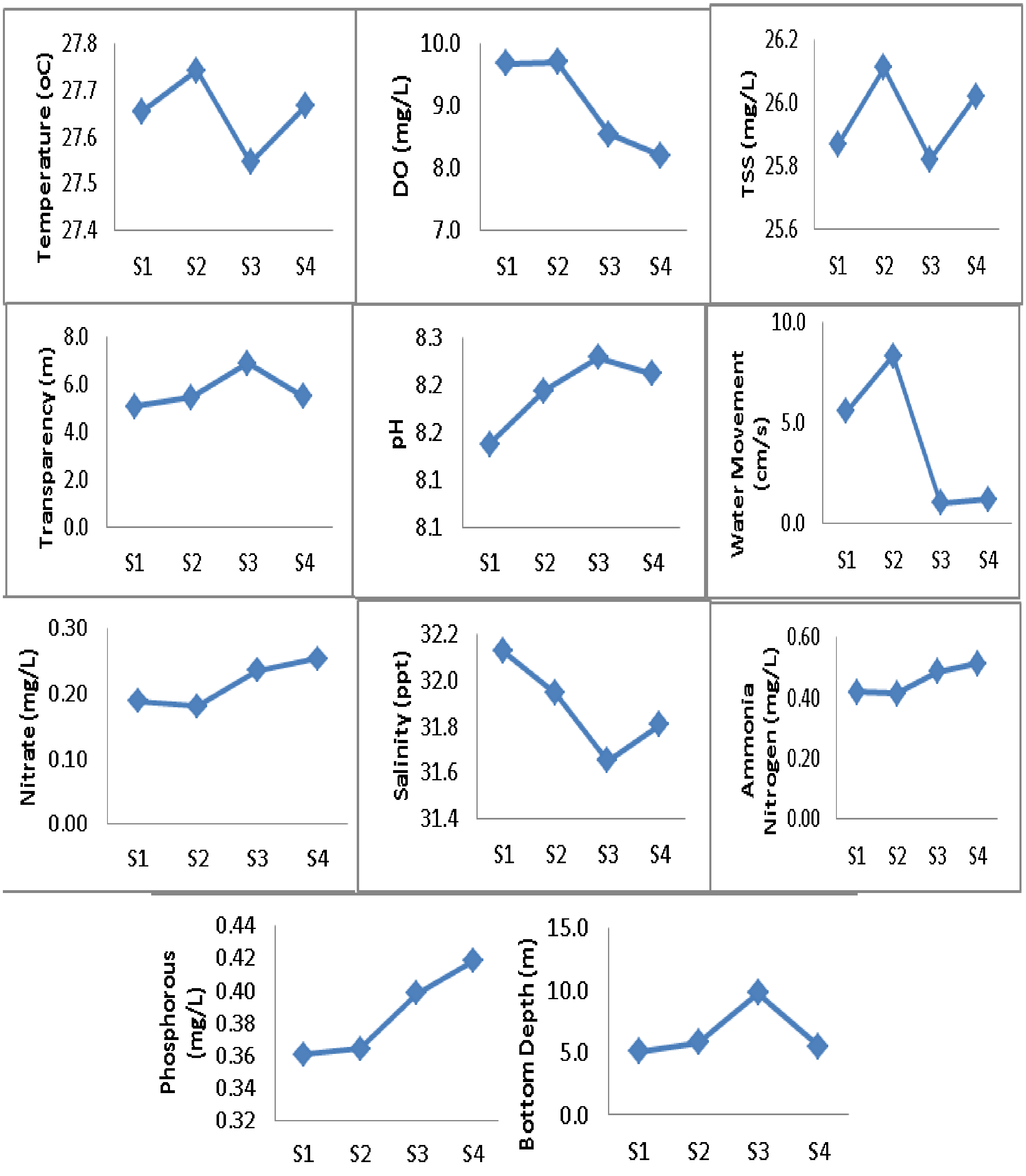

Figure 2. Fluctuations of the average physico-chemical parameters in 4 stations from February 2009 to January 2010

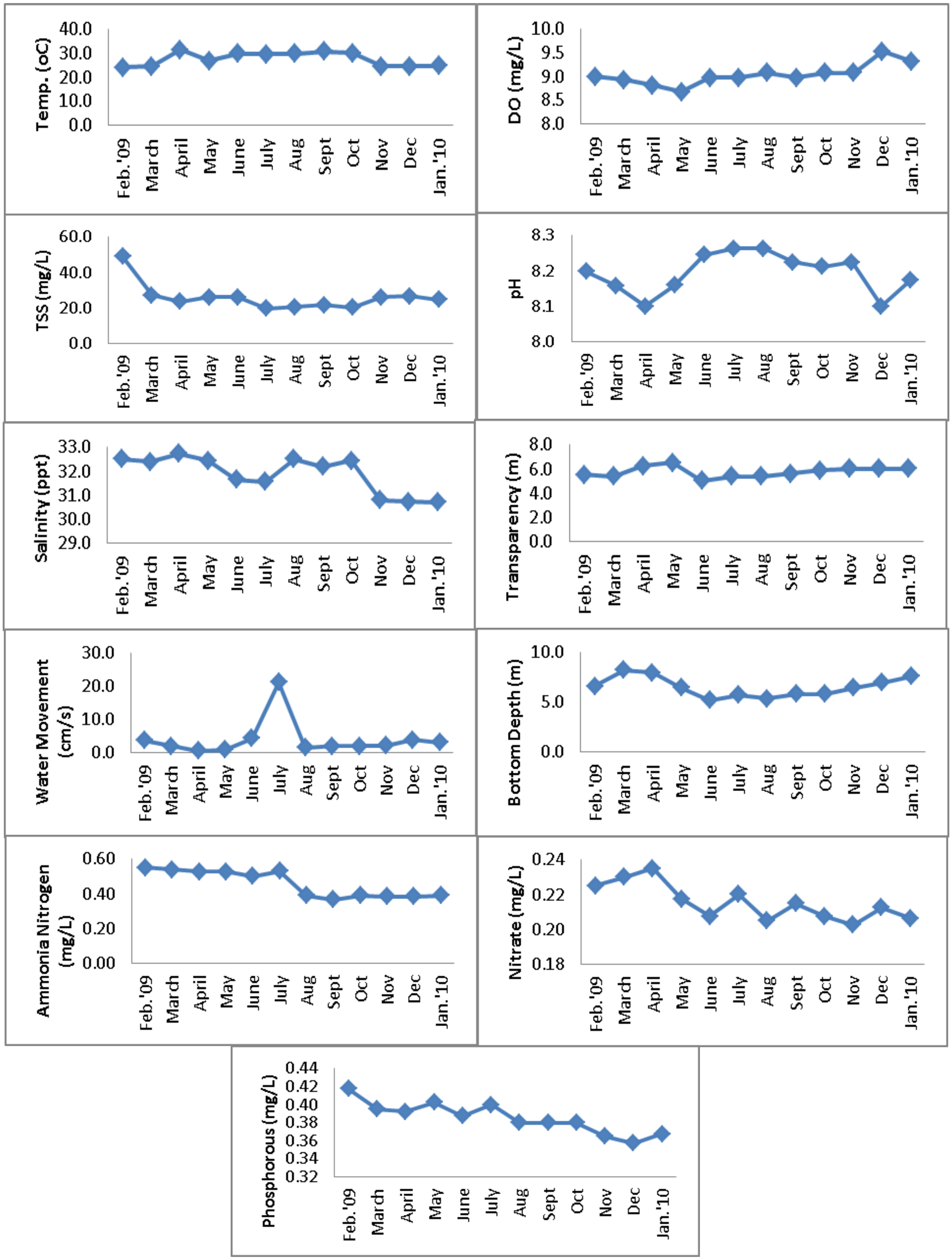

Figure 3. Monthly average fluctuations of the physico-chemical parameters in 4 stations

These variations could be attributed to the nutrient inputs from the anthropogenic activities of the nearby coastal communities with proximity to Stations 3 and 4. As observed many people residing along tributaries and coastline of Lianga Bay. As cited by Colijn (1998), several studies have provided a hint that possibility of internal cycles, whereas in many cases human activities, such as eutrophication, pollution, or fisheries, are seen as major driving forces behind the changes observed.

At temporal scale, monthly variations were noted on the temperature, TSS, pH, salinity water movement and concentration of ammonia nitrogen where significant differences were observed. Dissolved oxygen, bottom depth, transparency and concentration of nitrate and phosphorous had no significant difference between months. The high significant difference of salinity and TSS between months conforms to the significant difference of the monthly rainfall patterns. Significant variation of temperature is affected by the variation of salinity (SWRCB, 2002). According to Govindasamy et al. (2000), temperature is influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mix up with recede and flow from adjoining neritic waters. Likewise, the variation of temperature will change the ion concentrations thus shifting the pH value that explains the significant difference of pH between months (Larsen and Moestrup 1989). Monthly variation of ammonia nitrogen can be explained by the significant variation of pH since according to Pankow (1991) as the pH increases, ammonia will leave the aqueous solution by volatilization. Hence, variation of pH could affect the concentration of ammonia in water.

Considerable seasonal variations usually happened in the near shore waters and estuaries, that depends on the local conditions of rainfall, tidal incursions, various abiotic and biotic processes, quantum of fresh water inflow affecting the nutrient cycle of different coastal environments (Choudhury and Panigraphy, 1991).

3.2 Species Composition, Dominant Groups and Community Structure of Phytoplankton

A total of two hundred forty five (245) phytoplankton taxa belonging to sixty one (61) genera, twenty five (25) families and five (5) phyla of five (5) major groups (Diatoms, Dinoflagellates, Coccolitophores, Phytoflagellates and Cyanobacteria) were observed in four (4) sampling stations from the month of February 2009 to January 2010. Among the phytoplankton taxa, two hundred twenty nine (229) were identified up to species level and sixteen (16) up to genus level.

Two hundred five (205) species were noted common in all stations and all months including the forty two (42) species of *Chaetoceros* as the highest number of species. Potentially toxic species and indicator species of poor water quality were also observed in all monthly collections for all the sampling stations. Five potentially toxic species were recorded in all stations and all months where the appearance of *Dinophysis sp.* was the most important in terms of number present. With the exception of April and June samplings, the presence of poor water quality indicator species, *Ceratium macroceros* was observed in Stations 2, 3, and 4 while *Peridinium depressum* was absent in the months of June and September and was not observed in Station 1. The presence of 22 species of *Ceratium* was observed in the Coastal Waters of Barobo. *Ceratium spp.* is common dinoflagellates in coastal waters and their presence is a normal occurrence (McCormick and Thiuvathukal, 1981). Generally, there were thirty-eight (38) species of five (5) genera of red-tide causing organisms noted in all sampling stations and all sampling months. The highest abundance of phytoplankton was observed in Station 3 and the lowest was noted in Station 4 in all months of the year (fig. 2). This abundance indicates that marine coastal ecosystem of Lianga Bay is still in good condition. Although red-tide causing species were observed in all sampling stations, its occurrence could not indicate that Lianga bay is under pollution stress. Their abundance explains that the water in Lianga Bay is still in good condition that matches up to its physico-chemical parameters. However, the presence of this red-tide causing species informs that Harmful Algal Bloom (HAB) is potential in Lianga Bay if the physico-chemical parameters favor its growth.

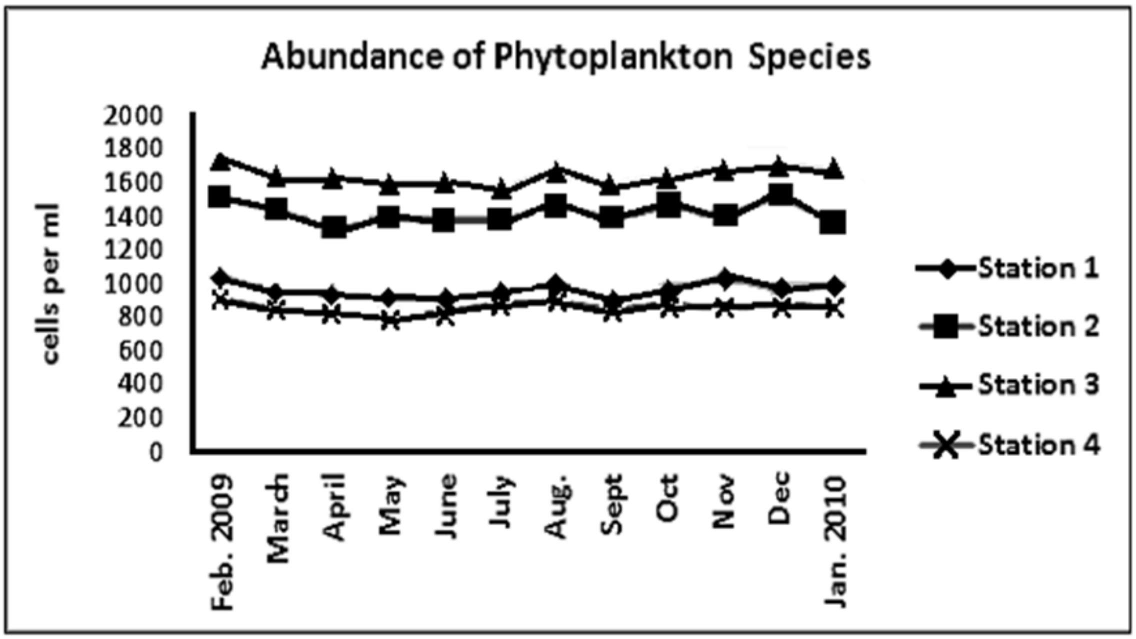

Figure 2. Variations in phytoplankton abundance (cells/ml) in 4 stations from February 2009 to January 2010.

3.3 Phytoplankton Species Diversity

Results in Table 2 shows the different levels of the diversity of phytoplankton in the four sampling stations of Barobo Coastal Waters.

It can be seen from the results that sampling station 4 had the most number of taxa observed while station 1 had the least number. The trend is S4>S3>S2>S1. Based on the diversity index, the trend is S3>S2>S1>S4. These result suggest that the more taxa observed could be attributed to favorable physico-chemical parameters. Further, abundance of taxa observed does not always relate to high diversity. As mentioned by Rothhaupt (2000), planktonic communities are influenced by the prevailing physico-chemical parameters and these determine their abundance, occurrence and seasonal variations. Plankters respond quickly to environmental

Table 2. Species richness, Shannon's index, dominance and evenness values of phytoplankton in selected sampling stations in Barobo Coastal Waters

Diversity Indices	Sampling Stations			
	Station 1	**Station 2**	**Station 3**	**Station 4**
Taxa S	215	232	237	244
Individuals	11541	16972	19760	10324
Dominance (D)	0.01068	0.006491	0.005765	0.007141
Shannon (H’)	4.847	5.19	5.273	5.167
Eveness (e^H/S)	0.5926	0.7736	0.8226	0.7187

changes because of their short life cycle, hence, their species composition are more likely to indicate the quality of the water which they are found. The relative abundance of chlorophyll is indicative of productive water (Jenkerson and Hickman, 2007).

The pattern of diversity observed among all the sampling sites was re-evaluated by specifically looking at patterns observable during monthly collections. This is to specifically determine if variations between sampling sites are due to differences in monthly collections of the different taxa of phytoplankton. Table 3 shows the variations of values in species richness, index of dominance, evenness and diversity among the 4 sampling stations from February 2009 to January 2010.

Table 3. Species richness, Shannon's index, dominance and evenness values of phytoplankton from February 2009 to January 2010 sampling months in Barobo Coastal Waters

Sampling Months	Diversity Indices				
	Taxa (S)	**Individuals**	**Dominance (D)**	**Shannon (H’)**	**Evenness (e^H/S)**
February	239	5207	0.006734	5.203	0.7605
March	235	4879	0.006604	5.208	0.7779
April	229	4701	0.006541	5.205	0.7959
May	223	4687	0.006613	5.198	0.8113
June	218	4720	0.006713	5.188	0.8215
July	224	4763	0.006423	5.214	0.8208
August	238	5054	0.006841	5.195	0.7581
September	224	4715	0.006696	5.194	0.8045
October	237	4956	0.006719	5.204	0.7678
November	238	4956	0.006324	5.230	0.7852
December	235	5077	0.006313	5.238	0.8011
January	236	4871	0.006427	5.223	0.7862

As depicted in the table, monthly differences of diversity were observed in 4 stations. The highest number of species was observed in the month of February and had also the highest number of individuals. Since there was a high evenness value at 0.7605 indicating that the abundance was evenly distributed among all the species since there is a minimal dominance value. The lowest number of species was observed in June with a diversity value of 5.188. This value is still considered as high diversity.

Across all sampling stations, the order of abundance of taxa is February> August= November> October> January> March= December> April> July=September> May> June. The number of individuals is in the following order: February> December> August> November> October> March> January> July> June> September> April> May. Diversity based on Shannon index is in the following order: December> November> January> July> March> April> October> February> May> August> September> June. It can be observed from this rank order that diversity is not correlated with both abundance of taxa and number of individuals (table 3). There were highly significant differences on abundance and diversity between months while no significant difference on number of taxa. Between stations, there was no significant difference of abundance, number of taxa and diversity (table 4).

Table 4. ANOVA results with F values of the differences of the abundance and diversity of phytoplankton between stations and between months at $p \leq 0.05$.

Parameters	F Values	
	Months	**Stations**
Abundance	0.4942**	31.1^{ns}
Taxa S	0.1266^{ns}	148.2^{ns}
Diversity	0.01123**	0.9981^{ns}

This finding is similar to the study of Jagadeeshappa et al., (2013) which shows that increased concentration of plankton diversity could likely be attributed to monsoon patterns. The results of the present investigations is comparable to the study of Jagadeeshappa et al., (2013) which reveals that fluctuation in the physico-chemical characteristics of the water will be due to entry of rain water and change in the temperature and salinity as season changes.

3.4 Species Composition, Dominant Groups and Community Structure of Zooplankton

A total of one hundred twenty eight (128) zooplankton taxa belonging to ninety one (91) genera and four orders were observed in four (4) sampling stations from the month of February 2009 to January 2010. Among the zooplankton taxa, one hundred twenty two (122) were identified up to species level, five (5) up to genus level and one (1) unknown species. All of the species were noted common in all stations and all months with *Calanus* as the highest (6) species such as *Calanus cristatus, Calanus glacialis, Calanus minor,Calanus plumchrus, Calanus sinicus* and *Calanus teuicornis.* The bivalve larvae were the most abundant species (4.67% of the total zooplankton) and were distributed in all stations.

Monthly zooplankton abundance was also measured for the four sampling stations (fig. 4). The results showed variability in monthly abundance. Station 4 had the highest abundance of zooplankton (6,406 ind. /m^3) and the lowest abundance was observed in Station 2 (6,166 ind./m^3). Although station 4 had the highest abundance of zooplankton, the ANOVA test for spatial variations returned insignificant results (ANOVA test on different zooplankton species across all stations, P = 0.2716).

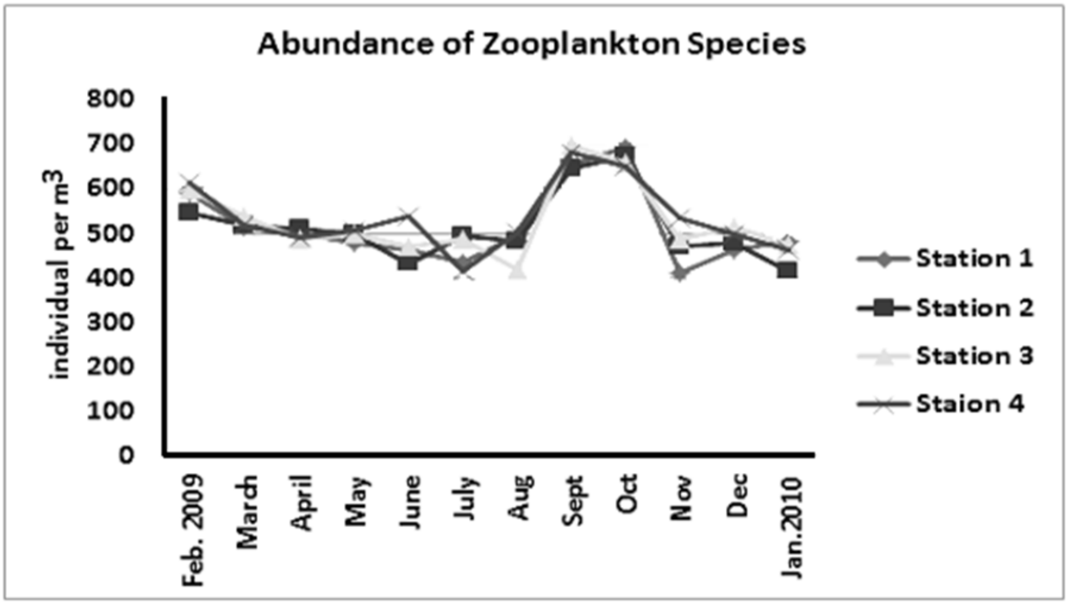

Figure 4. Variations in zooplankton abundance (ind/m^3) in 4 stations from February 2009 to January 2010

On the other hand, the highest abundance was observed in the month of February and the tests for temporal variations showed significant results (ANOVA test on different zooplankton species over all the months sampled, P = 3.176E^{-07}). There were no significant differences observed between the four sampling stations (ANOVA test on mean abundance of different zooplankton species across all stations, P= 0.911). However, there were significant differences noted between the twelve sampling months (ANOVA test on mean abundance of different zooplankton species across sampling months, P= 7.199E^{-08}).

3.5 Zooplankton Species Diversity

The different levels of the diversity of zooplankton in the four sampling stations of Barobo Coastal Waters are presented in table 5. Results show that the number of taxa was the same in all sampling stations however slight differences were observed in abundance, diversity, dominance and evenness values, which indicate that abundance of taxa is not directly correlated with high diversity. The pattern of diversity observed among all the sampling sites was re-evaluated by specifically looking at patterns observable during monthly collections. This is to specifically determine if there are variations between sampling

Table 5. Species richness, Shannon's index, dominance and evenness values of zooplankton in selected sampling stations in Barobo Coastal Waters

Diversity Indices	Sampling Stations			
	Station 1	Station 2	Station 3	Station 4
Taxa S	128	128	128	128
Individuals	6171	6166	6328	6406
Dominance (D)	0.009568	0.009503	0.00954	0.009625
Shannon (H')	4.794	4.796	4.794	4.791
Eveness (e^H/S)	0.9435	0.9456	0.9438	0.9404

sites due to differences in monthly collections of the different taxa of zooplankton. Table 6 shows no variation of values in species richness but index of dominance, evenness and diversity among the 4 sampling stations from February 2009 to January 2010 show otherwise. Monthly differences of diversity were observed in twelve sampling months.

The highest number of individuals was observed in the month of February and had also the highest number of dominance but the evenness value was low indicating that the abundance was not so evenly distributed among all the species. The lowest number of individuals was observed in July with a diversity value of 4.833 which is still considered as high diversity.

The order of the number of individuals in all sampling stations, is February>

Table 6. Species richness, Shannon's index, dominance and evenness values of zooplankton from February 2009 to January 2010 sampling months in Barobo Coastal Waters

Sampling Months	Diversity Indices				
	Taxa (S)	Individuals	Dominance (D)	Shannon (H')	Evenness (e^H/S)
February	128	2348	0.009516	4.759	0.9108
March	128	2091	0.008102	4.834	0.9817
April	128	1989	0.007981	4.841	0.9892
May	128	1979	0.008055	4.836	0.9844
June	128	1904	0.008046	4.837	0.9852
July	128	1827	0.008107	4.833	0.9811
August	128	1897	0.008121	4.833	0.9807
September	128	2677	0.04267	4.306	0.5795
October	128	2674	0.004747	4.251	0.5483
November	128	1901	0.008161	4.829	0.9772
December	128	1952	0.008126	4.832	0.9801
January	128	1832	0.008164	4.829	0.9774

September> October> March> April> May> December> June> November> August> January> July. Diversity based on Shannon index is in the following order: April> June> May> March> July= August> December> January= November> February > September > October (table 6).

Since the number of species across sampling stations and sampling months were similar, only abundance and diversity between stations and between months were determined using ANOVA. Results show that there were no significant differences in abundance of zooplankton between stations but it was noted between months. Likewise, diversity shows no significant differences between stations but had significant differences between months (table 7). Findings on the distribution, abundance and occurrences of zooplanktons are similar to the findings with phytoplankton of which its communities are influenced by the prevailing physico-chemical parameters respective to its seasonal variations. This finding is supported by the evidences compiled by Colijn (1998) that different time series shows that variability of plankton occurs in patterns – cycles, fluctuations, unusual events and in various scales at different frequencies – hours, days, seasons, years and etc. Both individual species and the entire community exhibit variable behaviour in response to regionally varying or site-specific factors.

Table 7. ANOVA results with F values of the differences of the abundance and diversity of zooplankton between stations and between months at $p \leq 0.05$.

Parameters	**F Values**	
	Stations	**Months**
Diversity	0.01059^{ns}	119.8**
Abundance	0.1769^{ns}	30.0**

4.0 Conclusions

The physico-chemical characteristics and the abundance of planktons in Lianga Bay are varied in temporal aspect. The physico-chemical parameters and the abundance of planktons indicate that the condition of water in Lianga bay is still good at present. The presence of potentially toxic species could not be apprehended that the Bay is under pollution stress; however it tells that HAB is potential in the area at favorable condition. Hence, the distribution of plankton and the physico-chemial parameters of Lianga Bay are favorable for the growth of the higher trophic organisms including Tikod Amo oyster.

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