Composition of Dinoflagellate Species in Barobo Coastal Waters, Barobo, Surigao del Sur

Gemma A. Asufre, Luzviminda M. Panes & Cynthia S. Alvez

Surigao del Sur State University

Abstract

Dinoflagellates play an important role in marine environment. The primary task of this study is to document species diversity and abundance of dinoflagellates in Coastal Waters of Barobo. Four sampling stations were established in the area for the collection of samples. Nine physicochemical parameters of the waters were also determined in a one- shot sampling in the month of October 2011. Dinoflagellates were determined up to species level. Among the nine physicochemical parameters determined in the four sampling stations, only temperature, Total Suspended Solids (TSS) and salinity showed significant differences between stations while the rest had no significant differences. A total of 42 dinoflagellate taxa were recorded in the coastal waters of Barobo during the month of October 2011. There were 886 total number of individuals with *Pyrocystis sp.* had the highest count with the percentage abundance of 12.10. Out of 42 taxa, 10 taxa were common in all sampling stations where *Ceratium* dominated the species composition followed by *Peridinium*. This abundance of dinoflagellate species are still at the normal scenario that could be considered out of its harmful effect to the organisms at the higher trophic levels however, due to the high diversity of dinoflagellate species in this area harmful algal bloom is potential.

Keywords: dinoflagellates, phytoplankton, physicochemical parameters, diversity, abundance

1. INTRODUCTION

Dinoflagellates are group of phytoplankton that plays an important part to any marine environment. According to Cembella (2003), about 75-80% of toxic phytoplankton species are dinoflagellates that cause "red tides". It often kills fish and/or shellfish either directly, because of toxin production, or because of effects caused by large numbers of cells that clog animal gills. During the night when photosynthesis halts, such a high concentration of individuals can deplete the oxygen in the water, suffocating fish (Snayda 1997).

There has been Paralytic Shellfish Poisoning (PSP) recorded in Barobo coastal waters caused by toxic phytoplankton bloom of *P. bahamense* in December, 1997 and continued to persist the whole year round of 1998 (Gonzales et al., 2004). This phenomenon indicates the vulnerability of the area particularly to its water quality condition for fishery resources and other beneficial organisms for food.

There are different types of harmful dinoflagellate blooms that in recent years, however, the phenomenon, especially the toxic kind, has spread rapidly to harbor around the world. The tides are showing up in places where previously they had never been reported, and new types of organisms are being identified. This deliberate species introductions can wreak havoc an ecosystem.

Scientists believe that cysts stirred up and swept along by ocean currents as one of the ways by which red tides can appear in previously unaffected waters. In addition, as blooms of phytoplankton move with currents, they can leave a trail of cysts that will eventually bloom under favorable conditions. Ships carrying phytoplankton or cysts in their ballast water can introduce the organisms to a new region when they empty their ballast tanks at ports.

Barobo Coastal Waters is accessible to ships with international destination which could be an avenue of introduction of dinoflagellate species from other regions around the world or vice-versa. At present, no efforts have been made to assess the dinoflagellates species in this particular coastal area. Hence, the primary task of this study is to document the diversity and abundance of dinoflagellates species and the physicochemical parameters of the coastal waters of Barobo Coastal Waters, Barobo, Surigao del Sur, Philippines.

3. MATERIALS and METHODS

3.1 Study Area, Sampling Stations and Sampling Period

The coastal waters of Barobo have an area of approximately 12,000 hectares along the coast of Lianga Bay with geographical grid coordinates of 8^{0}33$^{'}$ N Latitude and 126^{0} 08'E Longitude (Figure 1). (MPDO, Barobo Surigao del Sur).

Using a Global Positioning Syste (GPS), a total of four (4) stations were established in the coastal waters of Barobo, Surigao del Sur. Four (4) sampling stations were located in the following grid coordinates; Station 1-8^{o}33'08.3" N Latitude and 126 ^{o}08'53.3" E Longitude; Station 2-8^{o}33'01.8" N Latitude and126^{o}08'46.8" E Longitude; Station 3 – 8^{o}33'42.9" N Latitude and 126 ^{o} 07'24.9" E Longitude; and Station 4-8 ^{o}34'07.7"N Latitude & 126 ^{o}07'14.3" E Longitude. Sampling was conducted once from 10:30 a.m. to 1:00 p.m. on October 10, 2011.

3.2 Determination of Physicochemical Parameters

Water temperature was determined in situ using a field thermometer. The thermometer was dipped for 15 seconds into the water sample that was collected from a depth of five (5) meters using the water sampler. Water transparency was determined using a Secchi disc painted

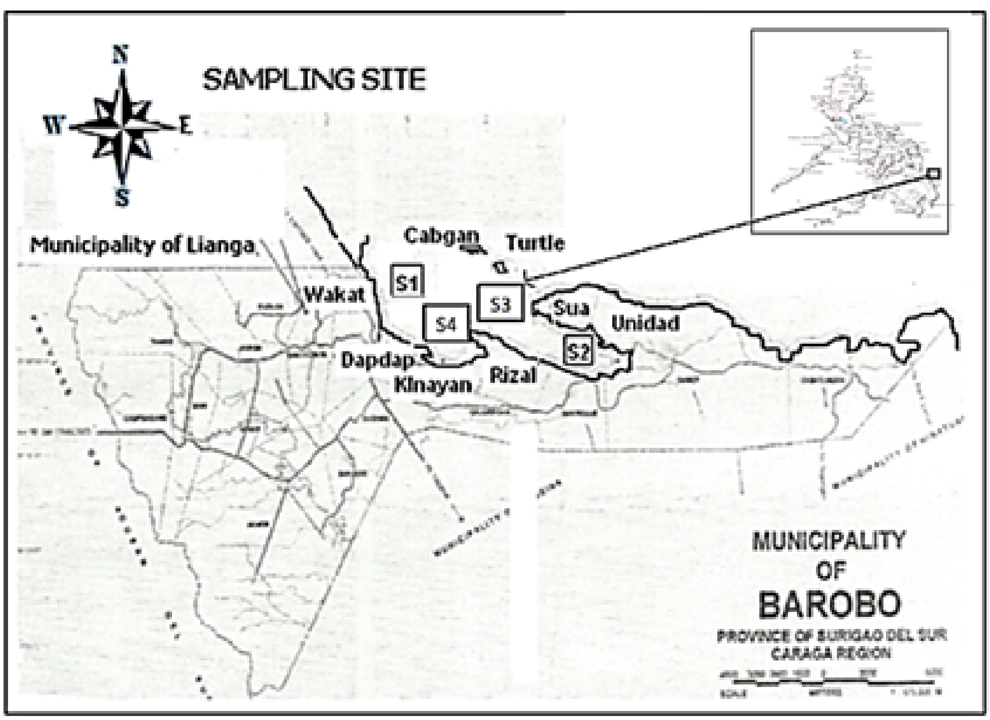

Figure 1. Map of Barobo coastal waters, Lianga Bay

alternately with black and white. Salinity was estimated in situ using a refractometer (ATAGO). Total suspended solids were measured using the gravitational filtration set-up while Winkler's titration method was used in the estimation of dissolved oxygen as outlined by Grasshoff et al. (1993). pH was measured using a portable pH (Multiline F/SET-3) meter. For dissolved reactive phosphate and nitrate in water were estimated adopting the methods given by Menzel and Corwin (1965), Christopher et al. (1977) and Strickland and Parsons (1972).

Surface water movement (based on current speed and direction) was measured using an improvised weighted current drogue. The drogue is made from a heavy duty vinyl coated material (size: 48 inches; weight: 3 lbs.; stowed dimensions: 12" x 6" x 4"). It 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 was 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.

3.3 Collection of Dinoflagellate Samples

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

3.4 Laboratory Analysis of the Dinoflagellate 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 mm^2; volume: 1 ml). Each dinoflagellate individuals or species encountered under the inverted microscope (ULWCD 0.30, Olympus CK2) was identified, counted and tallied into the designated tally sheet. Three (3) 1-ml subsamples were analyzed, and then the average was taken. The abundance of each phytoplankton species was calculated using the formula of Newell& Newell (1963) and Gonzales et al. (2004): Dinoflagellates samples were identified up to the species level using the references of Yamaji (1982), Umali and Cuvin (1988), Gonzales et al., (2004), and Newell and Newell (1963).

3.5 Statistical Analysis of the Data

One-Way ANOVA was used to determine the significant differences of the physicochemical parameters and the abundance of dinoflagellates between stations, Shannon-Weaner's Index was utilized for diversity analysis of dinoflagellates using PAST.

4. RESULTS and DISCUSSION

The Barobo coastal waters along the coastal zone of Lianga Bay have been traditional places for fishing, which has been a primary food source for many communities within and outside CARAGA Region. Some phytoplankton like the dinoflagellates however would serve as a parasite on fish or on other protists (Liping et al. 1985). These organisms may reproduce in such great number and at a faster rate that in some cases, the water may appear golden or red, producing a “red tide”. There has been Paralytic Shellfish Poisoning (PSP) recorded in Barobo waters caused by toxic phytoplankton bloom of *P. bahamense* in December, 1997 and continued to persist the whole year round of 1998 (Gonzales et al., 2004). This phenomenon indicates the vulnerability of the area particularly to its water quality condition for fishery resources and other beneficial organisms for food.

4.1. *Physico-chemical Parameters*

The following physicochemical factors were determined to evaluate the quality of the coastal water of Barobo coastal area: temperature, water transparency, salinity, total suspended solids, pH, water movement, dissolved oxygen, nitrate and phosphorous concentrations (Figure 2).

Temperature

Environmental temperature was done by sampling from 10:30 am to 1:00 pm. Water temperature ranged from 29.75^{o}C to 30.5^{o}C from in all stations (Figure 2a). Highest temperature was observed in Station 4, and the lowest were observed in Stations 2 and 3. There was a slight variability in temperature in all sampling stations hence; there is no significant difference on the temperature between stations.

pH

pH is the amount of hydrogen ions in the seawater. Seawater pH ranged from 7 to 8.01 and is slightly basic (Lalli and Parsons, 1993). Generally, pH of water only fluctuates at a narrow range, as it is largely regulated by the concentrations of bicarbonate and carbonate ions. Observed pH ranged from 8.1 to 8.2 (Figure 2.c), a favorable condition for phytoplankton growth. There are significant differences of pH observed between stations.

Total Suspended Solids

Turbidity (total suspended solids) varies periodically with the amount of sediment and the number of planktonic organisms in the water. Dawes (1981) suggested that the amount of suspended matter significantly influenced the quality and quantity of light that penetrates the water. As expected, the greatest turbidity was observed during the rainy season as the sediment load of streams increased as a result of erosion from land. As a consequence, increased turbidity reduced light penetration and since the depth of the coastal water varied in water depth, photosynthesis could be restricted to the surface layers, and this could reduce phytoplankton growth (Zottoli, 1978). Total suspended solids observed ranging from 25.75mg/L to 26mg/L, with the highest value seen at 26mg/L in stations 1, 2 and 3 and station 4 had the value of 25.75 mg/L in stations 1. A low value that was observed was due to less siltation from the mountain as less rain occurred during this month (Figure 2.d).

Water Movement (Speed)

Surface water movement (based on current speed and direction) plays a very significant role in the species composition of phytoplankton. The vertical circulation of open ocean water masses may be important for marine life. In upwelling, deep ocean water rich in dissolved nutrients moves up the continental slope into coastal surface waters aided by offshore wind patterns (Microsoft Encarta, 2008).

The highest current speed of water (11 cm/s) was noticed in Station 2, while the lowest current speed (0.29 cm/s) was observed in Station 3 (Figure 2.e). The directions of the water movement were all going to north due to the prevailing wind during the time of sampling.

Water Transparency

Transparency is basically affected by amount of sediments found in the water. In this study, at what depth is the water transparent or clear was investigated within and among sampling stations of the coastal waters of

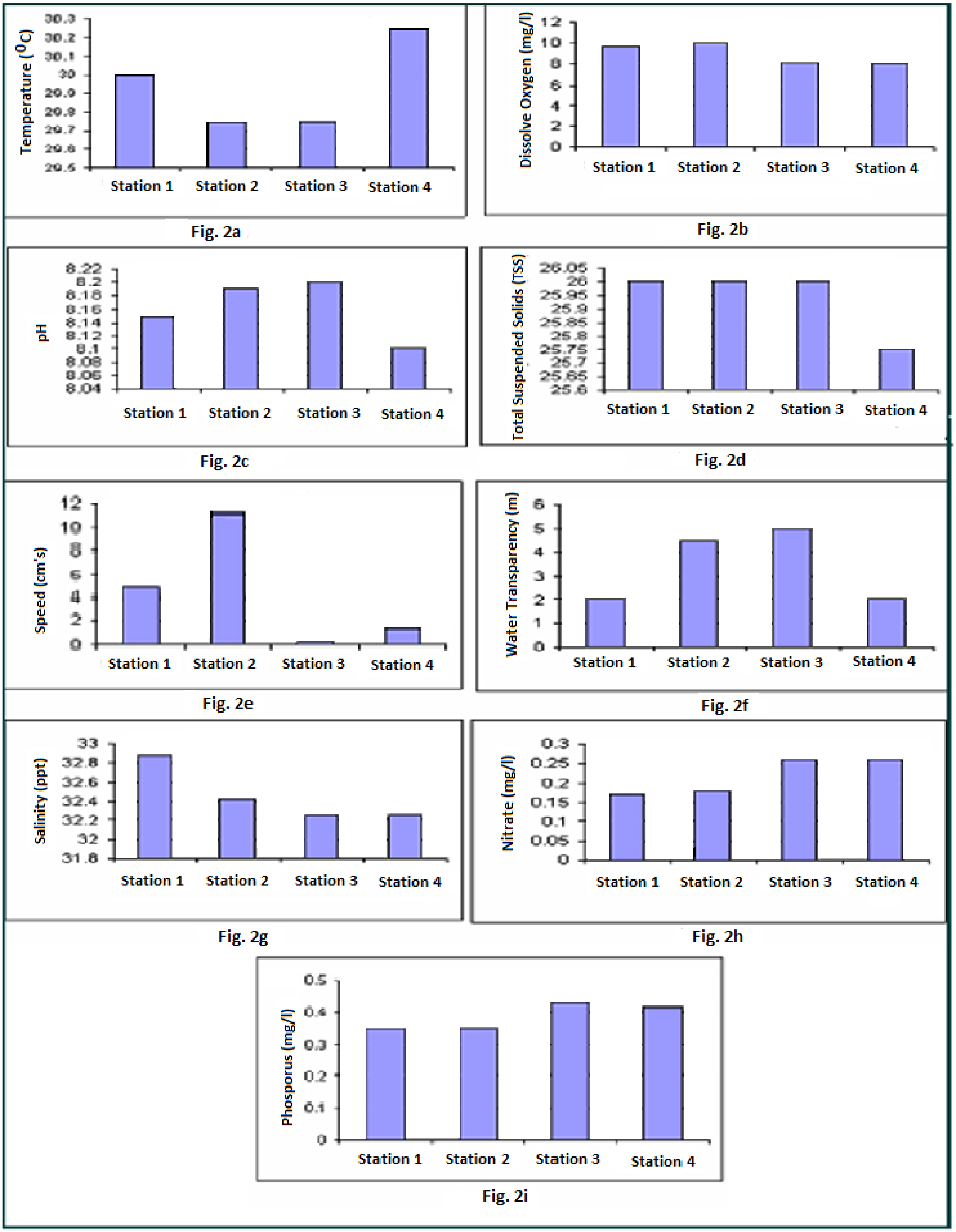

Figure 2. Physicochemical parameters of the four sampling stations

Barobo. Generally, water transparency could be related to amount of sunlight that penetrates into the water. This is affected by degree of turbidity thus could be the limiting factor of photosynthesis (Umali and Cuvin, 1988). As shown in Figure 2.f, Station 3 was observed to have the highest water transparency at 8.5 meters when compared to other stations. The lowest measure of water transparency was observed at 2 meters in stations 1 and 4.

Salinity

Salinity is the salt content of water and is greatly affected by temperature, the degree of evaporation and the amount of freshwater influx (Nybakken, 1997). Figure 2.g shows a very slight variation of salinity ranging from 32.3 to 32.9 ppt in all the sampling stations. Lowest salinity was observed in Stations 3 and 4, and the highest was in station. These two stations are nearer to the small tributaries as sources of fresh water.

Nitrate

Nitrate is one of the important nutrients that encourage growth of plankton, which serves as the base for the food chain throughout the oceans. Figure 9 shows the concentration of nitrate in four sampling stations where the highest reading (0.26mg/l) was observed in Stations 3 and 4 and the lowest (0.16mg/l) was in Station 1 (Fig. 2.h).

Phosphorous

Dissolved reactive phosphorous concentrations in four sampling stations were observed in terms of mg/l. The results showed the highest concentration of Phosphorous (0.43mg/l) was observed in Station 3. The lowest reading (0.35 mg/l) was observed in Stations 1 and 2 (Figure 2.i).

4.2 *Diversity and Abundance of Dinoflagellates*

A total of 42 dinoflagellate taxa belonging to 9 genera (*Ceratium, Peridinium, Dinophysis, Gonyaulax, Gymnodinium, Ornithocercus, Prorocentrum, Protoperidinium and Pyrocystis*) and 8 families were observed in 4 sampling stations in Barobo coastal waters in the month of October 2011. Among the dinoflagellates, 37 were identified up to species level and 5 up to genus level. *Ceratium* has the highest number of species (19) followed by *Peridinium* (12) It is noted that *Pyrocystis sp*. has the highest percent abundance followed by *Pyrocystis fusiformis.* (Table 1).

Ten dinoflagellate species were noted common in all stations including 6 species of *Ceratium.* This species was the most important in terms of number present followed by *Peridinium.* The presence of poor water quality indicator species, *Ceratium spp.*was observed in all sampling stations. Since *Ceratium spp*. are common dinoflagellates in coastal waters (McCormick and Thiuvathukal, 1981), their presence is a normal occurrence .

Station 4 had the highest number of dinoflagellate taxa (41) with a total of 305 individuals. Station 4 is located near the mouth of the tributary, which could influence the number of dinoflagellate species present. It maybe influenced also by the movements of water that tend to affect the population density and composition of phytoplankton since these organisms have little or no capacity of large horizontal driving force to move against the surface current of the ocean for dispersal (Harvey et al., 1935).

The lowest number of taxa (17) was observed in Station 1. Station 3 had the highest number of individuals (389), and though ranked the second in terms of the number of taxa (34), such would conform that the production of dinoflagellates varies to latitude, season and time of the day (Dawes, 1981).

There was significant difference ($p < 0.01$) abundance between stations (F value of 5.129

Table 1. Dinoflagellate species in four sampling stations

Species	S1	S2	S3	S4	Total	% Abundance
1. *Ceratium arcticum* (Ehrenberg) Cleve	2	2	24	41	69	8.00
2. *Ceratium candelabrum* (Ehrenberg) Stein	3	5	21	46	55	6.20
3. *Ceratium carriense* (Gourret)	2	2	1	12	17	2.00
4. *Ceratium contortum* (Gourret) Cleve	0	2	0	10	12	1.40
5. *Ceratium extensum* (Gourret) Cleve	1	0	2	14	17	2.00
6. *Ceratium furca* (Ehrenberg) Claparede et Lachmann	2	3	2	5	12	1.40
7. *Ceratium fusus* (Ehrenberg) Duujardin	0	0	2	3	5	0.60
8. *Ceratium gracile* (Gourret) Jorgensen	1	0	1	1	3	0.34
9. *Ceratium inflexum* (Gourret) Kofoid	0	1	1	2	4	0.45
10.*Ceratium kofoidii* (Jorgensen)	1	1	1	3	6	0.70
11. *Ceratium longipes* (Bailey) Gran	2	0	0	2	4	0.45
12. *Ceratium lanula* (Schimper)	0	0	0	1	1	0.11
13. *Ceratium macroceros* (Ehrenberg) Vanhoffer	0	1	1	3	5	0.60
14. *Ceratium palmatum* (Schroder)	0	0	1	1	2	0.23
15. *Ceratium pentagonium* (Gourret)	0	1	1	1	3	0.34
16. *Ceratium strictum* (Okamura & Nishikawa) Kofoid	0	1	1	1	3	0.34
17. *Ceratium trichoceros* (Gourret) Kofoid	0	3	2	2	7	1.00
18. *Ceratium tripos* (Muller) Nitzsch	3	3	3	4	13	1.50
19. *Ceratium vultur* (Schroder) Jorgensen	0	1	0	1	2	0.23
20. *Dinophysis homunculus* (Stein)	0	0	1	1	2	0.23
21. *Dinophysis schroderi* (Pavillard)	0	0	1	1	2	0.23
22. *Dinophysis sp.*	0	2	2	5	9	1.02
23. *Gonyaulax sp.*	0	0	1	1	2	0.23
24. *Gymnodinium sp.*	0	0	0	1	1	0.11
25. *Ornithocercus magnificus* (Stein)	12	25	32	28	97	11.0
26. *Peridinium depressum* (Bailey)	0	0	23	1	24	3.00
27. *Peridinium excentricum* (Paulsen)	0	1	1	2	4	0.45
28.*Peridinium grande* (Kofoid)	0	0	41	1	42	5.00
29. *Peridinium granii* (Ostenfeld)	0	0	12	1	13	1.50
30. *Peridinium longipes* (Karsten)	0	0	23	1	24	3.00
31. *Peridinium oceanicum* (Vanhoffer) Balech	0	0	1	1	2	0.23
32. *Peridinium pallidum* (Ostenfeld)	0	0	0	1	1	0.11
33. *Peridinium puncutulatum* (Paulsen)	0	1	0	1	2	0.23
34. *Peridinium rectum* (Kofoid) Pavilliard	0	0	1	1	2	0.23
35. *Peridinium sp.*	2	0	0	2	4	0.45
36. *Peridinium steinii* (Jorgensen)	0	0	1	1	2	0.23
37. *Peridinium tripos* (Murray &Whitting)	1	0	0	1	2	0.23
38. *Prorocentrum micans* (Ehernberg)	0	23	43	21	87	10.00
39. *Protoperidinium oceanicum* (Vanhoffer) Balech	0	1	1	0	2	0.23
40. *Pyrocystis fusiformis* (Schroden)	8	14	54	28	104	12.0
41. *Pyrocystis noctiluca* (Murray)	5	23	43	20	91	10.30
42. *Pyrocystis sp.*	9	22	44	32	107	12.10
TOTAL	**54**	**138**	**389**	**305**	**886**	**100**

and a p value of 0.002041). To provide a visual representation of the pattern of proximities among the abundance of species, multivariate Non-Metric Multidimensional Scaling (NMMDS) was conducted. Analysis by Non-Metric Multidimensional Scaling (NMMDS) showed clear differences between stations in the abundance of the 42 taxa (Figure 3). The NMMDS configuration plot for all taxa appears to show 5 distinct groups (Fig. 3). All the most common species present in the largest cluster were persistent and did not appear to be closely linked with individual stations.

Results in Table 2 show the different levels of the diversity of dinoflagellates 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 Shannon_H index of diversity, the trend is S4>S3>S2>S1. The trend of the number of taxa and diversity are

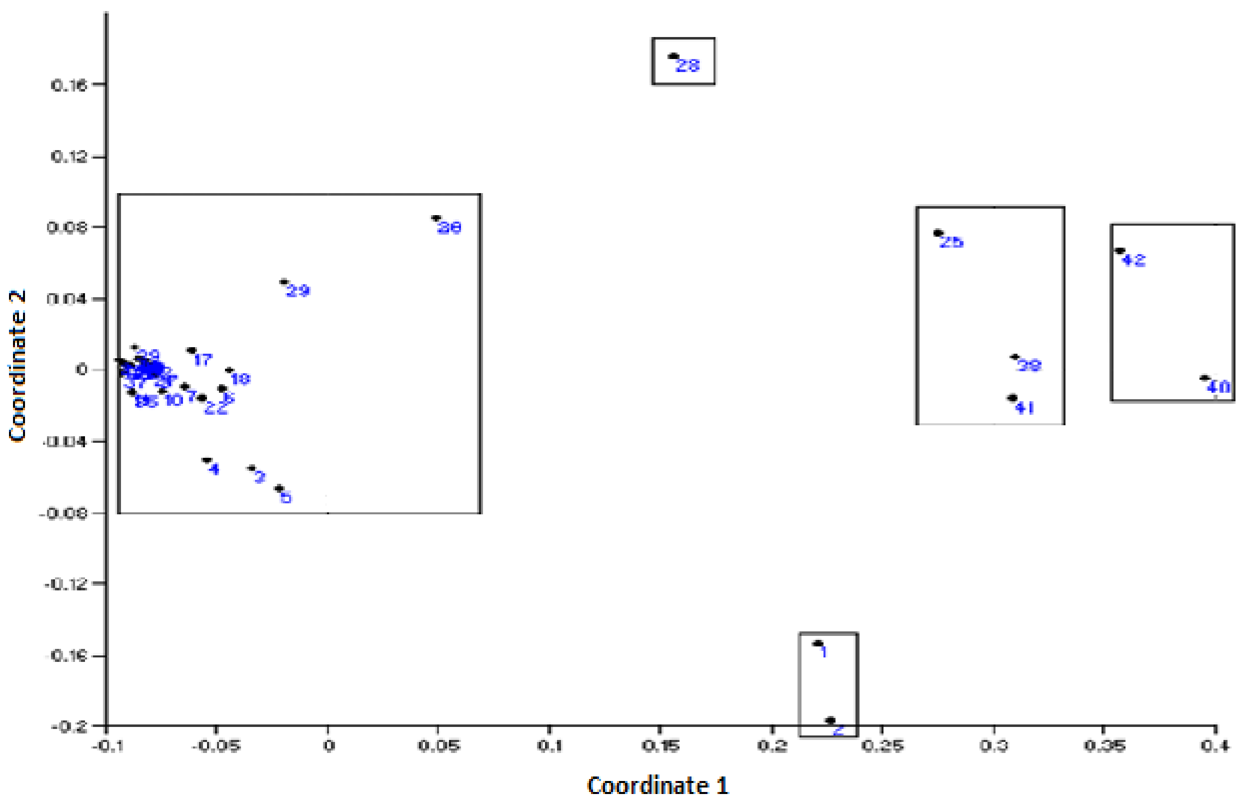

Figure 3. Non-metric multidimensional scaling (NMMDS) ordination of 42 dinoflagellate species based on the configuration of the scaling analysis for the four stations

Table 2. Diversity Indices of Dinoflagellates (Species richness, index of dominance, Shannon's index, Evenness Index) in the 4 sampling stations.

	Station 1	**Station 2**	**Station 3**	**Station 4**
Taxa_S	15	22	33	41
Individuals	54	138	389	305
Dominance_D	0.1221	0.1281	0.08934	0.08388
Shannon_H	2.363	2.368	2.64	2.842
Evenness-e^H/S	0.7082	0.4854	0.4245	0.4182

similar while the number of individuals noted otherwise with a trend of S3>S4>S2>S1. These results revealed that abundance is not directly correlated with high diversity.

The diversity and abundance of the different families of dinoflagellates were also analyzed. Table 3 shows the different levels of diversity of *Ceratium spp.* where Station 4 had the highest number of taxa and the lowest was observed in station 1. The trend for the number of *Ceratium* individuals is S4>S3>S2>S1 while the trend of diversity is S2>S4>S1>S3, which further revealed that an abundance of taxa is not directly correlated with high diversity.

The diversity of *Peridinium* was also observed. Table 4 shows the trend of the number of taxa of *Peridinium spp.*, S4>S3>S2=S1, while the number of individuals has the trend, S3>S4>S1>S2. However, based on the Shannon diversity index the trend is S4>S3>S2>S1.

The dynamics of rapid increase or decrease of plankton populations is an important subject in marine plankton ecology and generally fascinated many plankton ecologists. Many studies have shown that high nutrient levels and favorable conditions play a key role in rapid growth of algae.

In contrast, low nutrient concentrations as well as unfavorable conditions limit their growth. It is claimed that the water must contain high levels of inorganic nutrients (nitrogen and phosphorus) for the algae to feed on and also water temperature and salinity levels must be within a certain range to be conducive to planktonic growth.

Table 3. Diversity indices of *Ceratium* (species richness, index of dominance, Shannon's index, evenness index) in the 4 sampling stations

	Station 1	**Station 2**	**Station 3**	**Station 4**
Taxa_S	9	13	15	19
Individuals	17	26	64	153
Dominance_D	0.128	0.1036	0.2563	0.1847
Shannon_H	2.119	2.408	1.83	2.117
Evenness-e^H/S	0.925	0.855	0.4156	0.437

Table 4. Diversity Indices of *Peridinium* (species richness, index of dominance, Shannon 's index, evenness index) in the 4 sampling stations

	Station 1	**Station 2**	**Station 3**	**Station 4**
Taxa_S	2	2	8	12
Individuals	3	2	103	14
Dominance_D	0.5556	0.5	0.2721	0.09184
Shannon_H	0.6365	0.6931	1.467	2.441
Evenness-e^H/S	0.9449	1	0.5419	0.9571

The results of this study that showed variations in abundance, number and diversity within sampling sites clearly indicates spatial changes in species composition of dinoflagellates. This could be attributed to variations in inorganic nutrients present in the sampling sites, and the unintentional introduction of new species from other parts of the world due to ballast of ships that carry water with microscopic algae.

The physicochemical properties like water temperature and salinity of the sampling sites were within range and the similarities and variations in taxonomic compositions of dinoflagellates. Other potential causes may include variations in light, advection and turbulence, nutrients, production of resting stages, ectocrines, and predation, as well as water mass movement. In the present study, correlation analysis of the physicochemical parameters and abundance of dinoflagellates could not become possible in this study since sampling was conducted once only. However, due to some other factors that prove that other species could be introduced to a particular area within and outside the coastal areas around the world, this study has a big impact to monitor the new species of dinoflagellates introduced into the coastal waters of Barobo for mitigating measures and environmental management.

5. CONCLUSIONS

A total of forty five (45) dinoflagellate taxa were recorded in the coastal waters of Barobo during the month of September 2009. There were 886 total number of individuals with *Pyrocystis sp.* had the highest count with the percentage abundance of 12.19. Out of 42 taxa, 10 were common in all sampling stations where *Ceratium* dominated the species composition followed by *Peridinium.* Then the abundance of dinoflagellate species are still at the normal scenario that could be considered out of its harmful effect to the organisms at the higher trophic levels however, due to the high diversity of dinoflagellate species in this area harmful algal bloom is potential.

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