Research Article

Phytoplankton Community Composition of Carigara Bay, Leyte and its Freshwater Tributaries

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ABSTRACT

Carigara Bay is one of the acclaimed richer fishing waters in the entire Philippines because of its multi-gear fishery system. Filipinos living around the bay considered its marine life as one of their livelihood. However, the biodiversity of phytoplankton are still unexplored evident by the dearth of published data in scientific journals. Thus, this study was undertaken. Sampling was conducted on the five coastal towns surrounding the bay and its freshwater tributaries are Lindog and Bislig River found in Brgy. Uyawan and Bislig respectively situated in Carigara, Himanglos and Canomantag River in Brgy. Hilaba and Canomantag in Barugo, stream located in Brgy, Libertad, Capoocan, Caraycaray River and Lipasan Falls in Brgy. Caraycaray and Pinarigusan in San Miguel and Tula-an and Busay Falls in Brgy. Tula-an and Busay in Babatngon. Water samples were collected using a 2.5-3L Plexi glass sampler, transferred in three 1L cap bottle and brought in the laboratory for phytoplankton identification. Physico-chemical parameters were also gathered in all sampling sites to correlate with the phytoplankton density. Data were subjected to statistical analyses such as two way ANOVA. Results showed that there are three phyla quantified such as Bacillariophyta, Chlorophyta and Cyanophyta which are 44, 37 and 19% of the total phytoplankton. These were correlated with the physico-chemical parameters where in there was a significant positive correlation between water pH (r = 0.499; p = 0 .001), conductivity (r=0.519; p=0.001) and amount of phosphates (r = 0.446; p = 0.003) to the total cell density of all the three groups of phytoplankton identified.

Key words: Bacillariophyta, Freshwater resources, Microalgae, Physico-chemical parameters, positive correlation.

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INTRODUCTION

Algae have approximately about 50,000 species and more, but only half of the total species are known taxonomically. Microalgae or commonly known as phytoplankton are the base or bottom of the aquatic food chain that produce food and natural nutrients for many vertebrates and invertebrates living in the freshwater and marine niches.[1] These producers cover 75% of the total species and contribute half of the total percentage of oxygen in the atmosphere. In addition, microalgae are considered to be major indicators of oceanic health and water quality.[2] This is shown by the green water technique wherein phytoplankton are introduced in the ponds of reared aquatic animals for survival, growth and development.[3] This technique is necessary for the improvement of water quality such as pH, turbidity and dissolved oxygen, immunity and other health conditions, larval metamorphosis and regulation of bacterial species and other pathogenic organisms.[4] More importantly, only 15 micro algal species are involved in the current commercial production such as feed, food and other important products in various fields and industries yet they are thought of as the most poorly studied group of aquatic organisms. Carigara Bay, one of the richer fishing

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waters in the Philippines, is located in the Province of Leyte, Region 8 or the Eastern Visayas. Its freshwater tributaries such as streams and rivers emptying into the Pacific Ocean, keeps the marine life moist in condition over many months.[5] The bay itself and its freshwater resources abound with a diversity of organisms, but poorly studied as shown by dearth of reports. In fact, the study on the assessment of water quality and initial identification of zooplankton and phytoplankton is solely the existing biological report about Carigara bay.[6] Thus, this study on the identification and assessment of phytoplankton in Carigara Bay and freshwater resources in its vicinity easily serves as baseline information for future studies. The objectives of this study included the following: identify and quantify phytoplankton found in Carigara bay and its freshwater tributaries and correlate the phytoplankton density to the physico-chemical parameters at the different sampling stations established.

METHODOLOGY

Sampling Sites

Carigara bay located in Leyte, a sister island of Samar is one of the biggest land masses in the Philippines. Carigara bay is connected by freshwater tributaries in the five (5) coastal towns surrounding the marine life. Fourteen (14) stations were established at the upper coastal towns adjoining the Carigara Bay (Figure 1). Station 1 was the Carigara Bay at Brgy. Libertad (Capoocan) (11°39'N 124°53'E); Station 2 was a stream at Brgy. Libertad (Capoocan) (11°37'N 124°52'E); Station 3 Carigara Bay at Brgy. Visoria (Carigara) (11°30'N 124°68'E); Station 4 was the Lindog River at Brgy. Uyawan (Carigara) (11°27'N 124°66'E); Station 5 was the Bislig River at Brgy Bislig (Carigara) (11°29'N 124°67'E); Station 6 was the Carigara Bay at Brgy. Duka (Barugo) (11°36'N 124°78'E); Station 7 was the Himanglos River at Brgy. Hilaba (Barugo) (11°31'N 124°73'E); Station 8 was the Canomantag River at Brgy. Canomantag (Barugo) (11°30'N 124°71'E); Station 9 was the Carigara Bay at Brgy. Mawod-pawod (San Miguel) (11°19'N 124°51'E); Station 10 was the Caraycaray River at Brgy. Caraycaray (San Miguel) (11°20'N 124°52'E); Station 11 was the Lipasan Falls at Brgy. Pinarigusan (San Miguel) (11°21'N 124°53'E); Station 12 was the Carigara Bay at Brgy. Kalangawan Guti (Babatngon) (11°23'N 124°51'E); Station 13 was the Tula-an Falls at Brgy. Tula-an (Babatngon) (11°24'N 124°52'E) and Station 14 was the Busay Falls at Brgy. Busay (Babatngon) (11°25'N 124°53'E).

Collection of Water Samples

The water samples were collected during July 2-8, 2018 which was considered as the 1st sampling and on November 23-26, 2018, the 2nd sampling. Collection of water samples from the bay was done by towing 30 meters away from the shoreline. The water samples from the bay for phytoplankton qualitative and quantitative analyses were gathered 30 meters away from the shoreline with a depth of 1-1.5 meters only. For the freshwater tributaries of the bay, the water samples were collected in integrated manner, thus, from surface, middle and approximately 0.5 meter away from the bottom. Most have depths ranging from 0.75- 2 meters. Depths were measured using the plexi glass sampler attached to a rope with measurement in meters and/or the sec chi disk. The 3L water samples from the river/falls were apportioned for the different analyses from which 1L was taken for phytoplankton analysis and fixed with Lugol's solution to preserve the cell wall of phytoplankton; 1L was kept cold during the transport at University of Santo Tomas, Manila and immediately stored in freezer or placed in a refrigerated condition upon arrival in the laboratory for *ex situ* nutrient determination of the water samples such as nitrate and phosphates. The other 1L was used as a live sample for plankton verification. Furthermore, prior to collection, physical parameters such as surface water temperature, column depth, light penetration or transparency and chemical parameters such as water pH, conductivity and dissolved oxygen were recorded *in situ*. All of the parameters were measured using the Explorer GLX (PAASCO) water quality instrument except for the light penetration or transparency which was determined using a Secchi disc. In addition, analyses of nitrogen and phosphorus were measured using the spectrophotometer (Hach DR/2010) at the Roque Laboratory, Old Graduate School, University of Santo Tomas.

Qualitative and Quantitative Analyses of Phytoplankton

For quantification, an appropriate amount of phytoplankton sample was loaded in a Neubauer Counting Chamber for density determination as viewed using the Olympus CH20 compound light microscope.[7,8,9] For qualitative determination of phytoplankton, several references on algal taxonomy and biodiversity were used such as the following: Taxonomy and Ecology of Algae in Fishponds and Fishpens of Laguna and some Physiological Studies of Navicula accomoda Hust; [10] Taxonomy of the Freshwater Algae of Laguna de Bay and Vicinity;[11] Illustrations of the Freshwater

Plankton of Japan;[12] Algae of the Western Great Lakes Area;[13] and How to Know the Freshwater Algae.[14]

Statistical Analyses

Statistical analysis such as the Two-way ANOVA with replication was used to compare the physico-chemical parameters of the 9 freshwater ecosystems. Pearson's Correlation was applied to determine the relationship between the cell density of phytoplankton and the physico-chemical parameters of the sampling sites. Mean and standard deviations were used to summarize the data in quantitative form such as surface water temperature, column depth, light penetration, pH, conductivity, and dissolved oxygen for water quality as well as the amount of nutrients in the water samples such as nitrates and phosphates.

RESULTS

Phytoplankton Groups and Composition

The percentages of the different phytoplankton groups are shown in Figure 2 with a total of 28 phytoplankton were represented by diverse groups: 44% Bacillariophyceae, 37% Chlorophyceae and 19% Cyanophyceae. Bacillariophytes or diatoms dominated the area where 44% of the total percentage of phytoplankton were observed.

Meanwhile, Tables 1 and 2 present the list of phytoplankton genera found in all sampling stations monitored in July and November 2018. Most of the identifed phytoplankton genera are under the Phylum Bacillariophyta and few from the Phylum Chlorophyta. The most common genera observed for Diatoms are *Fragilaria* sp., *Navicula* spp., *Nitzschia* sp. and *Synedra* sp.; for the Green algae, *Stigeoclonium* sp. and *Chlorella* sp. were identified and finally for the Blue-green algae, *Merismopedia* spp. and *Oscillatoria* spp. were documented.

Furthermore, Figure 3 presents the similarities and differences of the phytoplankton composition during the 2 months of sampling. Diatoms such as *Navicula* sp., *Nitzschia* sp., *Stauroneis* sp., *Synedra* sp., *Fragilaria* sp.; only *Stigeoclonium* sp. for green algae and *Oscillatoria* spp. and *Merismopedia* sp. were observed and quantified both in the sampling months. More phytoplankton genera have identified on the month of July compared on the month of November. More so, there was no blue-green algae unique on the said month.

The 3 groups of phytoplankton, Bacillariophyta, Chlorophyta and Cyanophyta were all present in the 5 stations established in Carigara bay on the month of July and November 2018. Figure 4 and 5 summarize the cell density of the different algal groups found in the sampling stations of the said bay. The Chlorophyta groups in Stations 1 and 6 dominated and gave the highest cell density compared to other phytoplankton in July 2018. Also, the Cyanophyta groups in Stations 9 and 12 had the highest cell density compared to other phytoplankton in November 2018.

Meanwhile, Figure 6 and 7 detail the cell density of phytoplankton recorded in all the freshwater tributaries of Carigara bay respectively. *Stigeoclonium* sp., a filamentous Chlorophyta identified in Stations 2 and 7 gave the highest cell density, followed by the *Oscillatoria* sp., a filamentous blue-green algae which is found in all stations except station 5. Moreover, *Schizomeris* sp. was quantified at station 4 only. To highlight, *Oscillatoria* sp. gave the highest cell density during the month of November 2018.

Finally, the cell density of the 3 phyla of phytoplankton found in Carigara Bay were totaled and analyzed. Chlorophytes have the highest cell density of $12x10^3$ cells/ml in the month of July and Cyanophytes have $2x10^3$ cells/ml on the month of November. This is directly proportional to the cell density of the phytoplankton genera observed in all sampling freshwater stations of Carigara Bay where $2.5x10^3$ cells/ml and $3.5x10^3$ cells/ml of Chlorophytes and Cyanophytes respectively. *Oscillatoria* sp. and *Merismopedia* sp. (Cyanophyta) and *Stigeoclonium* sp. and *Chlorella* sp. (Chlorophyta) gave the highest cell density to the total cell density of the 2 highest phyla. Also, *Nitzschia* sp. and *Fragilaria* sp. have the highest cell density in Phylum Bacillariophyta.

Effects of the Physico-Chemical Parameters

The variety of these biological organisms in certain ecosystems like the freshwater and marine is attributed to biotic and abiotic factors. These are the physico-chemical parameters and the type of ecological features which are bounded in the sampling areas in order to understand and explore the variety of living organisms present in the said locations.[15] Table 3 displays the correlation analysis on the mean values of the physico-chemical parameters and the total cell density of the 3 phyla namely Bacillariophyta, Chlorophyta and Cyanophyta.

As demonstrated in the table, the total cell density of the Cyanophyta (blue-green algae) gave no significant correlation (*p= 0.01; 0.05)* to all the physico-chemical parameters. In contrast, the Bacillariophytes (diatoms) are positive and negatively correlated significantly to conductivity, r=390; p=0.11 (Mean= 264.14; SD=295.75) and dissolved oxygen, r=-0.339; p=0.028 (Mean=7.76; SD=1.82) respectively. Furthermore, the Chlorophytes (green algae) are positively correlated to water pH, *r*=0.49; *p*= 0.001 (Mean= 8.20; SD=0.40), conductivity, *r*= 0.53; *p*=0.00 (Mean=264.14; SD= 295.75) nutrients such as nitrates, *r*=0.307; *p*=0.048 (Mean=3.22; SD= 2.83) and phosphates, *r*=0.427; *p*=0.005 (Mean=5.22; SD= 3.83) significantly and negatively correlated to dissolved oxygen, *r*= -0.353; *p*= 0.022 (Mean= 7.76; SD= 1.82) significantly. Meanwhile, Table 4 summarizes the correlation analysis on the mean of the physico-chemical parameters and the total cell density of phytoplankton found in Carigara bay and its freshwater tributaries.

The table above showed that there was a significant positive correlation between water pH (Mean = 8.20; SD = 0.40) and the total number of phytoplankton found in the water sample (M = 16.88; SD = 15.86), *r* = 0.499; *p* = 0 .001. Same results were obtained between conductivity (Mean= 264.14; SD=295.75) and the total number of phytoplankton, *r*=0.519; *p*=0.001. It was also found out that a significant positive correlation between the amount of phosphates (Mean= 5.22; SD= 3.83) and the total number of micro algal cells found in the water sample, *r* = 0.446; *p* = 0.003. This means that increasing the water pH, conductivity and amount of phosphates in the water samples will lead to an increase in the number of micro algal cells found in the water sample. On the other hand, there was a negative correlation between the amount of dissolved oxygen (Mean= 7.76; SD= 1.82) and total number of micro algal cells, *r*=-0.351; *p*=0.023. This means that a higher amount of dissolved oxygen in water will result to a corresponding decrease in the total number of phytoplankton in the water sample. Finally, no significant relationships were observed between the total cell density of phytoplankton and the following parameters: water temperature (Mean= 29.10; SD= 3.20), column depth (Mean= 0.9464; SD= 0.50), light penetration (Mean= 0.65; SD= 0.25) and nitrate content (Mean= 3.22; SD= 2.83). This means that changes in these parameters do not affect the total amount of phytoplankton cells in the water samples.

DISCUSSION

Phytoplankton represent an exceptional, diverse and ubiquitous array of organisms but highly specialized group adapted in many ecological and environmental changes.The phytoplankton composition in Carigara Bay and its freshwater resources signifies the strong latitudinal, longitudinal and altitudinal gradients in

Table 1: List of phytoplankton genera identified in various stations collected in July 2018.

Stations	Bacillariophyta	Chlorophyta	Cyanophyta
1 (Carigara Bay, Brgy. Libertad, Capoocan)	*Coscinodiscus* sp. *Cymbela* sp. *Fragilaria* spp. *Melosira* sp. *Navicula* spp. *Nitzschia* spp. *Synedra* sp. *Coconeis* sp.	*Chlorella* spp. *Sphaerocystis* sp. *Stigeoclonium* sp.	*Merismopedia* spp. *Nostoc* sp. *Oscillatoria* spp.
2 (Stream, Brgy. Libertad, Capoocan)	*Stauroneis* sp.	*Stigeoclonium* spp.	*Merismopedia* sp. *Oscillatoria* sp.
3 (Carigara bay, Brgy. Visoria, Carigara)	*Cocconeis* sp. *Fragilaria* sp. *Navicula* sp. *Nitzschia* spp. *Synedra* sp.	*Ulothrix* sp.	*Merismopedia* sp. *Oscillatoria* spp.
4 (Lindog River, Brgy. Uyawan, Carigara)	*Navicula* sp.	*Schizomeris* sp. *Stigeoclonium* spp.	*Lyngbya* sp. *Merismopedia* sp. *Oscillatoria* sp.
5 (Bislig River, Brgy. Bislig, Carigara)	*Navicula* spp. *Nitzschia* sp.		*Merismopedia* sp. *Oscillatoria* sp.
6 (Carigara bay, Brgy. Duka, Barugo)		*Chlorella* sp.	*Oscillatoria* sp. *Merismopedia* spp.
7 (Himanglos River, Brgy. Hilaba, Barugo)	*Coconeis* sp. *Fragilaria* sp.	*Stigeoclonium* sp.	*Lyngbya* sp. *Merismopedia* sp. *Oscillatoria* spp.
8 (Canomantag River, Brgy. Canomantag, Barugo)	*Fragilaria* sp.	*Chlorella* sp.	*Oscillatoria* spp. *Merismopedia* sp. *Chroococcus* sp. *Lyngbya* spp.

freshwater and marine ecosystem across the world.[16,17] Diatoms are micro algal organisms which contain silica shells or frustules with different shapes and various sizes. They are one of the major sources of food in the aquatic environment both in fresh and marine waters. Diatoms can be also used for the present water quality conditions to the previous and future water quality trends.[18] The sediments in water bodies hold chemical and biological clues to the environment and water quality of the past and present can be determine as long as the dead and living diatoms are found in the substrate. Noteworthy, Diatoms in the first centimeter represent the current condition of the water, while the Diatoms found in deeper sediment are representative of past water quality. The high reproductive rates of diatoms make them respond quickly to environmental changes and many diatom species, as well, have specific tolerances for water quality. In addition, the dominance of Bacillariophytes is attributed to the high concentration of silica, while the high amount of nitrate, phosphate and sulfate increase the abundance of Chlorophytes and Cyanophytes[19] where 37 and 19% respectively are composed of the said phytoplankton in the sampling stations. Moreover, it is also recognized the predominance of diatoms over chlorophytes and cyanophytes[20] to the increased pollution in water bodies such as bay, rivers, falls and other types of freshwater resources. The high number of diatoms in the area both in Carigara Bay and its freshwater tributaries pictures water pollution due to the many anthropogenic disturbances. Most of the stations are situated around local communities of the 5 coastal towns of Leyte surrounding the Carigara Bay. In particular, the bay around the town of Carigara is proximate to the market where water and habitat pollutions are likely to escalate. In contrast, the Department of Environment and

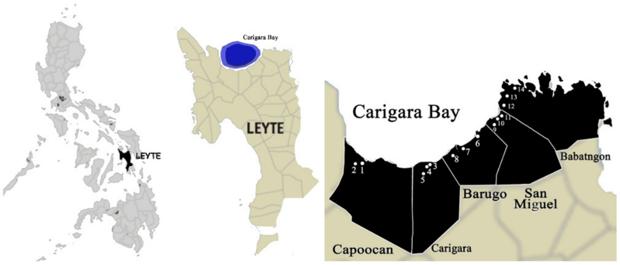

Figure 1: Fourteen (14) Sampling Stations at Carigara bay and its Freshwater Resources.

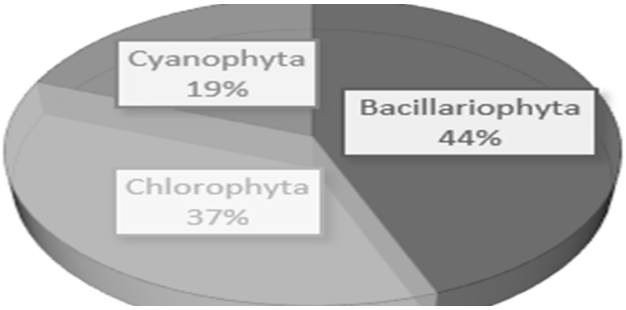

Figure 2: Percentages of all the phytoplankton identified.

Table 2: List of phytoplankton genera identified in various stations collected in November 2018.

Stations	Bacillariophyta	Chlorophyta	Cyanophyta
9 (Carigara Bay, Brgy. Mawod-pawod, San Miguel)	*Navicula* sp. *Nitzschia* sp.	*Coelastrum* sp.	*Merismopedia* spp. *Oscillatoria* spp.
10 (Caraycaray River, Brgy. Caraycaray, San Miguel)	*Fragilaria* sp. *Gomphonema* sp. *Navicula* sp.		*Oscillatoria* spp.
11 (Lipasan Falls, Brgy. Pinarigusan, San Miguel)	*Fragilaria* sp. *Gomphonema* spp. *Navicula* spp. *Nitzschia* spp. *Stauroneis* spp.		*Merismopedia* spp. *Oscillatoria* sp.
12 (Carigara bay, Brgy. Kalangawan Guti, Babatngon)	*Fragilaria* spp. *Nitzschia* sp.	*Closteridium* sp.	*Merismopedia* sp. *Oscillatoria* sp.
13 (Tula-an Falls, Brgy. Tula-an, Babatngon)	*Diploneis* sp. *Neidium* sp. *Nitzschia* spp. *Synedra* sp.	*Closteridium* sp. *Pediastrum* sp. *Stigeoclonium* spp.	*Oscillatoria* sp. *Merismopedia* spp.
14 (Busay Falls, Brgy. Busay, Babatngon)	*Fragilaria* sp. *Synedra* sp.	*Closterium* sp.	*Oscillatoria* spp. *Merismopedia* spp.

Natural Resources still classified Carigara Bay as Class SC (DENR Administrative Order 2016 No. 08) which is intended for boating, fishing, mangrove areas and as well as the propagation, growth of aquatic resources such as fishes and for the sustainability of fishing industry in the said area. This DENR administrative order defines also various Water Quality Guidelines (WCG) which are useful for the maintenance and preservation of the quality of all water bodies in the country to prevent unwanted circumstances like water pollution, contamination in all biological aspects and heavy sedimentation in the area. Moreover, according to the DENR- Administrative Order 2016-08, the freshwater resources connected in Carigara Bay were

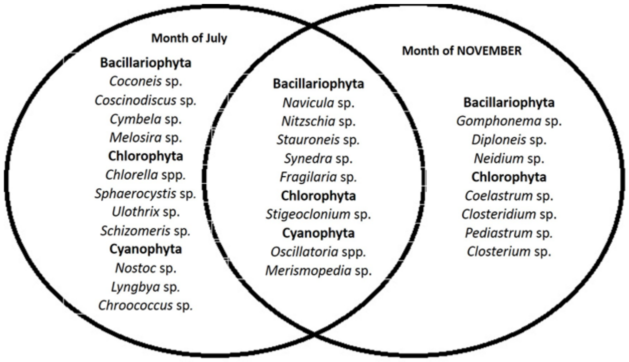

Figure 3: Venn Diagram of Phytoplankton composition during the month of July and November 2018.

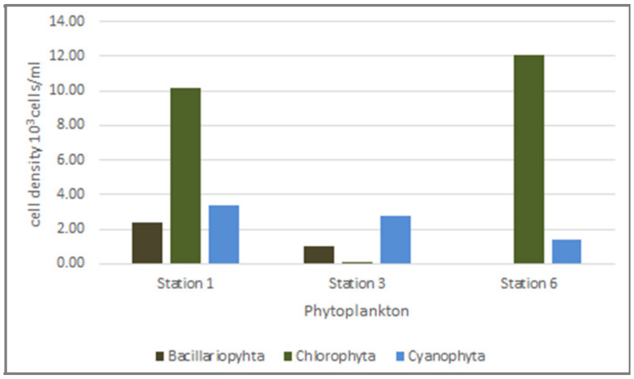

Figure 4: Cell density of phytoplankton in Stations 1, 3 and 6 in July 2018.

Table 3: Correlation Analysis on the Mean of the Physico-chemical Parameters and the total cell density of each phylum.

Physico-chemical Parameters	Mean	Standard Deviation	Correlation Analysis (*N*=42)	Bacillariophyta (1x10^{-4} cells/ml)	Chlorophyta (1x10^{-4} cells/ml)	Cyanophyta (1x10^{-4} cells/ml)
Surface Water Temperature, °*C*	29.10	3.20	Pearson correlation	-0.20	0.22	-0.07
			Sig (2-tailed)	0.20	0.16	0.64
Column Depth, *meters*	0.9464	0.50	Pearson correlation	0.10	-0.067	-0.012
			Sig (2-tailed)	0.53	0.674	0.91
Light Penetration, *meters*	0.65	0.25	Pearson correlation	-0.166	-0.144	0.21
			Sig (2-tailed)	0.293	0.362	0.18
Water pH	8.20	0.40	Pearson correlation	0.178	0.49**	0.22
			Sig (2-tailed)	0.258	0.001	0.15
Conductivity, *Siemens per meter*	264.14	295.75	Pearson correlation	0.390*	0.53**	0.043
			Sig (2-tailed)	0.11	0.00	0.789
Dissolved Oxygen, *mg/L*	7.76	1.82	Pearson correlation	-0.339*	-0.353*	-0.009
			Sig (2-tailed)	0.028	0.022	0.954
Nitrates, *mg/L*	3.22	2.83	Pearson correlation	0.015	0.307*	-0.065
			Sig (2-tailed)	0.924	0.048	0.68
Phosphates, *mg/L*	5.22	3.83	Pearson correlation	0.112	0.427**	0.26
			Sig (2-tailed)	0.48	0.005	0.094

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

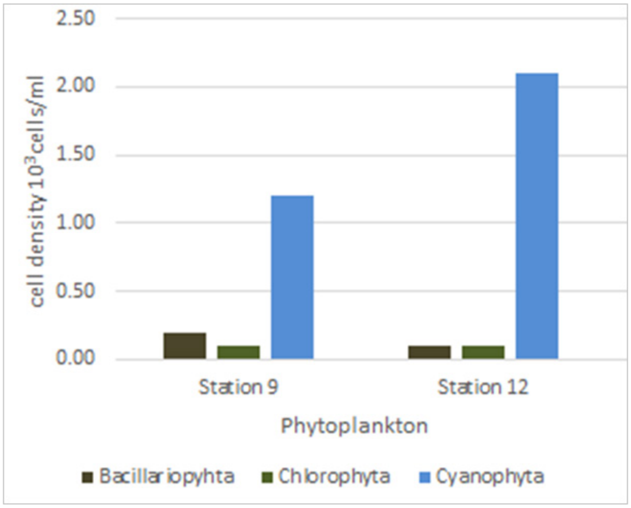

Figure 5: Cell density of phytoplankton in Stations 9 and 12 in November 2018.

also designated as Class C. These are used for the propagation and growth of fishes and other aquatic resources as well as for boating, agriculture, irrigation and livestock watering. Indeed, despite the pollution and contamination of the bay and its freshwater resources, DENR assures the implementation of its objectives specifically the water quality management entire the Philippines.

More so, the physico-chemical parameters of the 14 stations were summarized and analyzed. Temperature is one of the primary parameters which are required for the monitoring of water bodies according to the Water Quality Guidelines (WCG) of the administrative order set by DENR. WCG set the standard temperature for Class SC and C, these include Carigara bay and its freshwater resources respectively ranging from 25-31°C. This means that most of the water temperatures of Carigara Bay and its resources are in accordance with the standard temperature. For the column depth and light penetration where water samples were taken, most of the stations have 0.75m-1.0m and 0.50-0.75m depths and penetration respectively. These factors are necessary for the phytoplankton population distribution and absorbance of light in the water column.[21] pH is critical to aquatic life because it is also one of the several factors for the survival of living organisms. Most of the stations have pH of 8.25-8.75, thus, in accordance to the pH 6.5 to 8.2 which are ideal for many aquatic organisms. The highest pH that aquatic organisms can thrive is 8.50-8.55 in the upper layer most especially during summer season.[22] Freshwater studies suggested that species succession is determined by the ability of certain species to proliferate at high pH. High and low pH are associated with increase and decrease of phytoplankton correspondingly.[23] Moreover, conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, sulfate, nitrate and phosphate anions (negative charge) and sodium, magnesium, calcium (positive charge). This physical factor is also affected by temperature. Temperature and conductivity are directly proportional to each other. The conductivity in freshwater ranged from 10 to 1000 but not exceeding 1000, thus, all of the stations are in the range of conductivity values needed for phytoplankton to thrive in communities. Noteworthy, low values of conductivity are characterized by low nutrients in certain aquatic ecosystem and high values of conductivity are observed to have high plant nutrients, thus, increase in phytoplankton quantity.[24] For dissolved oxygen, most of the stations have dissolved oxygen ranging from 7.73-9.83mg/L and the standard dissolved oxygen set by DENR ranges from 5-6 mg/L which is already sufficient for many aquatic organisms but a healthy freshwater ecosystem can withstand DO level of up to 8 mg/L. Thus, all of the stations have appropriate DO level for phytoplankton occurrence and abundance. Dissolved oxygen can range from 0-18 parts per million (ppm) but most natural typical water systems entail

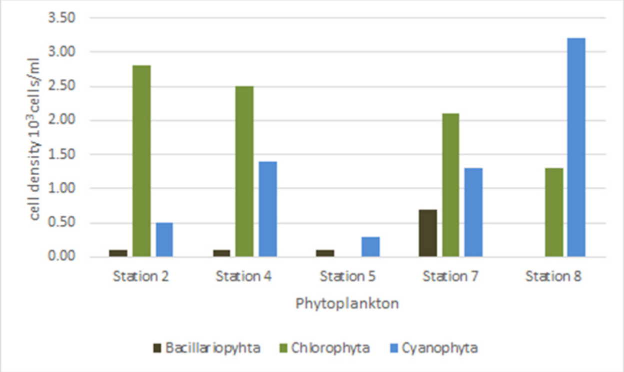

Figure 6: Cell density of phytoplankton in Stations 2, 4, 5, 7 and 8 in July 2018.

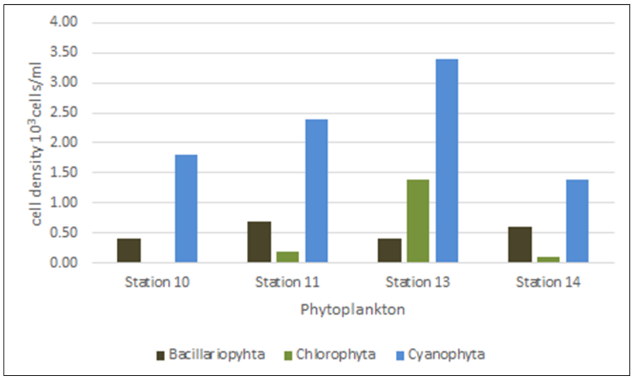

Figure 7: Cell density of phytoplankton in Stations 10, 11, 13 and 14 collected in November 2018.

5-6 mg/L. This chemical factor is as important as the other parameters for the survival of living organisms in water particularly pH because these factors are directly proportional to each other. The main source of water dissolved oxygen is the atmosphere where in the oxygen dissolves readily in water from the atmosphere until water is saturated. The manufacturing of oxygen also involves photosynthesis mediated by many aquatic resources including algae. Finally for the analysis of water nutrients, the nitrates and phosphates load of the water samples in all have the same results in mean, 6.067 and 8.35 mg/L respectively. The mean nitrate of the water samples, 6.067 mg/L gathered from the sites is in congruence to the standard set by DENR which is from 5-10 mg/L and this is in contrast with the result of the mean phosphates of the water samples, 8.35 mg/L which has a standard value of 0.05 mg/L only. Nitrate is important because it controls the productivity of freshwater ecosystems.[25] The nitrate concentration in freshwater ecosystems vary greatly as a function of wastewater loading, agricultural runoff and groundwater input. Its effect to the abundance of microalgae differ also, for example, diatoms increase when levels of nitrate increases; in green algae, desmids and blue green algae, it is correlated with low levels of nitrate.[26] Also, Phosphorus occurs as phosphate in natural waters and they can come both in natural as well as in human activities like household and agriculture and the ideal average concentration is 0.05 mg/L.[27,28] Phosphorus is another important inorganic source for algal growth and eventually energy storage and release systems of all organisms. For water nutrients, phosphorus is the limiting nutrient in freshwater aquatic systems. That is, if all phosphorous is used, plant growth will cease, notwithstanding the amount of nitrogen available. Many bodies of freshwater are presently experiencing influxes of nitrogen and phosphorus from external sources. The increasing concentration of available phosphorus allows plants to ingest more nitrogen before the phosphorus is depleted. Thus, if sufficient phosphorus is available, high concentrations of nitrates will lead to phytoplankton (algae) and macrophyte (aquatic plant) production.[29]

These physico-chemical parameters were correlated with the cell density of the 3 phytoplankton phyla gathered. The phytoplankton density are positively correlated with pH, conductivity and amount of phosphorus (phosphates) significantly. Specifically, these 3 factors are also correlated positively to Chlorophytes and Bacillariophytes except for the amount of phosphates rather significantly related to the amount of nitrogen (nitrates). The said correlation in conductivity explains the presence of more suspended particulates such as organic matter and nutrients, thus, escalating the algal growth. Therefore, the increasing phytoplankton growth also contributes to the turbidity of the water.[30,31] Similarly, nitrate was positively correlated to the phytoplankton density significantly. This is in relation to the study conducted where nutrients were manipulated and observed phytoplankton abundance significantly correlated with nitrogen concentration compared to phosphorus concentration.[32] Chlorophytes alone are correlated significantly both to nitrates and phosphates but the total cell density of phytoplankton is correlated significantly to phosphorus only. Noteworthy, dissolved oxygen is negatively correlated with the total phytoplankton cell density and specifically to the total cell density of chlorophytes (green-algae) in significant manner. The decrease in dissolved oxygen indicates influx of organic pollutants and consequently the increase of the density of diatoms which signifies water pollution in the area. Hence, we can assess that the primary drivers in phytoplankton growth in Carigara bay and its connected freshwater resources are conductivity and amount of nitrogen and phosphorus.

SUMMARY AND CONCLUSION

Carigara Bay is one of the successful fishing waters in the entire Philippines because of its multi-gear fishery system. People living around the bay considered its marine life as one of their livelihood. However, the biodiversity and biological importance of phytoplankton are still unexplored evident by the dearth of published data in scientific journals, thus, this study was undertaken. Fourteen (14) stations were established at the upper coastal towns adjoining the Carigara Bay. Water samples from the bay, stream, rivers and falls were collected using a 2.5-3L Plexi glass sampler, transferred in three (3) 1L cap bottle and brought in the laboratory for phytoplankton identification and micro algal culture. Physico-chemical parameters were also gathered in all sampling sites to correlate with the microalgae diversity. Data were subjected to statistical analyses such as one way and two way Analysis of Variance (ANOVA). Results showed that there are three (3) phyla quantified such as Phyla Bacillariophyta, Chlorophyta and Cyanophyta which are 44, 37 and 19% of the total phytoplankton identified. Moreover, the total cell density of Cyanophyta (blue-green algae) gave no significant correlation to all the physico-chemical parameters. In contrast, Bacillariophytes (diatoms) are positive and negatively correlated significantly to conductivity, r=390; p=0.11

(mean=264.14; SD=295.75) and dissolved oxygen, *r*=0.339; *p*=0.028 (mean=7.76; SD=1.82) respectively. Furthermore, Chlorophytes (green algae) are positively correlated to water pH, *r*=0.49; *p*=0.001 (mean=8.20; SD=0.40), conductivity, *r*=0.53; *p*=0.00 (mean=264.14; SD=295.75); nutrients such as nitrates, *r*=0.307; *p*=0.048 (mean=3.22; SD=2.83) and phosphates, *r*=0.427; *p*=0.005 (mean=5.22; SD=3.83) significantly and negatively correlated to dissolved oxygen, *r*=-0.353; *p*=0.022 (mean=7.76; SD=1.82) significantly. In summary, there was a significant positive correlation between water pH (*r* = 0.499; *p* = 0 .001), conductivity (*r*=0.519; *p*=0.001) and amount of phosphates (*r* = 0.446; *p* = 0.003) to the total cell density of all the three (3) groups of phytoplankton presented and identified. Finally, the phytoplankton density and the physico-chemical parameters obtained in the bay and its freshwater tributaries can be used as baseline data in assessing the said aquatic ecosystem since there has not been published data on the said habitats.

In addition, the primary factors that influence phytoplankton growth in Carigara Bay and its freshwater resources are conductivity and nutrients such as nitrogen and phosphorus.

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CONFLICT OF INTEREST

Declaring no conflict of Interest.

ABBREVIATIONS

DENR: Department of Environment and Natural Resources; **WCG:** Water Quality Guidelines; **ANOVA:** Analysis of Variance; **SD:** Standard deviation.

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