Comparison of Phytoplankton Abundance and Diversity in Selected Sites Along Iloilo-Guimaras Strait near Panay Energy Development

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Abstract

Phytoplankton community diversity in selected sites along Iloilo-Guimaras Strait near Panay Energy Development Corporation (PEDC) coal-fired power plant in Brgy. Ingore, La Paz, Iloilo City was compared with those from two other areas one kilometer away from the plant. The vertical tow method was applied during sampling, with the use of a plankton net (25 μm). Water physical parameters including turbidity, pH, temperature, and salinity were also measured. It was found that the most abundant phytoplankter for all sampling stations was the Cyanophyta (A 36.5%, B 25.4%, and C 46.3%). The Shannon-Wiener and Simpson's diversity indexes both indicate that the sampling station closest to PEDC had the most diverse phytoplankton community. Water pH was the only parameter that showed statistically significant difference (One-way ANOVA $p < 0.05$). The operation of PEDC coal-fired power plant, particularly the high water turbulence that it generates, causes nutrient circulation, which in turn favors the growth of certain phytoplankton species in the Iloilo-Guimaras Strait. Certain modifications in methods are recommended including the use of Sedgewick-Rafter chamber and the increase of number of repetitions of the counting procedure per sample. It is recommended that similar studies be conducted at another power plant in the Philippines, considering treatment facilities and chemical parameters, or conducting at different times of the day.

Keywords: *phytoplankton, diversity, abundance, Iloilo-Guimaras Strait, coal-fired power plant*

Introduction. Phytoplankton are the primary producers in most marine food webs, especially in shallow coastal areas, and they generate half of the oxygen in the world. Factors such as the presence of sunlight, food-availability, physical parameters of the environment, and the presence of predators and competition affect the growth and population of a certain phytoplankton species [1,2,3]. Phytoplankton community structures are sensitive to environmental variations and long-term extreme changes in water conditions [4]. As such, surveying local phytoplankton communities could give an indication of the overall state of the body of water in the surveyed area.

The effects of anthropogenic activities on phytoplankton community structure–population, diversity, and composition–must be monitored. This is because stressors from coal-fired power plants, may it be chemical, mechanical, or thermal effluents, may change the overall state of the body of water surrounding the area [4,5,6]. To determine the effect of power plant processes to the body of water, several case studies have been conducted on bodies of water near energy power plants, surveying and monitoring both water characteristics and species diversity, and then, relating both variables to each other [4,6,7]. In these studies, sampling stations were located near and progressively farther from water discharge areas of power plants to compare the differences in temperature and population structure of phytoplankton, investigating if the differences were significant among varying distances from the power plant. According to a study by Lo et al. [4] at two nuclear power plants in Northern Taiwan, the area that could be affected by the thermal effluents should be within 500 m to 1000 m away from the discharge point. Furthermore, a positive correlation was found between temperature and dinoflagellates; while a negative correlation was found between temperature and diatoms [4]. This suggests that the effects of thermal effluents vary among different plankton taxa. Sufficient evidence suggests a correlation between temperature changes and plankton community structure. Although, results and discussion from pieces of literature were varied in terms of significant difference; and since the studies were conducted in different parts of the world, inconsistency in results were attributed to diverse phytoplankton species in different environments being surveyed; therefore, it is desirable to survey the occurrence of such phenomenon on a local scale.

Panay Energy Development Corporation (PEDC) coal-fired power plant is located along the coast of Brgy. Ingore, La Paz and is one of the largest power producers and is the largest single generation unit in the Visayas, expected to provide adequate, reliable, clean, and cost-efficient power to the residents and businesses in the region. From the combustion of coal to the production of electricity, coal-fired power plants follow the Rankine Cycle. This cycle involves a condenser which in the case of PEDC is the cool water from Iloilo-Guimaras Strait. The plant takes in water from the strait, utilizes the water in the condenser, and releases the now heated water back to the strait at the rate of 44,000 cubic meters per hour. PEDC may have an effect on the general condition of the concerned body of water.

Hence, the present study was conducted to compare the phytoplankton community abundance and diversity in one sampling areas along Iloilo Guimaras Strait near PEDC coal-fired power plant in Brgy. Ingore, La Paz, and two sampling areas a kilometer away.

The objective of this study was to determine and compare phytoplankton diversity in three sampling stations along the Iloilo Guimaras Strait near PEDC, a coal-fired power plant. It specifically aims to:

(i) Identify the phytoplankton composition in the three sampling stations along Iloilo-Guimaras Strait near PEDC

(ii) Determine and compare the phytoplankton abundance and diversity in the three sampling stations along Iloilo-Guimaras Strait near PEDC using biodiversity indexes

(iii) Measure physical parameters as supplementary data for the analysis

Methods. Phytoplankton sampling was conducted at each sampling station using the vertical tow method. Two hundred milliliters of water samples were then collected and preserved with 5% Lugol's Iodine solution. After preservation, collected samples were brought to Research Laboratory at Philippine Science High School-Western Visayas (PSHS-WV), Brgy. Bito-on, Jaro, Iloilo City, and subjected to the process of cell concentration. The concentrated phytoplankton cells were counted and identified using hemocytometer and compound light microscope in the same laboratory. Using standard procedures, water physical parameters, namely temperature, turbidity, salinity, and pH, were measured.

Sampling Stations. There were three major sampling stations (stations A, B, and C; see Figure 1) along the Iloilo Guimaras Strait. Each sampling station had three sampling sites.

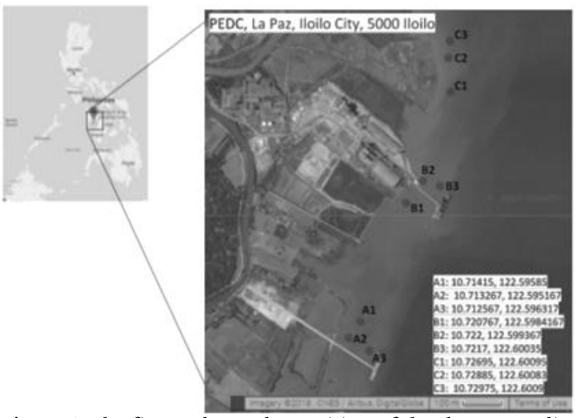

Figure 1. The figure shows the position of the three sampling stations and their subsequent sampling sites. On the lower-right corner, the GPS-generated coordinates are indicated.

Station B was the sampling station dependent on the effects of the power plant as it is within the approximated 2000 m mixing zone that directly receives effluents from the power plant. Station A was located near a private port of a flour mill. Station C was located in an area where the local inhabitants have built fishing gears. Each sampling station had three sampling sites which were approximately 200 m apart. In total, there were nine sampling sites. A Garmin eTrex 20x Handheld GPS was used to generate the coordinates of each sampling site, as well as to approximate the distances between sites and between stations.

Field Sampling. In the field, two independent sampling methods were conducted: the phytoplankton sampling which primarily made use of the plankton net; and the water sampling into properly-labeled, screw-cap bottles.

Phytoplankton Sampling. The vertical tow as described by Milroy (2016) [8] was used as the phytoplankton sampling method. Collection of samples was conducted during high tide hours, at around 10:00 AM, of April 28, 2018. Phytoplankton sampling was conducted with the use of a conical plankton net with mesh size of 25 μm, a mouth diameter of six inches, and clamped rubber tube at the cod-end. The plankton net was acquired from University of the Philippines-Visayas (UPV), Miag-ao. The vertical tow was conducted until the phytoplankton sample amounted to over 200 mL in the sample bottle.

The 5% Lugol's Iodine solution, purchased from Patagonian Enterprises, Jaro, Iloilo City, was used for the preservation of phytoplankton cells. Five drops of 5% Lugol's Iodine solution were added to each sample bottle.

Water Sampling. Nine separate properly-labeled, screw-cap bottles were filled with 100mL water samples taken from each sampling site. These bottles were later brought to the PSHS-WV laboratory for determining of water salinity and pH.

Counting and Identification. Each phytoplankton samples from the screw cap bottles were transferred to a 250mL graduated cylinder and was covered with a cling wrap. This solution was left undisturbed at a shaded area at room temperature for 24 hours, thereby allowing the phytoplankton cells to concentrate at the bottom of the graduated cylinder. After 24 hours, the top layer of the phytoplankton samples was removed without disturbing the remaining 30mL. This was done with the use of a 10mL glass transfer pipette. The remaining 30 mL was then transferred to another properly-labeled, screw cap bottle. The bottom 30 mL from the solution was homogenized by manual mixing, and using a dropper, two drops of an aliquot from the now concentrated sample was transferred to both counting chambers of the hemocytometer. Then a cover slip was placed on the top of each chamber.

A compound light microscope (LW Scientific) was used for counting of phytoplankton cells. Once the filled hemocytometer is set on its stage, counting commenced and was repeated for the second counting chamber of the hemocytometer. The entire procedure was repeated for all collected samples. Except for the filamentous *Cyanophyta*, for which one filament equaled one count, all phytoplankton were counted as one cell equaled one count.

Drawings and pictures of the phytoplankton compared to literature were used to count and identify them [9, 10, 11, 12]. The phytoplankton identified were later verified by Marie Frances J. Nievales, Chairperson of the Division of Biological Sciences, University of the Philippines - Visayas. Each phytoplankton was identified and verified down to at least the genus level and, whenever possible, the species level.

Water Physical Parameters. Water temperature and turbidity were taken during the field sampling. Water temperature was measured with the use of a Garmin Fish Finder while turbidity was measured using a Secchi Disk. Salinity and pH were measured in PSHS-WVC Biology Lab within water samples taken from the field sampling. The pH of each water sample was measured using a Satorius pH Basic benchtop pH meter while salinity was measured using an OEM Hand-held Salt Refractometer.

Data Analysis. After acquiring raw data from each of the sampling stations, the relative abundance of each phytoplankter, and Shannon-Wiener Diversity Index, and Simpson's Diversity Index of each of the three sampling stations were calculated. Relative abundance shows how common or rare a species is, relative to the other species present that specific sampling station; this is important in knowing which species are dominant or diminishing in a sampling station. The diversity indexes were measures of richness of species—the number of species in the sampling station—combined with the evenness of species in a community. This was used to determine the biodiversity of the sampling station, the higher the biodiversity in a habitat, the more chance it has of reproducing and surviving. Lastly, to compare the physical water parameters, One-way Analysis of Variance (One-way ANOVA; $p < 0.05$) was used to test for significant difference among data from each of the three sampling stations; while the Tukey's Post Hoc test was used to determine exactly between which two data sets were the significant differences present.

Safety Procedure. Both laboratory safety and field safety were observed during the conduct of the study. In the laboratory, the researchers wore their laboratory gowns and closed footwear, carefully handled all glass wares, and familiarized themselves with the Safety Data Sheet of 5% Lugol's iodine solution. In the field, the researchers wore their life vests. All liquids were disposed of in accordance with the prescribed protocol of PSHS-WV through the Science Research Specialist.

Results and Discussion. This study aimed to determine and compare phytoplankton community abundance and diversity in three sampling stations along Iloilo-Guimaras Strait near PEDC coal-fired power-plant. Specifically, this was done by collecting phytoplankton samples at three selected sampling stations and calculating the biodiversity indexes for each station. Water physical parameters were also measured at all stations.

Phytoplankton Community Composition. Thirty-five different phytoplankton species were found in all three sampling stations, six of which were not identified. Identified phytoplankton were classified into seven classes namely diatoms, cyanobacteria, algae, cryptophytes, brown algae, dinoflagellates, and ciliates [13]. The total number of phytoplankton species (n) present in each sampling station were as follows: sampling station A, n=30; sampling station B, n=32; and sampling station C, n=17. It was found that *Cyanophyta* was the most abundant phytoplankton for all three sampling stations (station A, RA=36.5%; station B, RA=25.4%; and station C, RA=46.3%).

Table 1. Phytoplankton species and relative abundance (in %) in each sampling station.

Phytoplankton	Relative Abundance (in %)		
	Station A	Station B	Station C
Asterionellopsis glacialis	-	0.39	-
Bacillaria paxillifera	1.6	1.2	2.4
Bacteriastrum furcatum	0.26	0.52	-
Ballerochea horologicales	5.3	7.1	1.6
Bellerochea malleus	2.5	2.1	-
Biddulphia sp.	-	0.52	-
Cerataulina bergonii	3.8	6.5	8.1
Ceratium furca	0.13	13.0	-
Ceratium tripos	0.13	0.26	-
Chaetoceros peruvianus	-	0.65	-
Chaetoceros sp.	1.9	1.3	1.6
Chroomonas sp.	-	1.9	-
Coscinodiscus sp.	2.5	1.3	4.1
Cyanophyta	37.0	25.0	46.0
Ditylum sp.	0.13	0.13	-
Eucampia zoodiacus	3.6	0.78	2.4
Favella sp.	4.8	5.7	2.4
Guinardia striata	2.4	3.1	3.3
Navicula sp.	4.6	9.6	0.81
Nitzschia longissimi	4.2	3.6	5.7

Odontella longicruris	0.26	0.13	-
Odontella mobiliensis	1.7	0.78	-
Odontella sinensis	2.6	2.3	3.3
Pleurosigma normanii	2.5	1.9	5.7
Protoperidinium oceanicum	0.13	-	-
Rhizosolenia sp.	5.8	8.1	2.4
Skeletonema costatum	1.7	3.8	-
Thalassionema nitzschioides	0.4	0.13	4.1
Triceratium favus	0.8	0.26	-
Unidentified phytoplankton			
Total	100	100	100

Table 2. Phytoplankton class and relative abundance (in %) in each sampling station.

Phyto-plankton class	Relative Abundance (in %)		
	Station A	Station B	Station C
Algae	9.3	19.7	9.5
Brown Algae	2.7	2.1	6.0
Ciliates	5.2	6.2	2.6
Cryptophytes	-	2.1	-
Cyanobacteria	41.0	27.7	49.1
Siatoms	41.4	41.7	32.8
Dinoflagellates	0.4	0.4	-

Table 3. Shannon-Wiener Diversity Index (*H'*) and Simpson's Diversity Index (*D*) values of sampling station A, B, and C.

Bio-diversity Index	Station A	Station B	Station C
H'	2.51	2.68	2.09
D	0.843	0.895	0.768

Species Diversity. Table 3 shows that the sampling station closest to PEDC coal-fired power plant (station B) was the most biologically diverse (H'=2.683; D=0.895), followed by the sampling station around the private port of a flour mill (station A; H'=2.511; D=0.843), and finally, the least diverse sampling station was situated around a fishing gear (station C; H'=2.0912; D=0.768).

Water Physical Parameters. The four water physical parameters measured at each sampling station were surface temperature, turbidity, salinity, and pH. Surface temperature was relatively higher at station A (surface temperature at station A=29.33 °C; B=28.33 °C; and C=28.33 °C). Turbidity was relatively higher at station B (turbidity at station B=88.9 cm; A=85.0 cm; and C=66.7 cm). Salinity is relatively higher at station C (salinity at station C=34.7 ppt; B=34.6 ppt; and A=34.0 ppt). One-Way ANOVA ($p < 0.05$) has shown that the differences were not significant for surface temperature ($p=0.125$), turbidity ($p=0.745$), and salinity ($p=0.224$). The only parameter that showed significant difference across sampling stations was water pH ($p=0.010$), particularly between stations A and B and stations B and C.

Discussion. The present study yielded the following key findings: first, the taxon with the highest relative abundance in all three sampling stations was *Cyanophyta*; second, through Shannon-Weiner Diversity and Simpson's Diversity indexes, it was determined that the sampling station closest to the coal-fired power plant had the most diverse phytoplankton community; and finally, the data sets for temperature, turbidity, and salinity yielded no significant difference as opposed to that of water pH. The values determined for temperature, turbidity, and salinity do not pose any possible harm to the immediate body of water and its inhabitants according to previous research and foreign and local standards. Also, the conducted statistical analyses concluded that there are no significant differences ($p > 0.05$) in the mean values of these three parameters between sampling stations.

The abundance, presence, or absence of certain phytoplankton in a sampling station denotes two things: that their high RA has several environmental implications on the sampling station; and that some behavioral characteristics of phytoplankton allow them to thrive in certain environments. The implications of the present and dominant phytoplankton species to the environmental condition of each sampling station is hereinafter discussed.

Deducing from the abundance of the cyanobacteria *Cyanophyta* (n=283; RA=36.5%), sampling station A was considered a nutrient-filled and alkaline environment as cyanobacteria are nuisance algae that can tolerate pH levels up to 9.0. This also allowed them to thrive in all sampling stations despite the calculated significant difference in pH. Sampling station A was relatively calm during the time of sampling which is confirmed by the dominance of *Rhizosolenia* sp. (n=44; RA=5.68%) among other diatoms, as well as its lesser count in station A than in station B.

The operation of PEDC allowed the diatoms *Navicula* sp. (RA in A=4.52%; RA in B=9.65%; RA in C=0.81%) and *Rhizosolenia* sp. (RA in A=5.68%; RA in B=8.08%; RA in C=2.40%) to promote their growth by taking advantage of the high nutrient circulation caused by increased water dynamics and water turbulence in station B [14]. It is for the same reason that the cryptophyte, *Chroomonas* sp. and the diatom, *Asterionellopsis glacialis* are found exclusively in sampling station B with RA of 1.9% (n=15) and 0.39% (n=3), respectively. These species react quickly to changes in the distribution of nutrients in the environment and reproduce accordingly [15,16].

The reason for the significant difference in overall phytoplankton counts between station C and other stations could be chemical and nutrient-based. Sampling station C may have a significantly different composition of nutrients that limits the growth of phytoplankton in the area. Two-thirds of the identified taxa in station C were diatoms. Compared to other classes, diatoms are the most complacent with environmental factors and most species are known to be tolerant to pollution and low levels of nutrients [17]. This is the characteristic that allowed diatoms to exist in an environment that had less nutrients. The diatom *Thalassionema nitzschioides* is especially notable as more of it was found in sampling station C (n=5) than in sampling stations A (n=1) and B (n=1). Finally, the most dominant phytoplankton in station C was *Cyanophyta* which accounted for almost half of the community (n=57; and RA=46.34%). Cyanobacteria are more likely to bloom in conditions with calm weather and low turbulence [17].

To determine and compare the phytoplankton diversity, Shannon-Wiener and Simpson's indexes were used. Though the diversity of sampling stations A, B, and C can be ranked in descending order as follows: B, A, and C; the values of H' do not dramatically deviate from the mean of the general range of values (1.5 to 3.5; mean=2.5); thus the three sampling stations can be considered fairly diverse according to Shannon-Wiener index. For Simpson's index, generally, the values of D approached 1.00 in descending order as follows: B, A, and C. In the case of sampling station C, because the phytoplankton Cyanophyta had a relative abundance (RA) of 46.34%, almost half of the entire population in that station and the highest among the RA recorded in all three sampling stations, it can be said that Cyanophyta was a dominant taxon in sampling station C. This caused sampling station C to yield the lowest Simpson's index (D = 0.768). Despite the large gap between the RA of the most abundant phytoplankton Cyanophyta and the second most abundant phytoplankton in each sampling station, the gap does not lead each sampling station to approach monoculture.

In general, the following notable observations were made: that the more turbulent waters of station B caused enhanced water circulation, which in turn caused the abundance of certain cyanobacteria (*Cyanophyta*), diatoms (*Rhizosolenia* sp., *Navicula* sp., and *A. glaciales*), and cryptophyte (*Chroomonas* sp.); and that Shannon-Wiener and Simpson's indexes agree that while all three stations were fairly diverse and none of them approach monoculture, station B was the most biologically diverse.

Error analysis. For the phytoplankton counting procedure, the present study used a hemocytometer in place of the Sedgewick-Rafter counting chamber. Also, the counting procedure was repeated only twice per concentrated phytoplankton sample. To remedy the formerly stated error, an increase of the number of repetitions of counting procedure per sample to at least five is recommended.

Conclusion. Deducing from the presence of certain diatom (*Rhizosolenia* sp., *Navicula* sp., and *A. glachiales*) and cryptophyte (*Chroomonas* sp.), the operation of PEDC coal-fired power plant may be generating a higher water turbulence compared to other sampling stations, thereby, allowing a more effective circulation of nutrients and resources. Another factor affecting phytoplankton diversity is the time of sampling which is linked to certain phytoplankton behavioral characteristics, for instance, the carbohydrate ballast of the cyanobacteria causing them to remain afloat during the day and sink back to the bottom at night, and the diel vertical migration of the dinoflagellates aiding in their migration to deeper water columns to avoid intense light levels during the day.

Recommendations. Phytoplankton research and population surveys, although very essential, is not as widespread in the Philippines as it is in other countries. Thus, it is recommended that researchers venture in to this field. The present study can be replicated and/or modified should another study arise conducted case-specifically to another power plant in the Philippines. Different treatment facilities near bodies of water such as waste treatment plants and/or sewage treatment plants may also be investigated. In addition to water physical parameters, close observation is also recommended for chemical parameters: monitoring chemical traces for harmful substances. Finally, field sampling may also be done in different times of the day as presence of phytoplankton may vary at different ocean tides and/or intensity of sunlight.

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