Phytoplankton in Lake Mainit, Philippines

Teresita P. Senados, Bernard C. Gomez, Virgilio B. Ratunil Jr., Jayson D. Dela Peña, Gregorio Z. Gamboa, Jr., Emmylou A. Borja, Mauricio S. Adlaon, and Medielyn M. Odtojan

Surigao State College of Technology, Surigao City, Philippines
tsenador@ssct.ed.ph, bgomez@ssct.edu.ph, vratunil@ssct.edu.ph, jdelapena@ssct.edu.ph, ggamboa@ssct.edu.ph, eborja@ssct.edu.ph, madlaon@ssct.edu.ph, modtojan@ssct.edu.ph

Abstract. The study determined the composition, abundance, and distribution of phytoplankton in Lake Mainit. Plankton samples were collected in eight sampling stations four times in 2018. A total of 26 phytoplankton taxa in four groups – Bacillariophyceae/Myxophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae were identified. Aulacoseira was ranked as the most abundant taxa, followed by Zygnema, Fragilaria, Trichodesmium, and Ulothrix. ANOVA revealed no significant (P<0.05) difference in the number of phytoplankton between the eight stations during the first sampling. In the second sampling, Bunga showed a significantly (P<0.05) lower number of phytoplankton than the other stations. The third sampling also showed no significant (P<0.05) difference in the number of phytoplankton between stations. During the fourth sampling, Tagbuyawan had by far (P<0.05) the highest number of phytoplankton. Species diversity (H') of phytoplankton was stable at Magticao, Jaliobong, Dinarawan, Kalinawan, and Bunga. The dominance of some species (Aulacoseira, Fragilaria, and Zygnema) affected the diversity and distribution of plankton. Spectrophotometric readings recorded an average Chl- a of 0.75 µg/L. The lake was still considered oligotrophic. Remediation measures and further studies on the lake towards the primary variation of plankton are recommended. Management efforts should be strengthened to support the sustainability of life in the lake.

Keywords: Lake Mainit, phytoplankton, species diversity indices, primary productivity

1. Introduction

Life in lakes is inevitably influenced by plankton. Plankton are free-floating microscopic organisms in the aquatic ecosystems. They constitute diverse groups of organisms that play a major component of the food web structure (D’Alelio et al., 2016), serving as food for organisms in the upper trophic level. Phytoplankton produces oxygen and food, which sustains the life of others (Khan et al., 2003 and Fathi et al., 2001). Their distribution and community structure are driven by the combination and interactions between physical, chemical, and biological factors within the environment. Some plankton species are tolerant of adverse environmental conditions. They serve as bio-indicators and serve the purpose of monitoring environmental pollution. Ederosas and Jumawan (2016) pointed out that the presence of fish commodities in the lake is dependent on plankton in the aquatic food chain. The ecological status of the lake is determined by the planktonic structures, which translate the level of
productivity of the community benefiting the human population. Undoubtedly, the lake is a depository of plankton for influx from point and non-point sources in higher areas. Anthropogenic inputs of nutrients can cause eutrophication and adversely affect the food web structure (Glibert, 2012; Vitousek et al., 2012; Duong et al., 2012; Isbell et al., 2013) and thus, alter phytoplankton communities (Bockwoldt et al., 2017) and global climate change (increasing average global temperature, changes in rainfall pattern) have put remarkable pressure on the ecological conditions and sustainability of many aquatic ecosystems (Pearl et al., 2014).

Previous studies revealed the presence of phytoplankton in Lake Mainit. Lewis (1973) had identified 33 species; Tumanda et al (2003), 53 species; and 26 species by Ederosas and Jumawan (2016). The latter found out that the diversity of phytoplankton species was stable, and the species were evenly distributed in all areas. The present study determines the current composition, abundance, and distribution of plankton in Lake Mainit. Results would serve as a basis in validating information very vital in determining the condition of the lake and a guide in the review of current policies and/or in the formulation and implementation of new policies for the protection and conservation of the resources in the lake and its vicinities.

2. Materials and Methods

2.1. Study Area
Lake Mainit is one of the important aquatic ecosystems due to its potentials for food and habitat of various flora and fauna (Padilla et al, 2015). The lake borders the provinces of Surigao del Norte and Agusan del Norte, Northern Mindanao, Philippines. It is considered the deepest lake in the country with a maximum depth of about 223 m (Lewis, 1973) and the fourth largest having a surface area of about 149.86 km² and described as oligotrophic (Tumanda et al., 2003).

Phytoplankton samples were taken from eight sampling stations around Lake Mainit: Station 1(S1)-Tagbuyawan; Station 2 (S2)- Mayag; Station 3 (S3) - Magpayang; Station 4(S4)-Magtiacao; Station 5 (S5)-Jaliobong;Station 6 (S6)-Dinarawan; Station 7(S7)-Kalinawan; and Station 8 (S8)-Bunga (Table 1, Figure 1). The seven stations are located in river mouths while Station 8 (Bunga) is at the center of the lake.

![Figure 1. Map of the sampling stations in Lake Mainit, Mainit, Surigao del Norte, Philippines.](image-url)
2.2. Collection and Analysis of Samples
Collection of samples was done four times in 2018 (April 30-May 1, July 31-August 1, September 25-26, and December 5-6) between 0800-1400hrs. In each sampling station, vertical and horizontal towings were conducted to collect samples from the water column and surface, respectively. A plankton net, 64 µ mesh size, 1.2 m long, 0.3 m diameter (Figure 2) was lowered at a maximum of 1 m in deeper areas and at the bottom in shallow areas. In the surface, the net was towed at a distance of 1 m. Three replicate samples of 500 mL each were filtered both vertically and horizontally in all stations. After each tow, the net was carefully washed with lake water to dislodge the plankton that might adhere at the side of the net and to allow the plankton to be washed down to a cod-end bucket for collection. Collected samples were placed in pre-labeled bottles and treated with 10% formalin (Calumpong et al., 2013).

Collected samples were delivered to Naawan, Misamis Oriental for laboratory analysis. The identification of the organisms was performed until the lowest possible taxa using the guide of Tomas (1997) and Omura et al. (2013). Online references were also considered.

Figure 2. The plankton net used in the study.

2.3. Data and statistical analysis
The abundance of each species was calculated as the number of individuals per total number of individuals in 500 mL samples filtered.

Species diversity, dominance and evenness were determined using the indices: Shannon- Weiner Index of Biodiversity (H'), Simpson Index of Dominance (D) and Pielou’s Evenness Index (E) (Odum, 1993).

One-way Analysis of Variance (ANOVA) was used to determine the significant difference of the abundance of plankton in the sampling stations and seasonal variations. Tukey’s Post ad hoc test was done for significant findings.

3. Results and Discussion

3.1. Composition, abundance and distribution
A total of 26 phytoplankton taxa which belong to four groups were identified and recorded in Lake Mainit in 2018 (Table 1). Among the classes, Bacillariophyceae/Myxophyceae with 12 genera appeared as the dominant group in terms of total species and cell numbers. This was followed by Chlorophyceae with nine genera, Cyanophyceae, four genera and Euglenophyceae, one. This result coincides with the findings of Ederosas and Jumawan (2016) and Tumanda et al. (2003) who conducted plankton studies in Lake Mainit. They found Bacillariophyceae and Chlorophyceae to be contributing most of the phytoplankton community with the Euglenoid being the least abundant. Among the species,
**Aulacoseira, Zygnema, Fragilaria, Trichodesmium and Ulothrix** were the most abundant in that order, respectively.

**Table 1.** Phytoplankton in Lake Mainit, Mainit, Surigao del Norte, Philippines in 2018.

| Phytoplankton Groups and Taxa | Total (cells in 500mL) | RA % |
|-----------------------------|------------------------|------|
| **Chlorophyceae**           |                        |      |
| 1  Actinastrum              | 11000                  | 0.68 |
| 2  Cladophora               | 15000                  | 0.93 |
| 3  Closterium               | 500                    | 0.03 |
| 4  Sphaerocystis            | 44000                  | 2.72 |
| 5  Spirogyra                | 15500                  | 0.96 |
| 6  Staurastrum              | 26500                  | 1.64 |
| 7  Ulothrix                 | 51500                  | 3.19 |
| 8  Volvox                   | 17000                  | 1.05 |
| 9  Zygnema                  | 399500                 | 24.72|
|                             |                        | **35.92** |
| **Bacillariophyceae/Myxophyceae** |                    |      |
| 10  Aulacoseira             | 534500                 | 33.08|
| 11  Chaetoceros             | 500                    | 0.03 |
| 12  Cymbella                | 1000                   | 0.06 |
| 13  Denticulata             | 7000                   | 0.43 |
| 14  Fragilaria              | 276000                 | 17.08|
| 15  Gyrosigma               | 3000                   | 0.19 |
| 16  Melosira                | 9500                   | 0.59 |
| 17  Navicula                | 2500                   | 0.15 |
| 18  Nitzchia                | 8000                   | 0.51 |
| 19  Pleurosigma             | 500                    | 0.03 |
| 20  Suriella                | 8500                   | 0.53 |
| 21  Synedra                 | 1000                   | 0.06 |
|                             |                        | **52.72** |
| **Cyanophyceae**           |                        |      |
| 22  Myrocystis botrys       | 33000                  | 2.04 |
| 23  Lyngbya                 | 28500                  | 1.76 |
| 24  Oscillatoria            | 34000                  | 2.10 |
| 25  Trichodesmium           | 87500                  | 5.41 |
|                             |                        | **11.31** |
| **Euglenophyceae**         |                        |      |
| 26  Euglena                 | 500                    | 0.03 |
|                             |                        | **0.03** |

In this study, the number of phytoplankton species and total number of individuals cannot be differentiated with those of Ederosas and Jumawan (2016) and Tumanda et al (2003) due to differences in the sampling methods. The previous recorded 29 phytoplankton species with Diatom 1 as the most abundant in four stations, while Tumanda, et al (2003) found 41 species with Sphaerocystis as the most abundant in 21 stations. In the same lake, Lewis (1973) had identified 33 species. It is noted that 12 phytoplankton taxa/species are common among the three (3) studies. These are the Cymbella, Denticula elegans, Fragilaria, Lyngbia, Melosira, Navicula, Nitzchia, Sphaerocystis, Spirogyra, Staurastrum, Surirella, and Volvox.
The abundance of the genus Aulacoseira which appeared only in this study, proves that Lake Mainit is a tectonic lake. The genus is found in modern lakes from all parts of the world and ancient tectonic lakes. Lake Mainit is of tectonic type formed by movements of the earth’s crust (Punongbayan, 2003).

3.2. Spatial and seasonal variation

The abundance of phytoplankton in the sampling stations and during sampling periods are shown in Figures 3 and 4, respectively. Station 1 – Tagbuyawan (16.27%) has the highest relative abundance of phytoplankton individuals compared to stations 2-8, Mayag, Magpayang, Magtiaco, Jaliobong, Dinarawan, Kalinawan and Bunga. In terms of the sampling periods, phytoplankton was recorded at its highest abundance during the first sampling period (30.63%) which was summertime. High phytoplankton especially during hot season could be due to the inflow of domestic effluent from communities residing nearby and also due to malpractices by fish cage operators (Cordero and Baldia, 2015).

However, when compared between stations and sampling periods, ANOVA revealed no significant (P<0.05) difference in the number of phytoplankton between the eight (8) stations during the first sampling (Table 3). In the second sampling, Bunga showed a significantly (P<0.05) lower number of phytoplankton compared to the other stations. The third sampling also showed that there was no significant (P<0.05) difference in the number of phytoplankton between stations. Moreover, during the fourth sampling, Tagbuyawan showed by far the highest number (P<0.05) of phytoplankton compared to Bunga, Magtiaco and Mayag.

That there was no significant difference in the number of phytoplankton between the stations during the first and third sampling means phytoplankton was uniformly distributed in all stations. Bunga had the lowest number of phytoplankton during the second sampling. Tumanda, et al (2003) also found the lowest phytoplankton density at Bunga. The station is the deepest and is located at the center of the lake. Tagbuyawan on the fourth sampling had the most numbered taxa-Aulacoseira, Denticulata, Fragilaria, Lyngbia, Staurastrum and Zygnema. Distribution of phytoplankton is affected by the variation in physico-chemical parameters among sites (Baloloy et al., 2016).

Since the five sampling sites mentioned above are populated, garbage and waste disposal activities from residential, commercial and small industrial establishments were considered to affect the lake’s water quality. On the other hand, the small scale mining activities present in some sampling areas contributed to the siltation of the lake.

![Figure 3. Relative abundance (%) of phytoplankton in the eight sampling in Lake Mainit, Mainit, Surigao del Norte, 2018.](image-url)
Table 2. Mean number of phytoplankton in the sampling sites during the four sampling periods.

| Stations    | 1st Sampling | 2nd Sampling | 3rd Sampling | 4th Sampling |
|-------------|--------------|--------------|--------------|--------------|
| S1-Tagbuyawan | 139 <sup>a</sup> | 156 <sup>a</sup> | 151 <sup>a</sup> | 120 <sup>a</sup> |
| S2-Mayag     | 279 <sup>a</sup> | 99 <sup>a</sup>  | 129 <sup>a</sup> | 19 <sup>cd</sup> |
| S3- Magpayang| 176 <sup>a</sup> | 98 <sup>a</sup>  | 101 <sup>a</sup> | 85 <sup>ab</sup> |
| S4- Magtiaco | 170 <sup>a</sup> | 79 <sup>a</sup>  | 76 <sup>a</sup>  | 15 <sup>d</sup>  |
| S5- Jaliobong| 66 <sup>a</sup>  | 79 <sup>a</sup>  | 109 <sup>a</sup> | 70 <sup>abc</sup>|
| S6- Kalinawan| 64 <sup>a</sup>  | 75 <sup>a</sup>  | 75 <sup>a</sup>  | 48 <sup>abc</sup>|
| S7- Dinarawan| 79 <sup>a</sup>  | 107 <sup>a</sup>| 90 <sup>a</sup>  | 40 <sup>abc</sup>|
| S8- Bunga    | 77 <sup>a</sup>  | 10 <sup>b</sup>  | 60 <sup>a</sup>  | 31 <sup>bcd</sup>|

Note: Columns with different letters superscript are significantly different (P<0.05)

3.3. Diversity Indices

Figure 5 shows species indices such as species diversity (H’), dominance (D) and evenness (E) of plankton.

The majority of species diversity readings in stations 2,4-8 (Mayag, Magtiaco,Jaliobong, Dinarawan, Kalinawan and Bunga) are greater than 1. This means species diversity of phytoplankton is stable which coincides with those of Ederosas and Jumawan (2016) and Tumanda et al (2003). Unstable species diversity is seen in stations 1 and 3 (<1). Dominance of species is shown with even distributions of phytoplankton at stations 1, 5 and 7; 1 and 8; and 2,3 and 6. Dominance of some species such as Aulacoseira, Fragilaria and Zygnema affects the diversity of species.
Figure 5. Diversity indices (D, H’ and E) of phytoplankton species in Lake Mainit, Mainit, Surigao del Norte, 2018.

3.4. Primary productivity
Measurement of chlorophyll α (Chl-α) was used to estimate the primary productivity of the lake. Spectrophotometric readings revealed that Lake Mainit contained Chl-α of 0.75 (µg/L) (Table 3). This means the lake is oligotrophic. An oligotrophic lake is a lake with low primary productivity (Tumanda, et al. 2003), as a result of low nutrient content, thus, host very little or no aquatic vegetation and consequently, often have very clear waters, with high drinking-water quality (Wikipedia). It is noted that primary productivity of aquatic ecosystem is required to forecast fishery potential of an area (Perumal et al., 2000).

Numerical values show highest Chl-α during the summer time. This was affected by the high number of phytoplankton (30.63%) compared to the other sampling periods. This variation of Chl-α is due to changes in the phytoplankton composition (Fietz et al., 2005). In this study, the Chlorophyceae is the major contributor. As noted, light irradiance is high in the summer, driving photosynthetic activities among these green phytoplankton.

Table 3. Chlorophyll a readings (µg/L) of Lake Mainit, Mainit, Surigao del Norte, Philippines in 2018.

| Sampling Stations | 1st Sampling April 30, 2018 | 2nd Sampling July 24, 2018 | 3rd Sampling Sep. 25, 2018 | 4th Sampling Dec. 05, 2018 |
|-------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 1                 | 1.7                       | 0.5                       | 0.8                       | 0.6                       |
| 2                 | 0.2                       | 0.8                       | 0.7                       | 0.4                       |
| 3                 | 0.3                       | 0.5                       | 0.7                       | 0.3                       |
| 4                 | 1.1                       | 0.4                       | 0.8                       | 0.6                       |
| 5                 | 1.1                       | 0.3                       | 0.8                       | 0.6                       |
| 6                 | 1.4                       | 0.5                       | 0.6                       | 0.7                       |
| 7                 | 1.4                       | 0.6                       | 0.6                       | 0.9                       |
| 8                 | 1.5                       | 1.0                       | 1.0                       | 0.7                       |
| Average:          | 1.1                       | 0.6                       | 0.7                       | 0.6                       |

0.75 μg/L = Oligotrophic (Trophic State Index)
4. Conclusions and Recommendations

The differences between the plankton composition (presence and absence of species) in this study and those of the previous ones could be due to climatic changes and current biophysico-chemical parameters. Further studies on the extinction of other species and evolution of new species is recommended to include topographic records and biogeophysico-chemical condition of the lake at a longer period of data collection.

The lake remains to be oligotrophic which means it has low nutrients to support algal bloom. The water is still safe for swimming and boating and a potential source of water supply for domestic use and drinking source but is subjected to potability standards or conventional treatment under the National Standards for Drinking Water (NSDW). Regular monitoring of the water quality will clarify the information. Proper disposal of domestic wastes would be another great effort in the management of the lake.

Undoubtedly, Lake Mainit is considered a prime fishery resource of the villagers in the circumferential municipalities of Surigao del Norte and Agusan del Norte. Uncontrolled increase of anthropogenic activities such as illegal logging, quarrying and mining activities, inappropriate farming technology will be proportionate to increased nutrient entry to the lake water. All these lead to lake eutrophication. Thus, remediation measures must be directed in order to maintain the health and integrity of Lake Mainit.

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