Phytoplankton community structure in Menjer Lake, Central Java

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Abstract. The occurrence of land changes around Lake Menjer, Central Java Province will affect the condition of water quality subsequently will affect biota, including phytoplankton. The purposes of study was to analyze the composition and abundance of phytoplankton in Menjer Lake regarding to nutrient content i.e. nitrogen and phosphorus. Observations on the phytoplankton community were conducted in July and October 2019 at six locations in Menjer Lake. Water samples were taken at the water surface as much as 10 L filtered using plankton net. Identification was carried out under the inverted microscope Diaphot 300. The abundance was calculated using the Sedgwick Rafter cell counting (SRCC) method. Analysis of the phytoplankton community structure was derived by calculating the Diversity Index, Evenness Index, and Simpson Dominance Index. The nutrient content in Menjer Lake influences the structure of phytoplankton communities quantitatively and qualitatively. Observation showed that the diversity of phytoplankton was low and there was one species dominated, the result explained that the phytoplankton community in Menjer Lake is unstable and there is ecological pressure on the community. It can be concluded that the improvement of environmental conditions around Menjer Lake is the basis for the sustainable management of Menjer Lake.

1. Introduction
Phytoplankton are the primary producer in the aquatic ecosystem and the are the basic of the food chain [1]. Understanding the abundance and composition of phytoplankton can help in fisheries management and can further provide an understanding of the ecological balance [2]. The phytoplankton community is very sensitive to environmental changes because it is quick to respond to changes in water quality, therefore it is an important indicator in determining the ecological status of waters. Phytoplankton composition and abundance, as well as phytoplankton seasonal succession patterns, can be used to assess water quality [3]. The diversity and dynamics of phytoplankton in waters are influenced by seasonal variations in the environmental nutrient profile [4].

Menjer Lake is a small lake located in the highlands of Dieng, Wonosobo Regency, Central Java Province. Observations regarding water quality and phytoplankton have been made by several researchers [2, 5-7]. The observations indicate that the total nitrogen of Menjer Lake was high according to agricultural activity around the lake, such as fertilization for vegetable crops, especially potatoes and other vegetables such as cabbage, chili, peas, and others. Total suspended solid concentration was high especially in the floating cage area and the inlet of the lake. The high abundance and number of phytoplankton species in Menjer Lake are from the Bacillaryophyta, the phytoplankton diversity is moderate, and no species dominates Menjer Lake will be developed as a tourist area, development around the lake will affect the water quality of Menjer Lake, which will affect the biota in it including
phytoplankton. Therefore, it is necessary to make further observations about the composition and abundance of phytoplankton in Menjer Lake concerning water quality.

The purposes of study was to analyze the composition and abundance of phytoplankton in Menjer Lake regarding the nutrient content of nitrogen and phosphorus. The results of this study can be used as one of the important parameters in the management of Menjer Lake for its sustainability.

2. Methods

Menjer Lake is located in Maron Village, Wonosobo Regency, which is a lake located in the Dieng Mountains in Central Java (Indonesia) at an altitude of 1300 meters above sea level. The lake surface area of Menjer Lake was 0.61 km², and the maximum depth was 45 m [8]. Besides being used as a source of irrigation, fishery activities, and tourism, this lake has been used as a hydroelectric power plant since 1982.

Observations were conducted in July 2019 (dry season) and October 2019 (rainy season) at six locations in Menjer Lake. Station 1 is floating net cages location, Station 2 is inlet from the Serayu River and Klakah River, Station 3 is the area has no floating net cages, Station 4 is intermittent flow from the the Ciritis River, Station 5 is the middle of lake, and Station 6 is the area near the pier. The sampling map of the observation site are presented in Figure 1.

Figure 1. Sampling site in Lake Menjer, Central Java Province

For phytoplankton analyze, water samples were taken at the water surface as much as 10 litters [9], filtered using plankton net no. 25 (net mesh size 53 µm), and preserved using Lugol to a concentration of 1% or until the sample was brownish yellow [9, 10]. Identification of phytoplankton carried out under the inverted microscope NIKON Diaphot 300 at 100x, 200x and 400x magnification based on [11-17]. The species abundance was calculated using the Sedgwick Rafter cell counting (SRCC) method [9], the unit used is individuals per litter (individuals L⁻¹). Analysis of the phytoplankton community structure was figured by calculating the Shannon Wiener Diversity Index (H'), Evenness Index (E), and Simpson Dominance Index (C) based on [18]. Shannon Wiener index was formulated by the equation:
Where, $H' = \sum_{i=1}^{S} P_i \ln P_i$

Where, $H'$ = the Shannon diversity index, $P_i = \frac{n_i}{N}$, $n_i = \text{number of individual of taxon } i$, $N = \text{total number of individuals in the sample}$.

Evenness index was formulated by the equation:

$$E = \frac{H'}{H'_{\text{max}}}$$

Where, $E$=Evenness index, $H'$=Shannon-Wiener Index, $s = \text{numbers of species encountered}$, $H'_{\text{max}}$=the maximum possible value of $H'$ and it is equivalent to $\ln S$.

Simpson Dominance index was formulated by the equation:

$$D = \sum_{i=1}^{S} \left( \frac{n_i}{N} \right)^2$$

Where, $D = \text{the Simpson Dominance index}$, $n_i = \text{number of individuals of taxon } i$, $N = \text{total number of individuals in the sample}$, $s = \text{numbers of species encountered}$.

Water quality parameters measured were total phosphorus (TP), total nitrogen (TN), and chlorophyll-a. The samples were analyzed at The Limnology Research Center laboratory, using the 4500-PJ and 4500-PE method for TP and the 10200 H method for chlorophyll-a [9], and the Brucine method for TN [19].

3. Result and Discussion

The total nitrogen (TN) and total phosphorus (TP) content in Menjer Lake is presented in Table 1, the TN value ranged from 3.339 to 8.406 mg / L, and the TP ranged from 0.004 to 0.108 mg / L (Table 1). The TN value is high, based on the regulation of the Minister of Environment of Indonesia, this value was included in the criteria for hypereutrophic waters. The high value of TN in Menjer Lake was thought to be caused by agricultural activities around Menjer Lake, fertilization in this area is one of the causes. High nitrate concentrations in Menjer Lake were thought to originate from the surrounding agricultural activities, the steep walls around the lake cause sediments to erode easily and be carried into the lake [5], nitrate was a compound that was easily moved through soil or sediment [20].

Based on the Regulation of the Minister of Environment of Indonesia, the total phosphorus value at Menjer Lake was included in the category of mesotrophic to hypereutrophic criteria. TP value is high at station 2 compared to other stations. Station 2 is an inlet area originating from the Serayu River and Klakah River, which is thought to contain high nutrients, this can also be seen from the quite high TN value.

The chlorophyll-a content is 4.575-57.901 mg/m$^3$, this value includes mesotrophic to eutrophic criteria based on the regulations of the Indonesian Ministry of Environment. The concentration of chlorophyll-a in October was higher than July, this was thought to be related to the abundance of phytoplankton.

| Table 1. Total Nitrogen, Total Phosphorus, and Chlorophyll-a at Menjer Lake on July and October 2019 |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                 | St. 1            | St. 2            | St. 3            | St. 4            | St. 5            | St. 6            |                 |
|                                 | July 2019        | Oct 2019         | July 2019        | Oct 2019         | July 2019        | Oct 2019         | July 2019       |
| TN (mg/L)                       | 5.232            | 3.339            | 5.912            | 5.510            | 4.600            | 4.094            | 5.879           |
| TP (mg/L)                       | 0.027            | 0.016            | 0.108            | 0.050            | 0.010            | 0.009            | 0.012           |
| Chlorophyll-a (mg/m$^3$)        | 15.755           | 4.575            | 37.706           | 10.779           | 13.440           | 16.767           | 23.034          |

The phytoplankton abundance of the Menjer Lake ranged from 4,708 to 532,164 individuals L$^{-1}$ (Table 2), this value is quite high. Phytoplankton abundance in October was higher than July, this pattern was the same as the chlorophyll-a concentration, this shows that the chlorophyll-a concentration
reflects the abundance of phytoplankton. [4] observations over the past two years also show that phytoplankton abundance has the same pattern as chlorophyll-a concentration. The value of phytoplankton abundance in July and October 2019 was higher compared to the value of abundance in May 2015 and October 2016. The abundance of phytoplankton in May 2015 was around 8,476-11,884 individuals L$^{-1}$ [6], while the abundance of phytoplankton in October 2016 was around 60-1,300 individuals L$^{-1}$ [2]. This indicates that there has been an increase in fertility in Menjer Lake, which was shown by the high abundance of phytoplankton, thought to be caused by increased nutrients entering Lake Menjer. TN value in 2006 was 2.878 mg / L and TP was 0.042 mg / L [5], while in 2019, the TN value ranged from 3.339 to 8,406 mg/L, and the TP ranged from 0.004 to 0.108 mg/L. The increase in nutrients in Lake Menjer was caused by increased activities around the lake [2, 6]

### Table 2. Phytoplankton Abundance at Menjer Lake on July and October 2019

| Name of Phytoplankton | St. 1 (Jul-19) | St. 2 (Oct-19) | St. 3 (Jul-19) | St. 4 (Oct-19) | St. 5 (Jul-19) | St. 6 (Oct-19) |
|-----------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Baccillariophyceae     |                |                |                |                |                |                |
| Achnanthes inflata     | 1              |                |                |                |                |                |
| Cymbella sp.           | 1              | 6              |                |                |                |                |
| Epithemia sp.          | 1              | 8              | 1              |                | 10             |                |
| Fragilaria sp.         | 1              |                |                | 10             |                |                |
| Gymphonema sp.         | 1              |                |                |                |                |                |
| Gyrosigma sp.          |                |                |                |                |                |                |
| Melosira granulata     |                | 2              | 1              |                | 4              |                |
| Melosira italica       | 1              | 8              |                |                |                |                |
| Navicula sp.           | 1              | 1              | 1              | 1              |                |                |
| Navicula elegans       |                | 1              |                |                |                |                |
| Navicula pupula        |                | 1              |                | 1              |                |                |
| Nitzschia sp.          | 1              |                |                |                |                |                |
| Synedra ulna           | 29.91          | 64.85          | 82.02          | 35.56          | 12.42          | 9.54           | 21.0           | 523.35         | 44.00          | 25.78          |

| Chlorophyceae          |                |                |                |                |                |                |
| Actinastrum hantzschii  | 1              |                | 4              | 1              |                | 5              |
| Ankistrodesmus falcatus |                |                |                |                |                |                |
| Chlorella sp.          |                |                | 1              | 8              |                |                |
| Coelastrum sp.         |                |                |                |                | 6              |                |
| Crucigenia sp.         |                |                |                |                |                | 4              |
| Dictyosphaerium sp.    | 4              | 2              | 5              | 2              | 3              | 10             | 5              | 40             |
| Kirchneriella sp.      | 1              |                |                |                | 1              |                |
| Oocystis sp.           | 2              |                |                | 4              |                | 2              |
| Microspora sp.         |                |                | 1              |                | 6              |                |
| Mougeotia sp.          |                |                | 4              | 6              |                |                |
| Pandorina sp.          | 8              | 2              | 3              | 1              | 6              | 1              |
| Pediastrum duplex      | 1              |                | 2              | 3              | 1              | 6              | 1              |
| Pediastrum simplex     | 1              |                |                |                |                | 2              |                |
| Scenedesmus bijuga     | 1              | 4              |                | 40             | 16             | 56             | 1              | 120            |
| Sphaerocystis Schroeteri | 7              | 12             | 1              | 24             | 7              | 36             | 3              | 4              | 8              | 140            | 23             | 10             |
| Stauroastrum sp.       | 1              | 20             | 16             | 12             | 46             | 10             |                |
| Tetrachelon regulare   |                | 1              |                |                |                | 1              |                |

| Cyanophyceae           |                |                |                |                |                |                |
| Aphanocapsa sp.        | 184            | 404            | 2              | 108            | 168            | 1,296          | 270            |
| Microcystis aeruginosa | 48             | 48             | 12             | 64             | 740            | 90             |
| Oscillatoria sp.       |                |                |                |                |                | 4              |

| Dinophyceae            |                |                |                |                |                |                |
| Ceratium hirundinella  | 5              | 4              | 79             | 4              | 8              | 2              |
| Peridinium cinctum     |                |                |                |                |                |                |

| Euglenophyceae         |                |                |                |                |                |                |
| Trachelomonas sp.      | 588            | 4,050          | 108            | 2              | 568            | 6,466          | 8,580          |
| Abundance (Individuals/L) | 29.93          | 65.71          | 22.54          | 86.56          | 35.66          | 12.77          | 4.71           | 10.37          | 2.12           | 532.16         | 44.05          | 34.90          |
Table 3. The relative abundance of phytoplankton at Menjer Lake on July 2019 and October 2019

| Site | St 1  | St 2  | St 3  | St 4  | St 5  | St 6  |
|------|-------|-------|-------|-------|-------|-------|
|      | 99.08%| 95.82%| 99.10%| 94.44%| 98.35%| 88.39%|
|      | 0.06% | 0.05% | 0.26% | 0.21% | 0.06% | 0.28% |
|      | 0.24% | 0.41% | 0.26% | 1.54% | 0.38% | 0.46% |
|      | 0.01% | 0.01% | 0.16% | 0.03% | 0.00% | 0.00% |
|      | 0.61% | 3.71% | 0.22% | 3.78% | 1.21% | 10.87%|

The highest abundance of phytoplankton was from the phylum Bacillaryophyta, relative abundance ranges from 88.39% -99.08% (Table 3) with abundant species was Synedra ulna (Table 2). The height of Bacillaryophyta (Asterionella spp., Fragilaria crotenensis, Synedra, Stephanodiscus, and Melosira granulata) in the lake, shows an alkaline eutrophic lake with enrichment nutrients [21]. Bacillaryophyceae are cosmopolitan phytoplankton, adaptable, high tolerance to chemicals and nutrients, and resistant to extreme conditions, [1, 22, 23].

Phytoplankton species found in Menjer Lake in July and October 2019 are presented in Table 4, consisting of five phyla, namely Bacillaryophyta (13 species), Chlorophyta (17 species), Cyanophyta (3 species), Dinophyta (2 species), and Euglenophyta (1 species). The number of species found was 36 species, this number was smaller than the observation in May 2015 of 40 species [6], but higher than the observation in 2006 of 17 species [5], and in October 2016 of 12 species [2]. The type of phytoplankton that dominated in Menjer Lake during the observation was Synedra ulna. Synedra ulna is phytoplankton that generally dominates in small lakes on the Java island [5], this species is tolerant of waters polluted with organic matter [17].

Phytoplankton that was always found in all observation stations are Synedra ulna (Bacillaryophyta), Dictyosphaerium sp., and Sphaerocystis Schroeteri (Chlorophyta), Aphanocapsa sp. and Microcystis aeruginosa (Cyanophyta), and Trachelomonas sp. (Euglenophyta) (Table 4). Besides always being found at all stations, Synedra ulna has a higher abundance compared to other species (Table 2). Synedra ulna is one of bioindicator for high organic matter concentration [17]. Based on species that were commonly found, Menjer Lake is a lake with high organic material [2,6]. Source of organic material in Menjer Lake besides comes from outside the lake, it can also comes from the excess food in fish cultivation activities in floating net cages found in this lake.

Besides Bacillaryophyta, the number of Chlorophyta species was also quite high compared to Cyanophyta, Dinophyta, and Euglenophyta (Tables 2 and 4). A high number of Chlorophyta species in freshwater is commonly, such as in Remis Lake, Niler Lake, Gunung Lake, Cisanti Lake (West Java), Wara Lake, Pengilon Lake, and Drino Lake (Central Java), Grati Lake, Pakis Lake, Pane Lake, and Lake Regulo (East Java) [5], Rawa Kalong Lake (West Java) [24], Cibuntu Lake, Dora Lake and Lotus Lake (West Java) [25].

Diversity Index, Evenness Index, and Dominance Index of phytoplankton in Lake Menjer are presented in Table 5. According to [18], diversity index showed low values (0.010-0.943), this indicates that only a few species can adapt to their environmental conditions. Evenness index values close to zero (0.001-0.062) indicate the low uniformity of the phytoplankton community, there is a tendency of dominance by certain species. The dominance index close to one (0.606-0.999) indicates the presence of a dominant type. Observations showed that there is a dominant species, namely Synedra ulna. The presence of species dominating in waters indicates an unstable community structure due to ecological pressure [18].

Diversity index values in July and October 2019 were lower than in 2006 as 1.242 [5], May 2015 as 2.27-2.62 [6], and October 2016 as 1.09-1.22 [2]. Evenness index values in July and October 2019 were lower than in May 2015 as 0.84-0.92 [6], and October 2016 as 0.79 [2]. This shows that the phytoplankton community was more stable in 2015 and 2016 than in 2019 and there were no dominant
species in 2015 and 2016. The dominance index values in 2006, 2015, and 2016 are smaller than 0.5 or close to zero (0), which indicates that no species dominates. The lower value of the diversity index and evenness index, as well as the higher value of the dominance index in 2019 compared to previous years, indicate that there has been a decline in water quality in Menjer Lake. It also marked the presence of a dominant species in 2019.

Table 4. The Composition of Phytoplankton at Menjer Lake in July and October 2019

| Time  | Bacillariophyta                      | Chlorophyta                       | Cyanophyta                       | Dinophyta                  | Euglenophyta               |
|-------|-------------------------------------|-----------------------------------|----------------------------------|---------------------------|---------------------------|
| July  | Achnanthes inflata,                  | Actinastrium hantzschii,           | Aphanocapsa sp.                 | Ceratium hirundinella,     | Trachelomonas sp.          |
| 2019  | Epithemia sp.,                      | Ankistrodesmus falcatus,           |                                  | Peridinium cinctum        |                           |
|       | Fragilaria sp.,                      | Chlorella sp., Cruigenia sp.,     |                                  |                           |                           |
|       | Gymosigma sp.,                      | Dictyosphaerium sp.,              |                                  |                           |                           |
|       | Melosira granulata,                 | Kirchneriella sp., Oocystis sp.,   |                                  |                           |                           |
|       | Melosira italica,                   | Microspora sp., Pandorina sp.,    |                                  |                           |                           |
|       | Navicula sp.,                       | Pediastrum duplex,                |                                  |                           |                           |
|       | Navicula elegans,                   | Pediastrum simplex,               |                                  |                           |                           |
|       | Navicula pupula,                    | Scenedesmus bijuga,               |                                  |                           |                           |
|       | Nitzschia sp., Synedra ulna         | Sphaerocyctis schroeteri,         |                                  |                           |                           |
|       |                                    | Staurastrum sp., Tertaebron        |                                  |                           |                           |
| Oct   | Cymbella sp.,                        | Aphanocapsa sp.                   |                                  | Microcystis aeruginosa,    |                           |
| 2019  | Epithemia sp.,                      |                                  |                                  | Oscillatoria sp.           |                           |
|       | Fragilaria sp.,                     |                                  |                                  |                           |                           |
|       | Melosira granulata,                 |                                  |                                  |                           |                           |
|       | Synedra ulna                        |                                  |                                  |                           |                           |

Table 5. Diversity Index, Evenness Index and Dominance Index of Phytoplankton at Menjer Lake on July 2019 and October 2019

| St.  | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 | July 2019 | Oct 2019 |
|------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|
| Diversity Index | 0.010 | 0.119 | 0.019 | 0.329 | 0.032 | 0.248 | 0.062 | 0.509 | 0.109 | 0.143 | 0.016 | 0.943 | 0.001 | 0.007 | 0.001 | 0.020 | 0.002 | 0.018 | 0.005 | 0.038 | 0.010 | 0.008 | 0.001 | 0.062 |
| Evenness Index | 0.999 | 0.974 | 0.997 | 0.900 | 0.994 | 0.947 | 0.990 | 0.850 | 0.978 | 0.967 | 0.998 | 0.606 | 0.999 | 0.974 | 0.997 | 0.900 | 0.994 | 0.947 | 0.990 | 0.850 | 0.978 | 0.967 | 0.998 | 0.606 |

4. Conclusion
The nutrient content in Menjer Lake influences the structure of phytoplankton communities in abundance and composition. Observations show that the species diversity and evenness index lower than 0.5 and the species dominance higher than 0.5 and there was one species dominates, namely Synedra ulna. This indicate that the phytoplankton community in Menjer Lake is unstable due to ecological pressure.

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