Trophic Status of Waters in Poso Watershed, Central Sulawesi

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Abstract. Poso Watershed is a potential area for tropical eel fish resources, the disturbance of the ecosystem balance in the form of damage to the catchment area will affect the existence of eel fish. This study aimed to determine the trophic status of the Poso watershed. Observations were conducted in March 2021 in six zones of the basin, namely Kodina River (1 site), Lake Poso (2 sites), Poso outlets (3 sites), Poso River (2 sites), and Poso river estuaries (4 sites). The observed parameters were water quality (physics and chemistry) and biology (phytoplankton composition and abundance). In general, the conditions of the Poso Watershed are still good, temperatures range from 24.26 °C-29.24 °C, pH shows that these waters are alkaline (9.15-10.21), and dissolved oxygen (DO) indicates dissolved oxygen quite high (7.13-7.93 mg/L). The values of chlorophyll-a, total nitrogen (TN), and total phosphorus (TP) showed low. The value of turbidity and total suspended solids is higher at the mouth of the Poso River (MP1-MP4) compared to other stations. The abundance of phytoplankton is low (9-848 individuals/liter), and the species with high abundance is Staurastrum sp. (Chlorophyceae). Hence, this study shows the Poso Watershed, including oligotrophic to eutrophic waters.

1. Introduction
Poso watershed is a potential area for tropical eel fish resources, namely Anguilla marmorata, Anguilla bicolor pacific, Anguilla celebensis, Anguilla borneensis, and Anguilla interioris [1]. These waters are also known as fishing areas, the types of eels obtained are A. marmorata or A. mauritania, and A. celebensis [2]. A. marmorata is a type of eel that is mostly caught in Poso waters and dominates eel catches from Lake Poso [1].

The Poso River, which flows from Lake Poso and empties into Tomini Bay, is the habitat and area of eels in Poso. The area around the Poso river is a plantation area, agriculture, and forest area. There is no large industrial area in its water catchment area that has the potential to pollute Poso waters, so the condition of water quality in the Poso watershed is still good [3]. Lake Poso is oligotrophic water with a brightness value of 4.6 m [1]. Several studies have shown that there has been a decline in eel catches in Poso waters [2, 3, 4].

The decreasing trend of eel production in Poso waters is thought to be related to the pattern of eel fishing that does not pay attention to the sustainability aspect, also caused by changes in habitat both in the migration path and in their enlargement habitats [5]. The trophic status of the waters of Lake Poso based on the Carlson Trophic Status Index has a value between 42.94-53.05 with mesotrophic to mild eutrophic status [6]. [7] also mentions that in recent years Lake Poso has experienced disturbances in the balance of the ecosystem in the form of damage to the catchment area with indicators of high erosion.
and sedimentation rates, as well as increasing land and border damage; and the threat of the preservation of eel as an endemic biota in the waters of Lake Poso. Therefore, a study was conducted to assess the current condition of water quality in several types of eel habitats in Poso Watershed.

Research on water quality in the Poso Lake is necessary to determine the condition of water quality and trophic level of Poso Watershed as a habitat for eels. The results of these observations can be used as a basis for the management of Lake Poso for the preservation of the lake and eels in particular.

2. Method

2.1. Study Location
Lake Poso is located in Poso Regency, Central Sulawesi, stretching from north to south for 32 km with a width of 16 km [8]. It has an area of 368.9 km², a coastline length of 127 km, a maximum depth of 384.6 m with an average depth of 194.7 m, and a brightness of 10 m [9]. The Poso River flows from Lake Poso in Tentena and empties into Tomini Bay, the mouth of the Poso River is the largest estuary of the four main rivers. The area of the Poso Watershed is 1101.87 km² [9], the Poso watershed is a habitat and area for eels. Observations were made at several locations in the waters of Lake Poso, which are considered representative of the condition of Poso Watershed (figure 1). Observations were made in March 2021. Locations and descriptions of sampling are presented in table 1.

2.2. Research stages and Analysis method
The water quality parameters measured were pH, dissolved oxygen (DO), temperature, conductivity, total dissolved solids (TDS), and turbidity, measured in situ using a HORIBA water meter. While the parameters analyzed in the laboratory were total phosphorus/TP (4500-PJ and 4500-PE method), total nitrogen/TN (brucine method), ammonium (N-NH₄), chlorophyll-a (1020-0 method), total suspended solids/TSS (gravimetric method), and total organic matter/TOM (permanganate method) based on APHA [10,11]. In addition, the Secchi depth and water depth were also measured. The trophic status of Poso Watershed was analyzed using the Trophic State Index (TSI) Carlson [12], based on the parameters of TP and chlorophyll-a with the equation:

![Figure 1. Sampling sites in Poso in March 2021.](image-url)
Table 1. Location and Description of Poso Watershed Sampling, March 2021.

| No | Station | Location     | Description               |
|----|---------|--------------|---------------------------|
| 1  | Kodina  | Kodina River | Kodina River Estuary      |
| 2  | DP 5    | Lake Poso   | Southern Mid of Lake Poso |
| 3  | DP 1    | Lake Poso   | Northen Mid of Poso Lake  |
| 4  | OP 1    | Poso River  | Main Estuary              |
| 5  | OP 2    | Poso River  | Fence                     |
| 6  | OP 3    | Poso River  | Cave                      |
| 7  | SP 1    | Poso Energy 2| Poso River (Fishway)      |
| 8  | SP 2    | Poso Energy 1| Poso River (Fishway)      |
| 9  | MP 1    | Poso River Estuary | Poso River Estuary       |
| 10 | MP 2    | Poso River Estuary | Fish Auction Place     |
| 11 | MP 3    | Poso River Estuary | Poso Bridge           |
| 12 | MP 4    | Poso River Estuary | The Upper Part of Poso Estuary |

TSI Chlorella was formulated by the equation:

$$T_{SI(Chl)} = 10 \left(6 - \frac{2.04 - 0.68 \ln Chl}{\ln 2}\right)$$  \hspace{1cm} (1)

TSI TP was formulated by the equation:

$$T_{SI(TP)} = 10 \left(6 - \frac{\ln PP}{\ln 2}\right)$$  \hspace{1cm} (2)

The biological parameters analyzed were the composition and abundance of phytoplankton. A total of 1.6 - 10 liters of water were filtered using plankton net no. 25 (mesh size 53 µm), and preserved using Lugol's solution until the sample is yellowish [11]. Phytoplankton identification was carried out using an inverted microscope NIKON Diaphot 300 at 100x, 200x, and 400x magnification based [13,14,15,16,17]. Abundance was calculated using the Sedgwick Rafter method [11], colony and filamentous phytoplankton were counted as one phytoplankton unit [18].

Analysis of the phytoplankton community structure can be determined with the Shannon Wiener Diversity Index (H'), the Evenness Index (E), and the Simpson Dominance Index (C), based on [19].

Shannon Wiener Diversity Index was formulated by the equation:

$$H' = - \sum_{i=1}^{S} P_i \ln P_i$$  \hspace{1cm} (3)

Where:
H': the Shannon diversity index;
P_i: ni/N;
ni: number of individuals of taxon i;
N: total number of individuals in the sample;
s: number of species encountered.
Evenness index was formulated by the equation:

$$E = \frac{H'}{H'\text{max}}$$  \hspace{1cm} (4)

Where:
- $E$: evenness index;
- $H'$: Shannon-Wiener Index;
- $S$: number 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:

$$D = \sum_{i=1}^{S} \left(\frac{n_i}{N}\right)^2$$  \hspace{1cm} (5)

Where:
- $D$: the Simpson Dominance index;
- $n_i$: number of individuals of taxon i;
- $N$: total number of individuals in the sample;
- $S$: number of species encountered.

3. Result and Discussion

3.1. Physico-Chemical Parameters

Physico-chemical parameters data measured in March 2021 are presented in table 2 and 3. In general, the condition of the Poso Watershed is still good, the temperature ranges from 24.26°C-29.24°C, and pH ranges from 9.15-10.21, indicating that these waters are alkaline. Dissolved oxygen (DO) values ranged from 7.13-7.93 mg/L, indicating that dissolved oxygen was quite high. The value of chlorophyll-a ranged from 0.1897-0.7615 mg/m³, total nitrogen (TN) ranged from 0.0295-0.3480 mg/L, and total phosphorus (TP) ranged from 0.0119-0.0850 mg/L indicating a low value base on the Minister of Environment Regulation No. 28 of 2009 (table 4). Lake Poso includes oligotrophic waters with normal to alkaline pH values and poor nutrients [20], observations of [4] also show that the water quality of Lake Poso is still good.

The turbidity and TSS values were high at the Poso River estuary (MP1-MP4) compared to other stations, the values reached 75.3-91.9 NTU and 45.8-53.4 mg/L. Turbidity measurements are often used to assess the number of suspended solids in water, particles suspended in water cause scattering of light which causes turbidity [21]. The high turbidity and TSS in the Poso River estuary area compared to other areas can be caused by material carried from the Poso River flow and collected in the estuary area. As mentioned [22], that most of the TSS in water bodies is due to natural and human factors such as carried by river runoff, coastal erosion, dredging activities, and waves.

Eels are migratory fish, where migration is a very crucial time in the life of eels. Environmental conditions, both physical, chemical, and biological, will significantly affect the success of eel migration. Observations of [23] show that eels migration is influenced by turbidity, conductivity, rainfall, and flow rate. Peak turbidity and high flow rate appear to be the parameters most associated with peaks of eel migration, eels stop moving when turbidity and flow rate decrease suddenly, and will resume migration after these two parameters increase. Observations also show that the eels start migrating in the darkest conditions when the light is low, and the turbidity is high [23]. Based on some observations, eels are very rarely migrate during the day, and this is the reason why glass eel catches are done at night, especially when the dark moon.
The conductivity in the estuary area (M1 – M4) is relatively higher than in other areas, presumably related to the salinity value in the estuary, which is higher than in the river (table 1). The number of migrating eels is high when the conductivity is low, but the relationship between conductivity and eel migration is not known for certain [23]. Rainfall will affect the turbidity and flow rate, and the higher rainfall will increase the turbidity and speed of water flow. The highest abundance of glass eels occurs when rain affects the hydrological regime in the river, accompanied by an increase in water turbidity, and low to moderate water temperature conditions [24]

Table 2. In situ water quality in the Poso River Basin, March 2021.

| No | Station | Temp. (°C) | pH | Conductivity (mS/cm) | Turbidity (NTU) | Total Dissolve Solid (g/L) | Dissolved Oxygen (mg/L) |
|----|---------|------------|----|---------------------|----------------|---------------------------|------------------------|
| 1  | OP 1    | 28.46      | 9.40| 0.080              | 5.5            | 0.057                     | 7.47                   |
| 2  | OP 2    | 28.28      | 9.03| 0.089              | 5.6            | 0.058                     | 7.38                   |
| 3  | OP 3    | 28.12      | 9.21| 0.089              | 5.9            | 0.058                     | 7.39                   |
| 4  | SP 1    | 27.95      | 9.43| 0.089              | 9.4            | 0.058                     | 7.19                   |
| 5  | SP 2    | 28.26      | 9.15| 0.090              | 12.5           | 0.058                     | 7.13                   |
| 6  | MP 1    | 28.44      | 9.56| 0.107              | 75.3           | 0.069                     | 7.93                   |
| 7  | MP 2    | 28.71      | 10.21| 0.106             | 79.0           | 0.068                     | 7.83                   |
| 8  | MP 3    | 28.79      | 9.72| 0.104              | 91.9           | 0.067                     | 7.90                   |
| 9  | MP 4    | 28.83      | 9.67| 0.103              | 75.6           | 0.067                     | 7.87                   |
| 10 | DP 1    | 28.45      | 9.66| 0.089              | 16.0           | 0.056                     | 7.46                   |
| 11 | DP 5    | 29.24      | 9.50| 0.089              | 5.1            | 0.053                     | 7.52                   |
| 12 | Kodina  | 24.26      | 9.65| 0.130              | 58.9           | 0.084                     | 7.29                   |

Table 3. Data from the analysis of water quality parameters in the Poso River Basin, March 2021.

| No. | Station | Chlorophyll-a (mg/m³) | TSS (mg/L) | TN (mg/L) | TP (mg/L) |
|-----|---------|-----------------------|------------|-----------|-----------|
| 1   | OP 1    | 0.7339                | 0.9        | 0.4380    | 0.0481    |
| 2   | OP 2    | 0.7615                | 1.3        | 0.1500    | 0.0345    |
| 3   | OP 3    | 0.4761                | 1.0        | 0.0295    | 0.0374    |
| 4   | SP 1    | 0.4977                | 2.4        | 0.0321    | 0.0792    |
| 5   | SP 2    | 0.2876                | 4.5        | 0.0308    | 0.0850    |
| 6   | MP 1    | 0.4634                | 45.8       | 0.2150    | 0.0394    |
| 7   | MP 2    | 0.3318                | 49.4       | 0.0477    | 0.0491    |
| 8   | MP 3    | 0.3340                | 53.4       | 0.0620    | 0.0636    |
| 9   | MP 4    | 0.4203                | 51.6       | 0.3180    | 0.0514    |
| 10  | DP 1    | 0.1897                | 1.6        | 0.0438    | 0.0119    |
| 11  | DP 5    | 0.4846                | 1.2        | 0.2330    | 0.0122    |
| 12  | Kodina  | 0.2062                | 13.8       | 0.1370    | 0.0433    |

Based on the Minister of Environment Regulation No. 28 of 2009 (table 4), the value of TN is in the oligotrophic category. The TP value shows mesotrophic conditions in Lake Poso (DP) and eutrophic conditions in the rivers (OP, SP, and Kodina) and the mouth of the Poso River (MP). The value of chlorophyll-a indicates that the waters are still in the category of oligotrophic waters. The difference in trophic status based on TP in rivers and lakes is thought to be caused by the carrying of TP by suspended solids and suspended sediment into river waters. Algae, suspended solids, and suspended sediments can
carry more phosphorus to the water [21; 25], high surface erosion in rivers and high erodibility are important factors in increasing the concentration of TP and total suspended matter (TSM) in the estuary [26].

Table 4. Lake Trophic Status Criteria.

| Trophic Status | Average of TN Level (µg/L) | Average of TP Level (µg/L) | Average of Chlorophyll-a Level (µg/L) | Average Brightness (m) |
|----------------|---------------------------|---------------------------|--------------------------------------|------------------------|
| Oligotroph     | ≤ 650                     | < 10                      | < 2                                  | ≥ 10                   |
| Mesotroph      | ≤ 750                     | < 30                      | < 5                                  | ≥ 4                    |
| Eutroph        | ≤ 1900                    | < 100                     | < 15                                 | ≥ 2.5                  |
| Hyper-eutroph  | > 1900                    | ≥ 100                     | ≥ 200                                | < 2.5                  |

Source: Minister of Environment Regulation No. 28/2009 (Kementrian Lingkungan Hidup, 2009)

3.2. Trophic Status Index

The Carlson Trophic Status Index for chlorophyll-a and total phosphorus in the Poso Watershed is presented in figure 2. These waters are classified as oligotrophic waters based on the chlorophyll-a trophic status index, and includes oligotrophic (at Lake Poso) to eutrophic waters (at river and estuary) based on the total phosphorus trophic status index. Observations [6] show that the trophic status of Lake Poso is in the mesotrophic (in March, May, and September 2011) to eutrophic category (in November 2011).

Oligotrophic waters show clear waters with oxygen available throughout the year in the hypolimnion area, mesotrophic waters show waters with moderate brightness, and there is a possibility of an anoxic increase in the hypolimnion depth, while eutrophic waters have a decrease in brightness and the possibility of anoxic occurrence in the hypolimnion zone [12]. The value of the trophic status index in the Poso Watershed in March 2021, and supported by low TN, TP, and chlorophyll-a, indicates that the waters of Poso Watershed support fish life.

3.3. Phytoplankton Community

The composition and abundance of phytoplankton in the waters of Poso Watershed are presented in table 5, the abundance ranges from 9 – 848 individuals/L, and the number of species varies from 4 – 13 species. This value indicates that the waters of Lake Poso are oligotrophic, oligotrophic waters are
characterized by low abundance and number of species. The species with high abundance and always found at the sampling site is *Staurastrum* sp (table 4), the presence of this species is one of the characteristics of oligotrophic waters [20].

The types of phytoplankton found in the Poso Watershed are non-toxic and are a natural food source for eels. Plankton is one of the natural foods of eels, about 30% of the stomach contents of eels in the Air Manna River consist of plankton [27], analysis of the stomach of glass eels in the Cimandiri River shows that the main natural food is phytoplankton[28].

There is no data on phytoplankton in Lake Poso. Based on the abundance value, phytoplankton in Lake Poso is lower than in Lake Matano [29] and the waters of Lake Lindu [30], while the typical composition of phytoplankton in Lake Poso is more similar to Lake Matano compared to Lake Lindu. The same trophic status in Lake Matano and Lake Poso, namely oligotrophic, may cause this similarity, although each lake has its characteristics.

**Table 5.** Composition and abundance of phytoplankton in the Poso River Basin, March 2021.

| Genus                  | Station | Kodina | DP 5 | DP 1 | OP 1 | OP 2 | OP 3 | SP 1 | SP 2 | MP 1 | MP 2 | MP 3 | MP 4 |
|------------------------|---------|--------|------|------|------|------|------|------|------|------|------|------|------|
| Baccillariphyceae      |         |        |      |      |      |      |      |      |      |      |      |      |      |
| *Aulacoseira* sp.      |         | 8      | 10   | 3    | 3    | 3    | 3    | 2    |      |      |      |      |      |
| *Cyclorella* sp.       |         |        |      |      |      |      |      |      |      |      |      |      |      |
| *Cymbella* sp.         |         |        |      |      |      |      |      |      |      |      |      |      | 2    |
| *Cyclotella* sp.       |         | 2      | 99   | 17   | 32   | 36   |      |      |      |      |      |      |      |
| *Chlorophyceae*        |         |        |      |      |      |      |      |      |      |      |      |      |      |
| *Closterium* sp.       |         |        |      |      |      |      |      |      |      |      |      |      | 2    |
| *Cosmarium* sp.        |         | 105    | 5    | 3    | 6    | 9    | 2    |      |      |      |      |      |      |
| *Dictyosphaerium* sp.  |         | 8      |      |      |      |      |      |      |      |      |      |      |      |
| *Oocystis* sp.         |         | 8      | 5    |      |      |      |      |      |      |      |      |      |      |
| *Pediastrum* sp.       |         |        |      |      |      |      |      |      |      |      |      |      |      |
| *Scenedesmus* sp.      |         | 8      |      |      |      |      |      |      |      |      |      |      |      |
| *Sphaerocystis* sp.    |         | 90     | 3    | 3    | 9    | 3    | 2    | 2    |      |      |      |      |      |
| *Spirogyra* sp.        |         | 3      | 2    | 2    | 6    | 9    | 9    | 6    |      |      |      |      |      |
| *Staurastrum* sp.      |         | 3      | 623  | 293  | 133  | 118  | 55   | 138  | 159  | 198  | 84   | 48   | 35   |
| *Stigeoclonium* sp.    |         | 2      | 3    | 2    | 3    |      |      |      |      |      |      |      |      |
| *Synuma* sp.           |         | 15     | 2    | 14   | 3    |      |      |      |      |      |      |      |      |

7
The Diversity Index describes the state of the population of organisms mathematically. The Evenness Index shows the distribution pattern of biota, while The Dominance Index describes the dominance of certain species in a community. Diversity Index, Evenness Index, and Dominance Index of phytoplankton in Poso Watershed in March 2021 are presented in Table 6. Phytoplankton diversity index values ranged from 0.680 to 2.553, indicating that Poso Watershed has low to moderate phytoplankton diversity. The evenness index value tends to be close to zero, and the dominance index value at several sampling sites is greater than 0.5, indicating that the phytoplankton community structure in these waters is unstable, there is a species that dominates at a certain station, namely Staurastrum sp. As mentioned by [19], the smaller of the evenness index value means that the distribution of individuals for each species or genus is not evenly distributed, and there is a tendency for the community to be dominated by certain species or genera.

### Table 6. Diversity Index, Evenness Index, and Dominance Index in the Poso River Basin.

| Index                | Sampling Site       | Kodina | DP 5 | DP 1 | OP 1 | OP 2 | OP 3 | SP 1 | SP 2 | MP 1 | MP 2 | MP 3 | MP 4 |
|----------------------|---------------------|--------|------|------|------|------|------|------|------|------|------|------|------|
| Diversity Index (H') |                     | 1.918  | 1.285| 0.330| 1.399| 0.680| 1.156| 1.122| 1.111| 1.707| 2.154| 2.345| 2.553|
| Evenness Index (E)   |                     | 0.605  | 0.132| 0.040| 0.188| 0.097| 0.184| 0.152| 0.146| 0.199| 0.295| 0.333| 0.353|
| Dominance Index (D)  |                     | 0.278  | .566 | 0.906| 0.586| 0.819| 0.557| 0.692| 0.683| 0.372| 0.338| 0.245| 0.231|

4. Conclusion
The TP, TN, and chlorophyll-a values in Poso Watershed were lower. The trophic status of the Poso watershed based on nutrient and chlorophyll-a values is oligotrophic to eutrophic. The number of species and abundance of phytoplankton is low, the phytoplankton community structure is not stable with low to moderate diversity values. This study concludes that the condition of water quality in the Poso watershed in March 2021 shows a condition that can still support eels life.
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