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PLANKTON COMMUNITY STRUCTURE AS A BIOINDICATOR OF LAKE TOBA WATER CONDITIONS IN BALIGE DISTRICT TOBA REGENCY

Ewin Handoco[1]* & Welmar Olfan Basten Barat[2]
[1&2]Water Resources Management Study Program, Faculty of Water Resources Engineering and Management, HKBP Nommensen University Pematangsiantar, Sangnawaluh Street Number 4, Pematang Siantar, North Sumatera 21136, Indonesia
**Email: ewinhandoco@gmail.com*
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ABSTRACT: Plankton sampling was conducted at three observation stations in the study area, with samples collected from surface waters using standard plankton sampling techniques. Phytoplankton and zooplankton were identified microscopically, and community structure was evaluated using abundance, diversity (Shannon-Wiener), evenness, and dominance indices. A total of six phytoplankton classes and four zooplankton classes were identified. The phytoplankton community was represented mainly by members of Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Coscinodiscophyceae, and Zygnematophyceae, while the zooplankton community was dominated by taxa belonging to Crustacea, Rotatoria, Hexanauplia, and Tubulinea. Phytoplankton species richness was higher than zooplankton richness, indicating a relatively stable aquatic ecosystem with a well-developed primary producer community. Phytoplankton abundance ranged from 709,652 to 2,414,621 cells m^{-3} across stations, whereas zooplankton abundance ranged from 51,119 to 300,700 individuals m^{-3}. The Shannon-Wiener diversity index (H′) showed moderate diversity ($1 \leq H' \leq 3$), suggesting sufficient productivity, fairly balanced ecosystem conditions, and moderate ecological pressure. Evenness values indicated a relatively uniform distribution of plankton among sampling stations, while dominance index values showed that no single taxon dominated the community. The plankton community structure suggests that the study area remains in a relatively stable ecological condition and supports balanced aquatic ecosystem functioning.

Keywords: Bioindicator, Lake Toba, Phytoplankton, Plankton Community Structure, Water Quality, Zooplankton.

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INTRODUCTION

Lake Toba is the largest volcanic lake in Indonesia and plays an important ecological and economic role in the surrounding region. Balige District, located in Toba Regency, occupies part of the Lake Toba shoreline and serves as a center for tourism, transportation, and community activities. The presence of ports, recreational facilities, settlements, and commercial activities around the lake may contribute organic and inorganic waste inputs that can affect water quality and ecosystem health. Lake Toba supports various economic sectors, including fisheries, tourism, water transportation, and other local industries, making the sustainability of its aquatic ecosystem a critical concern (Irwandi et al., 2021). Therefore, continuous monitoring of water quality and aquatic biological communities is essential to assess environmental conditions and support sustainable lake management.

Despite its ecological and economic importance, Lake Toba faces increasing environmental pressure from domestic waste, tourism activities, aquaculture, agriculture, livestock production, industrial activities, and port operations (Yolanda et al., 2023). These anthropogenic activities have the potential to alter the physicochemical characteristics of the water, resulting in reduced water transparency, changes in dissolved oxygen concentrations, and increased organic matter loading. Such environmental changes may affect the structure and functioning of aquatic communities and can serve as indicators of ecosystem degradation (Fukushima et al., 2023).

Plankton communities are among the most sensitive biological indicators of water quality because they respond rapidly to environmental changes. Plankton are microscopic organisms that drift in the water column and form an essential component of aquatic food webs. Based on their ecological roles, plankton are generally classified into phytoplankton and zooplankton. Phytoplankton are photosynthetic microorganisms that function as primary producers and form the foundation of aquatic food chains, whereas zooplankton act as primary consumers that feed on phytoplankton and other microscopic organisms (Garno et al., 2020; Irnawati et al., 2020). The diversity, abundance, and community structure of plankton are therefore widely used to assess the ecological condition and trophic status of freshwater ecosystems.

Several studies have investigated water quality and ecological conditions in Lake Toba. However, information regarding the current structure of plankton communities in the waters of Balige District remains limited. In particular, there is insufficient recent data linking plankton community characteristics with ecological indices as indicators of environmental quality in areas influenced by tourism, transportation, and community activities. This knowledge gap highlights the need for updated assessments of plankton diversity and community structure in the Balige waters of Lake Toba.

Therefore, this study aims to analyze the composition, abundance, diversity, evenness, and dominance of phytoplankton and zooplankton communities in the waters of Balige District, Lake Toba. The novelty of this research lies in providing updated ecological information on plankton community structure in a strategically important area of Lake Toba that is directly influenced by multiple anthropogenic activities. The findings are expected to contribute to the evaluation of water quality and provide scientific information to support sustainable management of the Lake Toba ecosystem.

METHOD

This research was conducted in three stages, namely: 1) in situ measurement of water quality parameters; 2) ex situ analysis through plankton identification; and 3) calculation of plankton abundance and ecological indices (Witariningsih et al., 2020). Sampling was carried out at three observation stations in the lake. Station 1 was located near the lake shoreline, while Stations 2 and 3 were positioned toward the central area of the lake (Silaban & Silalahi, 2021). The geographic coordinates of each station were determined using a Global Positioning System (GPS) and recorded during field observations.

Water samples were collected using a water sampler. The sampler was lowered to the predetermined depth and then retrieved to the surface. Water quality parameters, including temperature, pH, Dissolved Oxygen (DO), and transparency, were measured directly in the field using a water quality test kit (Soliha & Rahayu, 2016). All measurement results were recorded on prepared field data sheets (Hastuti et al., 2024). The collected water samples were then properly labeled and transported to the laboratory for further analysis of plankton composition and abundance.

The concentrated plankton sample collected in the cod-end bottle was transferred into labeled sample bottles. Each sample was preserved using Lugol's solution at approximately 1-2% of the sample volume to prevent decomposition and maintain cell integrity during storage and transportation (Ridwan et al., 2016). Identification of phytoplankton and zooplankton was carried out using standard identification references from Bellinger & Sigee (2010). The identified plankton were counted and analyzed to determine abundance and ecological indices (Baghel, 2024; Safnowandi, 2019; Yuni & Mustaqim, 2020).

Plankton Abundance

Plankton abundance was calculated using the following formula:

$$\mathbf{N = (n \times Vr \times 1000) / (Vo \times Vs)}$$

Where:

N = Plankton abundance (ind/L);
n = Number of individuals counted;
Vr = Volume of concentrated sample (mL);
Vo = Volume observed under the microscope (mL); and
Vs = Volume of filtered water sample (L).

Shannon-Wiener Diversity Index (H')

The diversity index was calculated using the Shannon-Wiener formula:

$$\mathbf{H' = -\Sigma\ (pi\ ln\ pi)}$$

Where:

H' = Diversity index;
pi = ni/N;
ni = Number of individuals of species i; and
N = Total number of individuals.

Criteria:
H' < 1 = Low diversity;
1 ≤ H' ≤ 3 = Moderate diversity; and
H' > 3 = High diversity.

Evenness Index (E)

The evenness index was calculated using:

$$\mathbf{E = H' / ln(S)}$$

Where:
E = Evenness index;
H' = Shannon-Wiener diversity index; and
S = Total number of species.

Criteria:
$E < 0.4$ = Low evenness;
$0.4 \leq E \leq 0.6$ = Moderate evenness; and
$E > 0.6$ = High evenness.

Dominance Index (C)

The dominance index was calculated using Simpson's dominance formula:

$$C = \Sigma (ni/N)^2$$

Where:
C = Dominance index;
ni = Number of individuals of species i; and
N = Total number of individuals.

Criteria:
C approaching 0 indicates no dominant species.
C approaching 1 indicates dominance by one or a few species.

Data Analysis

The abundance, diversity, evenness, and dominance indices were analyzed descriptively to evaluate plankton community structure and ecological conditions of the lake ecosystem.

RESULTS AND DISCUSSION

Based on results in the research conducted, there were 6 classes Phytoplankton and 4 Classes of Zooplankton. Phytoplankton classes obtained from Bacillariophyceae, Chlorophyceae, Coscinodiscophyceae, Cyanophyceae, Dinophyceae, and Zygnematophyceae. Species Phytoplankton obtained from the Class Bacillariophyceae there are four species consisting of from *Eunotia* sp., *Fragilaria* sp., *Navicula* sp., and *Nilzschia* sp.

In the class Chlorophyceae there are five species that is *Ankistrodesmus* sp., *Coelastrum* sp., *Pediastrum* sp., *Scenedesmus* sp., and *Treubaria* sp. Class Coscinodiscophyceae there is one species that is *Melosira* sp. Class Cyanophyceae there is six species that is *Chroococcus* sp., *Merismopedia* sp., *Microcystis* sp., *Oscillatoria* sp., *Phormidium* spp., and *Spirulina* sp. Class Dinophyceae obtained two species that is *Ceratium* sp. and *Peridinium* sp. In the class sixth that is class Zygnematophyceae there is two species that is *Mougeotia* sp. and *Staurastrum* sp. Zooplankton obtained at the location study there is four class namely Crustacea, Furolatoria, Hexanauplia, and Tubulinea. In the Crustacea class there are one Zooplankton species, namely Nauplius. In the class Eurotatoria there are five types, namely *Brachionus* sp., *Keratella* sp., *Philodina* sp., *Polyarthra* sp. and *Trichocerca* sp. While in the class Hexanauplia there is two species namely *Canthocamptus* sp. and *Cyclops* sp. Tubulinea class there are *Arcella* sp. and *Fyalosphenia* sp. Classes and species that's what 's in the three point location sample taking phytoplankton and zooplankton.

The results of the study showed that phytoplankton exhibited higher species diversity than zooplankton. Higher phytoplankton diversity indicates that the aquatic ecosystem at the study site remains relatively stable, as phytoplankton serve as the primary producers and are more diverse than zooplankton, which function as primary consumers that feed directly on phytoplankton (Borics et al., 2021). In aquatic ecosystems with high phytoplankton diversity, environmental conditions are generally more stable and capable of supporting a greater variety of organisms at higher trophic levels. Consequently, overall ecosystem productivity tends to increase (Karakuş et al., 2022).

The study found that phytoplankton abundance varied among stations, with station 1 recording 2,414,621 cells m^{-3}, station 2 recording 1,527,556 cells m^{-3}, and station 3 recording 709,652 cells m^{-3}. Zooplankton abundance also differed among stations, with 51,119 ind. m^{-3} at station 1, 138,322 ind. m^{-3} at station 2, and 300,700 ind. m^{-3} at station 3. These results indicate a spatial variation in plankton distribution, which may be influenced by differences in environmental conditions and nutrient availability among sampling stations.

According to Anggara et al. (2017), waters with low fertility are characterized by plankton densities below 10^4 ind. L^{-1}, moderately fertile waters have densities exceeding 10^4 ind. L^{-1}, and highly fertile waters have densities above 10^7 ind. L^{-1}. The phytoplankton abundance observed in this study ($>10^6$ cells m^{-3}) indicates a high level of fertility, while the zooplankton abundance ($>10^5$ ind. m^{-3}) also suggests highly fertile conditions (Babaei et al., 2022). These findings indicate that the study area possesses favorable environmental conditions capable of supporting aquatic ecosystem functioning and biological productivity (Weenink et al., 2022). Analysis results calculation index diversity (H'), index uniformity (E), and index dominance (C) can shown in Table 1.

Table 1. Results of H', E, and C in Phytoplankton and Zooplankton.

Index Biology	Analysis Results	
	Phytoplankton	Zooplankton
H'	2.014	1.061
E	0.808	0.576
C	0.176	0.504

The Shannon-Wiener diversity index (H') obtained in this study ranged between 1 and 3, indicating a moderate level of plankton diversity. According to Shannon & Wiener (1949), such values generally reflect moderately productive waters, relatively balanced ecosystem conditions, and moderate ecological pressure. Similar findings have been reported in freshwater ecosystems where moderate diversity is associated with adequate nutrient availability and environmental conditions that support the growth and survival of various plankton taxa (Zhao et al., 2022). The moderate diversity observed in Lake Toba suggests that the aquatic environment around Balige District remains capable of supporting a variety of plankton species, although environmental pressures may still influence community structure.

The evenness index (E) indicated that plankton individuals were relatively evenly distributed among species across the sampling locations. High evenness

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values generally suggest that no single species overwhelmingly dominates the community and that available resources are utilized by multiple taxa. Similar patterns have been observed in other freshwater ecosystems, where balanced species distribution reflects stable environmental conditions and reduced competitive exclusion (Ali & Jawad, 2024). Nevertheless, continuous monitoring is necessary because changes in nutrient input, water quality, or other environmental factors may alter community composition and lead to uneven species distribution in the future.

The dominance index (C) ranged from 0.5 to 1.0. In ecological studies, higher dominance values indicate that one or a few species contribute disproportionately to the community structure. Therefore, the dominance values observed in this study suggest varying degrees of species dominance among sampling sites. This finding may indicate that certain plankton taxa are better adapted to local environmental conditions than others. Similar dominance patterns have been reported in freshwater ecosystems experiencing differences in nutrient availability and habitat characteristics (Dubey et al., 2022). However, the moderate diversity and relatively high evenness values indicate that dominance has not resulted in severe community imbalance. The plankton community in the waters of Lake Toba around Balige District remains relatively stable and capable of supporting aquatic ecosystem functions.

These findings are generally consistent with previous studies conducted in Lake Toba and other tropical freshwater ecosystems, which reported moderate diversity and relatively balanced plankton communities under favorable environmental conditions (Panggabean & Prastowo, 2017). Maintaining this ecological balance requires continued conservation efforts and regular environmental monitoring to prevent ecological disturbances that could negatively affect plankton diversity and ecosystem stability.

CONCLUSION

From the results study regarding plankton that was carried out there is a number of conclusion namely, the waters of Lake Toba in the area Balige Toba Regency still in condition stable in accordance with growth high phytoplankton and things the can support life aquatic in waters said. However although still in condition stable, necessary still done supervision to water quality in Lake Toba in general comprehensively to ensure water quality remains in condition stable for support aquatic life. Continuous monitoring and sustainable management efforts are therefore essential to prevent environmental degradation and maintain the ecological balance of Lake Toba in the future.

RECOMMENDATION

Regular monitoring of water quality and plankton abundance is recommended to maintain the stability of Lake Toba's aquatic ecosystem. Furthermore, management of community activities around the lake needs to be improved to prevent degradation of the aquatic environment. Future research is expected to use more diverse parameters and a longer observation period to obtain more comprehensive information on the condition of Lake Toba's ecosystem.

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