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Abundance and Diversity of Macrozoobenthos Based on Three Site Characteristics at Lake Tondano, North Sulawesi

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Abstract: Macrozoobenthos are aquatic organisms that play a crucial role as bioindicators of aquatic environmental quality. This study aims to determine the abundance and diversity of macrozoobenthos at three distinct locations in Lake Tondano, North Sulawesi. Sampling in this study was conducted using the purposive sampling method. Sampling was conducted at three stations: Station I (Inlet), Station II (Near the settlement), and Station III (Outlet). In this study, samples were collected directly from the aquatic substrate using a 30×30 cm *Ekman Grab*. The results of the study identified 8 species and 7 families belonging to the phyla Mollusca and Annelida in Lake Tondano, with a total of 1,728 individuals. Diversity index values indicated a moderate category at the inlet (H' = 1.22) but a low category at the settlement area (H' = 0.99) and the outlet (H' = 0.58). The highest evenness index value was found at the inlet (E = 0.76) and the lowest at the outlet (E = 0.30), while the highest dominance index value was found at the outlet (C = 0.70). The most abundant species were *Filopaludina sumatrensis* (1,137 individuals; 65.80%) and *Melanoides tuberculata* (377 individuals; 21.82%), which dominated the community, particularly in the settlement area and outlet. This indicates a decline in ecological quality from the inlet to the outlet, characterized by increased abundance, low diversity, and high dominance of tolerant species. Macrozoobenthos has proven effective as a bioindicator for assessing the ecological condition of Lake Tondano and can serve as a basis for sustainable lake management efforts.

Keywords: Macrozoobenthos; abundance; diversity; Lake Tondano

Introduction

Lakes are freshwater ecosystems that play a vital role in supporting biodiversity and providing essential resources such as water and fisheries (Reid et al., 2019). Lake Tondano, as the largest volcanic lake in Sulawesi, has a high level of multifunctionality and strategic value for the community, particularly for water supply, agriculture, fisheries, and energy (Von Rintelen et al., 2014). However, its current ecological condition is threatened by eutrophication due to increased nutrients (nitrogen and phosphorus) from agricultural and domestic waste (Watania et al., 2021).

Lake ecosystem health can be assessed through the macrozoobenthos community, which consists of bottom-dwelling aquatic organisms larger than 1.0 mm (Odum, 1993; Desmawati et al., 2020). These organisms play a crucial role in the decomposition of organic matter, energy transfer between trophic levels, and nutrient cycling, making them sensitive to environmental changes and effective as bioindicators of water quality (Onibala et al., 2025).

Macrozoobenthos diversity is determined not only by the number of species but also by the distribution of individuals of each species within the community, which is generally analyzed using the Shannon-Wiener diversity index. The abundance and distribution of macrozoobenthos are influenced by environmental factors, including physicochemical parameters such as temperature, pH, and dissolved oxygen (DO), as well as substrate characteristics such as mud, sand, or rock.

Research on macrozoobenthos in North Sulawesi generally still focuses on water quality, such as Setyono & Himawan, 2018 and Lake Sineleyan (Tulandi, 2022). However, few specific

studies have been conducted on the abundance and diversity of macrozoobenthos in Lake Tondano. Population growth around the lake has the potential to affect its ecosystem conditions, especially since Lake Tondano is among the 15 priority lakes experiencing degradation (Soeprobowati et al., 2016). Therefore, this study is important as it aims to estimate the abundance and analyze the diversity of macrozoobenthos as a basis for sustainable lake ecosystem management.

Method

Time and Place of Research

This research was conducted from September to November 2025 at Lake Tondano, Minahasa District, North Sulawesi Province (**Figure 1**).

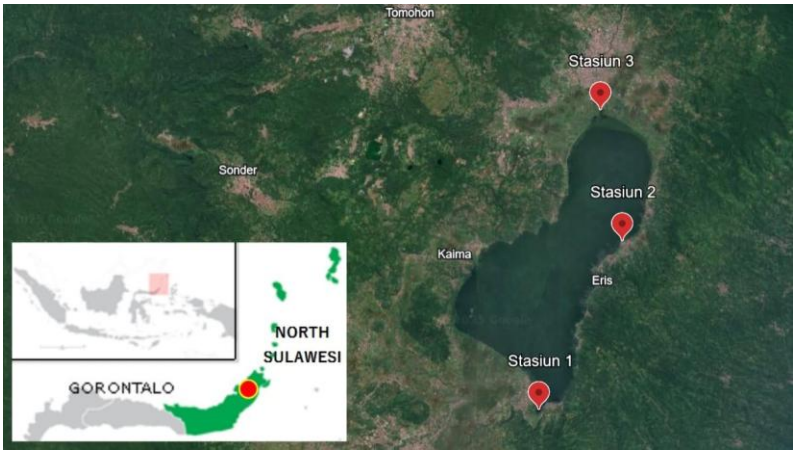

Figure 1. Map of the Research Site at Lake Tondano, North Sulawesi

Tools and Materials

The tools and materials used in this study included a Wilco Ekman Grab (30×30 cm), a sieve, a Garmin 73 GPS receiver, a water thermometer, a pH meter, a stereo microscope, an identification guidebook, writing utensils, a camera, tweezers, 70% alcohol, label paper, and sample bags.

Research Site Selection Techniques

This research employed a *purposive sampling* method to determine the locations and sampling points for comparing macrozoobenthos across three water characteristics of Lake Tondano, with locations selected to represent environmental conditions (Fachrul, 2007). The research area was divided into three stations based on water flow: Station I (inlet), Station II (area near settlements), and Station III (outlet). Initial identification was conducted in the field and continued at the Advanced Biology Laboratory, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University.

Sampling

Macrozoobenthos samples were collected using an Ekman Grab with the immediate capture method, then sieved to separate them from the substrate, stored in plastic, and preserved using 70% alcohol. Sampling was conducted at three stations, each at three points with three replicates, resulting in a total of 27 replicates.

Sample Identification

Sample handling and identification were performed in the laboratory using a microscope and tweezers, with reference to literature, the Macroinvertebrates.org website, and validation via WoRMS. Data were analyzed quantitatively to determine abundance, diversity, evenness, and dominance using the Shannon-Wiener index (H'), evenness (E), and dominance (D).

Data Analysis

The analysis in this study includes calculations of diversity index, evenness, and dominance, based on the formulas outlined below.

The diversity of macrozoobenthos was determined using the Shannon-Wiener index formula (Odum, 1994; Sagala et al., 2012) as follows:

$$H' = -\sum_{i=1}^{S} (Pi)\ In\ (Pi)$$

Description:
H' = Shannon-Wiener diversity index
Pi = Probability for each species = ni/N
ni = Number of individuals for each species
N = Total number of individuals
ln = Natural logarithm
Criteria:
H' < 1.00 : Low diversity
1.0 < H' < 3.00 : Moderate diversity
H' > 3.00 : High diversity

To determine species evenness, the Pielou index (1977) as cited in Ludwig and Reynold (1988) (Rawana et al., 2023) is used, and the following formula can be applied:

$$E = \frac{H'}{In\ (S)}$$

Description:
E = Evenness Index
H' = Shannon-Wiener
S = Total number of species
Criteria:
E < 0.4 : Low evenness
0.4 ≤ E ≤ 0.6: Moderate evenness
E > 0.6 : High evenness

The dominance index is calculated using Simpson's formula (Odum, 1994) as cited in Nugraha et al. (2024) as follows:

$$D = \sum \left(\frac{ni}{N}\right)^2$$

Description:
D = Simpson Dominance Index
ni = Number of individuals of species i
N = Total number of individuals of all species in the community
Criteria:

$0.0 < D < 0.5$: Low dominance
$0.5 > D \leq 1.0$: Moderate dominance
$D > 1.0$: High dominance

Results and Discussions

Macrozoobenthos Species

Based on the results of research conducted in Lake Tondano, the identified macrozoobenthos community consists of eight species from seven families belonging to two major phyla: Mollusca and Annelid, a total of 1,728 individuals were collected (**Table 1**). The species composition shows a dominance of the phylum Mollusca, particularly the class Gastropoda, reflecting this group's ability to adapt to varying environmental conditions in the lake's waters. The most abundant species were *Filopaludina sumatrensis* and *Melanoides tuberculata*, while several other species, such as *Meretrix meretrix*, *Physa acuta*, and *Tarebia granifera*, were found in very limited numbers. The uneven distribution of species across stations indicates differences in habitat conditions and environmental pressures at each location.

Table 1. Macrozoobenthos found in Lake Tondano

No	Species	number of individuals			Total	%
		Inlet	settlement area	Outlet		
1	*Filopaludina sumatrensis*	79	299	759	1137	65.80%
2	*Melanoides tuberculata*	97	259	21	377	21.82%
3	*Meretrix meretrix*	0	0	3	3	0.17%
4	*Physa acuta*	0	0	2	2	0.12%
5	*Sinanodonta woodiana*	1	5	3	9	0.52%
6	*Tarebia granifera*	0	2	0	2	0.12%
7	*Thiara scabra*	52	29	56	137	7.93%
8	*Tubifex tubifex*	10	12	39	61	3.53%
	Total	239	606	883	1728	100.00%
Diversity Index (H')		1.22	0.99	0.58		
Evenness Index (E)		0.76	0.55	0.30		
Dominance Index (D)		0.3	0.4	0.7		

Ecological Index

As shown in **Figure 2**, higher macrozoobenthos diversity index values at the estuary station indicate relatively better water quality. Conversely, the decline in diversity in residential areas and at the downstream station is associated with the influx of domestic wastewater and organic matter into the water. These conditions alter environmental quality, allowing only tolerant species to survive. This pattern aligns with previous findings in Lake Tondano and other eutrophic waters, which indicate that increased environmental stress contributes to a decline in macrozoobenthos diversity (Chazanah et al., 2020; Sulaeman et al., 2020).

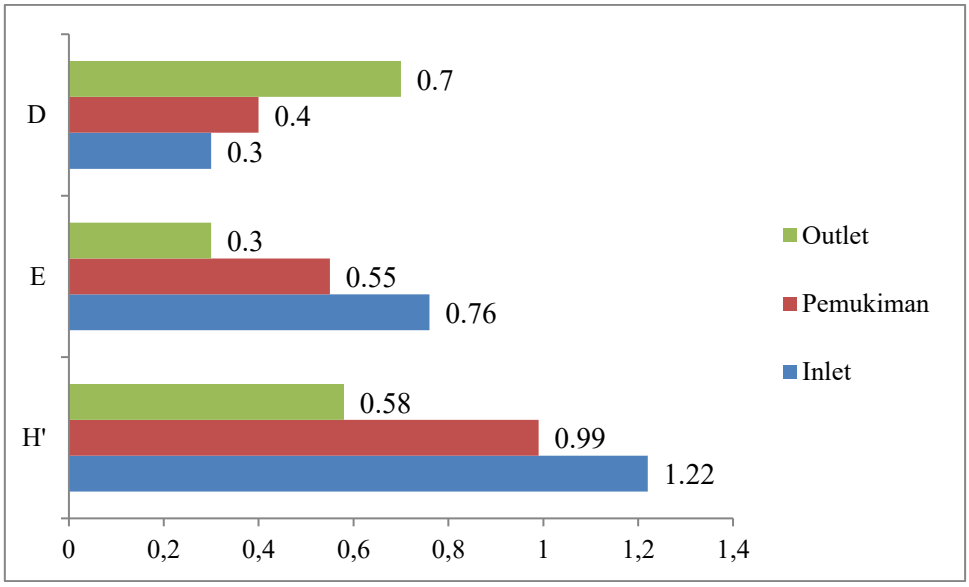

Figure 2. Ecological Index Diagram (H' = Diversity Index, E = Evenness Index, D= Dominance Index)

The high evenness index at the inlet station indicates a relatively balanced distribution of individuals across species, with no particular species dominating. In contrast, the lower evenness index in the residential area and at the outlet indicates an uneven distribution of individuals, concentrated in a few species, reflecting changes in community structure due to environmental pressures.

Increased dominance values in residential areas and the outlet indicate that the macrozoobenthos community is dominated by tolerant species, particularly *Filopaludina sumatrensis* and *Tubifex tubifex*, which have higher individual counts compared to other species. These species are known to thrive in water conditions with high organic matter content and low dissolved oxygen levels. This dominance pattern confirms a decline in environmental quality, consistent with previous studies reporting that tolerant species tend to dominate in ecologically stressed waters (Kadim et al., 2022; Putri & Kurniawan, 2023).

Environmental Parameters

Physical and chemical parameters of the water and substrate were measured at three stations in Lake Tondano: the inlet, the residential area, and the outlet. These measurements support the analysis of macrozoobenthos abundance. The data are presented in a **Table 2** to facilitate the comparison of variations among stations.

Table 2. Environmental Parameters at Three Stations on Lake Tondano

No	Parameter	Stasiun 1 Inlet	Stasiun 2 Residential	Stasiun 3 Outlet
1	Water Temperature (°C)	27	28	28
2	Acidity (pH)	7.3	7.4	7.2
3	Dissolve Oxygen (DO)	8	8	7
4	Substrate	Stony sand	Muddy with rocks	Muddy

Temperature remains relatively uniform (27–28 °C) and is still optimal for benthic organisms; thus, it is not a primary limiting factor, but it does play a role in accelerating the

decomposition of organic matter. The pH value is also stable within a neutral range (7.2–7.4), so it does not account for differences in community composition.

Dissolved oxygen (DO) decreases from the inlet and settlement area (8 mg/L) to the outlet (7 mg/L), indicating increased accumulation of organic matter, which impacts the decline of sensitive species and the increase of tolerant species. This aligns with the high abundance at the outlet despite lower diversity and evenness.

Substrate type had a significant effect on the macrozoobenthos community. The stony sand substrate at the inlet supported higher diversity and evenness, but lower abundance. Conversely, organic-rich muddy substrates in the residential area and outlet increase abundance in the residential area and outlet, but are dominated by tolerant species.

Conclusion

The abundance of macrozoobenthos in Lake Tondano increased from the inlet to the settlement area and was highest at the outlet, indicating that the muddy substrate and accumulation of organic matter are more conducive than the dynamic currents at the inlet. Diversity was moderate at the inlet (H' = 1.22) and low in the residential area (H' = 0.99) and at the outlet (H' = 0.58), with a dominance of tolerant species such as *Filopaludina sumatrensis* and *Melanoides tuberculata*, indicating a decline in ecological conditions from the inlet to the outlet due to increased human activity and organic matter.

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