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Diversity of Macrozoobenthos in River Waters around Palaes Waterfall, Likupang Barat District, North Sulawesi

Citra Julia Pontoh*, Saroyo and Adelfia Papu

Department of Biology, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University. Jl Kampus Unsrat Bahu- Manado 95115, North Sulawesi, Indonesia

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Corresponding Author:
Citra Julia Pontoh
citrapontoh102@student.unsrat.ac.id

Abstract: Macrozoobenthos are benthic organisms that are highly sensitive to environmental changes and are widely used as bioindicators of river water quality. This study aimed to analyze the species composition and diversity of macrozoobenthos in the Palaes Waterfall River, Likupang Barat, North Sulawesi. Sampling was conducted at three observation stations, namely the waterfall area, plantation area, and residential area, using a Surber net measuring 30 × 30 cm with a mesh size of 500 µm. The collected samples were identified in the laboratory using a stereo microscope and taxonomic identification keys. Community structure was analyzed using the Shannon–Wiener diversity index (H'), Simpson dominance index (D), and Pielou evenness index (E). The results showed that a total of 8 species belonging to 6 families were recorded, with 440 individuals in total. The diversity index (H') of macrozoobenthos in the Palaes Waterfall River was classified as moderate, with a dominance value of 0.36 and an evenness value of 0.45. These findings indicate that the river ecosystem remains relatively stable and provide essential baseline data for future monitoring and management of water quality in the study area.

Keywords: Macrozoobenthos; Palaes Waterfall; Diversity

Introduction

Freshwater ecosystems play a vital role both ecologically and socioeconomically. In addition to providing clean water, these ecosystems function within biogeochemical cycles, regulate local climate, and serve as habitats for various organisms. One of the most commonly used indicators for assessing the quality of freshwater ecosystems is benthic macroinvertebrates, also known as macrozoobenthos. Some of these organisms are sensitive to environmental changes, so fluctuations in their community structure can reflect ecological disturbances such as pollution, habitat degradation, or the impacts of climate change (Reid et al., 2019).

Macrozoobenthos is a group of organisms living on the bottom of water bodies with a size of more than 1 mm, consisting of aquatic insect larvae (Ephemeroptera and Trichoptera), mollusks (Gastropoda and Bivalvia), and Annelida (Oligochaeta) (Bo et al., 2016). Their role is crucial in maintaining ecosystem balance, both as decomposers in the nutrient recycling process and as a food source for higher-trophic-level organisms such as fish and waterbirds (Vaughn, 2018).

Research on macrozoobenthos in waterfall ecosystems is beginning to gain attention. This is because waterfalls possess distinctive environmental characteristics, such as high dissolved oxygen levels and strong water currents, which have the potential to support macrozoobenthos communities that differ from those found in ordinary rivers (Zikri et al., 2023). Macrozoobenthos itself is known to play a crucial role as a bioindicator of water quality, as its presence is significantly influenced by environmental changes—both natural and those resulting from human activities (Anshari et al., 2018; Fatimah & Herawati, 2020).

North Sulawesi possesses significant freshwater potential, including waterfall rivers that remain under-studied scientifically. Previous studies, such as at Tunan Waterfall, indicate that macrozoobenthos diversity is influenced by human activities (Pelealu et al., 2018). A study on the Ranoyapo River also revealed variations in water quality based on the macrozoobenthos diversity index (Marmita et al., 2013). Research at Way Kalam Waterfall confirms the role of macrozoobenthos as a bioindicator of water quality (Septiarila, 2021). However, to date, no data is available on the macrozoobenthos community in the Palaes Waterfall River, West Likupang, making preliminary research at that location necessary.

The lack of baseline data on the macrozoobenthos community in the Palaes Waterfall River may hinder efforts toward sustainable management of aquatic ecosystems. This research is important to provide preliminary information on the structure of the macrozoobenthos community in the Palaes River, which can be used as a scientific basis for biomonitoring water quality. Additionally, the research results are expected to enrich the local biodiversity database and support conservation policies and strategies for the sustainable management of freshwater resources in the West Likupang region.

Method

Time and Place of Research

Time and Location This study was conducted from September to December 2025 at Palaes Waterfall, West Likupang Subdistrict, North Minahasa Regency, North Sulawesi, with data collection at observation sites representative of the waterfall’s aquatic conditions. For a better understanding of the study location (**Figure 1**).

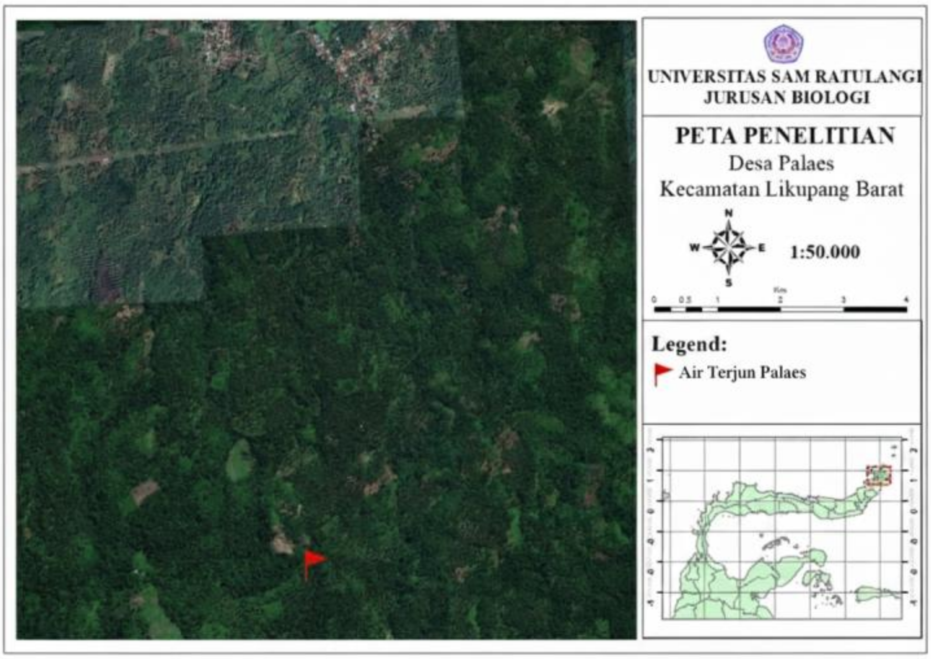

Figure 1. Research location

Tools and Materials

The toolst and materials prepared for the study include a 30x30 cm net (500 µm mesh), Canon EOS 1100D camera, Garmin 73 GPS receiver, Stick thermometer, Sample bags, 70% alcohol, Writing utensils, Labels, Stopwatch and cork, Stereo optical microscope, Tweezers, Macrozoobenthos samples.

Techniques for collecting data on Timor deer feeding activities

Macrozoobenthos sampling was performed using a Surber net (30 × 30 cm; 500 µm mesh) at three points based on dominant substrate types—rocky, gravelly, and sandy—with three replicates at each point, resulting in nine sample units. The collected samples were preserved using 70% alcohol and identified in the laboratory using a stereo microscope, referencing identification keys and taxonomic validation via WoRMS and GBIF, 2.3.3 Environmental parameters.

Environmental parameters including water temperature, current velocity, and substrate type, were measured simultaneously to support the interpretation of habitat conditions. Macrozoobenthos community structure data

Data analysis

Quantitative analysis was performed using PAST software by calculating the Shannon–Wiener diversity index (H’) (Hammer, *1999-2024*):

$$H' = -\sum_{i} \frac{n_{\mathrm{i}}}{n} In \frac{n_{\mathrm{i}}}{n}$$

Description:
H : Shannon Diversity Index
ni : Number of individuals of species i
n : Total number of individuals of all species in the community
ni/n : Proportion of individuals of species *i*
ln : Natural logarithm

Criteria:
H’≤1 : Diversity is classified as low
1<H’<3 : Diversity is at a moderate level
H’≥3 : Diversity is classified as high

Simpson’s dominance index (D) (Sirait et al., 2018);

$$DC = \sum \left(\frac{Ni}{N}\right)^2$$

Description:
D = Simpson’s Dominance Index
Ni = Number of individuals of the i-th species
N = Total number of individuals of all species in the community
Criteria:
0.00 < C ≤ 0.50: Dominance is classified as low
0.50 < C ≤ 0.75: Dominance is at a moderate level
0.75 < C ≤ 1.00: Dominance is classified as high

and Pielou’s evenness index (E) (Rawana et al., 2022):

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

Description:
E = Evenness Index

H' = Shannon–Wiener Index
S = Total number of species
ln S = Natural logarithm of the number of species
Criteria:
$E < 0.3$: Evenness is classified as low
$0.3 \leq E \leq 0.6$: Evenness is at a moderate level
$E > 0.6$: Evenness is classified as high
as indicators of the ecological conditions of the Palaes Waterfall.

Results and Discussions

Identification of macrozoobenthos species at the palaes waterfall

Based on the results of a study conducted at Palaes Waterfall, West Likupang District, North Sulawesi, a total of 8 macrozoobenthos species belonging to 6 families were identified, comprising 440 individuals. These macrozoobenthos were collected from a single observation site in the Palaes Waterfall area, with samples taken from three substrate types: rocky, gravelly, and sandy. The types and numbers of macrozoobenthos individuals found on each substrate type at Palaes Waterfall are presented in **Table 1**.

Table 1. Types and numbers of macrozoobenthos individuals founds

No.	Family	Species	(Waterfall)		
			Point 1 (rocky)	Point 2 (gravel)	Point 3 (sand)
1.	Thiaridae	*Thiara scabra*			3
2.	Neritidae	*Septaria porcellana*	6		
3.	Neritidae	*Neritina asperulata*	155	68	3
4.	Neritidae	*Neritina pulligera*	93	34	2
5.	Corduliidae	*Epitheca* sp.	5	3	4
6.	Chloroperlidae	*Alloperla* sp.	16	5	3
7.	Elmidae	*Optioservus* sp.	27	6	4
8.	Palaemonidae	*Macrobrachium tenuipes*			3
Total			440		

Macrobrachium tenuipes is characterized by a long rostrum with distinctive dorsal teeth and a very slender second pereiopod; it measures 4–10 cm and its body color matches the substrate; it is a tropical freshwater shrimp whose distribution is closely linked to lotic habitat conditions. It is found on rocky, gravelly, or sandy substrates in moderately flowing rivers (0.3–0.8 m/s) at temperatures of 22–30°C; temperatures outside this tropical range significantly reduce the survival and reproductive performance of the genus *Macrobrachium* (Rahman et al., 2022; Bir et al., 2024). Coarse, moderately flowing substrates provide protection from predators and support water quality; sand mining and river channelization, which homogenize the substrate and reduce natural flow, are major threats to this species' populations.

Thiara scabra has a conical-elongated shell measuring 1–3 cm with a rough surface and often spiny shoulders, and a blackish-brown, striated coloration. It is found on rocky, gravelly, and even muddy substrates in slow- to moderate-flowing waters (0–0.6 m/s) at temperatures of 18–32°C; its broad tolerance for various substrate types—from fine mud to rock—is a key factor in the species' wide distribution (Durán-Rodríguez et al., 2024; Mugnai et al., 2024). Its ability to survive across a wide range of temperatures and substrate conditions also underpins its status as an invasive species in several regions.

Septaria porcellana has a low-oval, patelliform shell (1–3 cm) with internal calcareous septa and a patterned brownish coloration; it is amphidromous, with larvae developing in estuaries before juveniles migrate upstream, and feeds on biofilms from rock surfaces. Its habitat consists of hard rock substrates in rivers with moderate to fast currents (0.5–1.5 m/s) at temperatures of 18–28°C. At the microhabitat scale, the density of amphidromous neritid gastropods is consistently higher on hard substrates (boulders and cobbles) than on fine substrates (Blanco & Scatena, 2006); strong currents are necessary to keep rock surfaces clear of sediment as feeding areas (Abdou et al., 2015).

Neritina asperulata has a neritoid shell measuring 1.5–2.5 cm with a characteristic coarse, granular surface; it is amphidromous, and its juveniles “hitchhike” by attaching themselves to larger individuals during their migration upstream (Kano, 2009). It inhabits rocky or gravel substrates in rivers with moderate to fast currents (0.4–1.0 m/s) at temperatures of 22–30°C; a preference for hard, flowing substrates supports oxygenation and the availability of food biofilms. Studies of the spatial distribution of Neritidae indicate that the highest densities are found on coarse stone substrates in areas with moderate to fast currents, which ensure a supply of larvae from the sea (Blanco & Scatena, 2006; Kano, 2009).

Neritina pulligera has a low-domed, globular shell (1.5–3 cm), uniformly dark black to dark brown in color, with a smooth, glossy surface; it is amphidromous, making river–estuary connectivity essential to its life cycle. It inhabits rocky hard substrates in the littoral zone of rivers with moderate currents (0.3–0.8 m/s) at temperatures of 18–30°C; the distribution of Neritidae is strongly linked to river–sea connectivity, as substrate type and current velocity in the downstream section influence the recruitment of juveniles newly arriving from the sea (Blanco & Scatena, 2006). Physical barriers such as dams that disrupt larval migration routes are the primary threat to this species (Abdou et al., 2015).

Epitheca sp. has a broad head with strong mandibles, a compact abdomen, long legs with sturdy claws, and distinct wing pads in the late instar; Corduliidae larvae are generally classified as crawlers or sprawlers that inhabit soft substrates with accumulations of leaf litter. These larvae are found on aquatic vegetation substrates, leaf litter, or muddy-sandy bottoms in slow- to moderate-flowing waters (0–0.5 m/s) at temperatures of 15–28°C; Odonata larvae generally prefer coarse inorganic substrates and low- to moderate-flow rates (Pešić et al., 2017). Functional studies indicate that sensitive Odonata genera are more abundant in areas with good substrate quality and varied flow conditions (Silva et al., 2024), while rising temperatures negatively affect the growth and survival of Odonata larvae (Stahl & Johansson, 2024).

Alloperla sp. has a slender body (6–12 mm) with three long terminal cerci, double-clawed legs, and a filiform setae pattern on the abdomen as key identifying characteristics. These larvae inhabit coarse stone and gravel substrates in fast-flowing rivers (>0.5 m/s) at temperatures of 10–22°C; Plecoptera are consistently more abundant in high-flow erosional zones than in depositional zones (Cristiano & Di Sabatino, 2023). The emergence of Plecoptera is positively correlated with flow velocity and negatively correlated with temperature; in North America, coarse substrates and cold temperatures significantly determine the timing of Plecoptera imago emergence (Cheney et al., 2019). Global Plecoptera diversity is highest in the mountain rivers of Temperate Asia with rocky, fast-flowing substrates (DeWalt & Ower, 2019).

Optioservus sp. has a yellowish-brown elateriform body, short, robust legs with strong terminal claws for clinging to the substrate, a prognathous head, and a characteristically shaped prothorax. The larvae are found on the surfaces of rocks and pebbles in rivers with moderate to fast currents (0.4–1.0 m/s) at temperatures of 15–28°C. Experimental studies in Japan have demonstrated that Elmidae abundance positively correlates with substrate grain size and flow velocity; on fine-grained, slow-flowing substrates, Elmidae are nearly absent (Fujiwara et al., 2022). This pattern is consistent with findings that the macroinvertebrate communities of the erosional zone with coarse substrate differ significantly in composition from those of the depositional zone (Cristiano & Di Sabatino, 2023; Urbanič et al., 2005).

Ecological Index Values for the Macrozoobenthos

An analysis of macrozoobenthos ecological indices was conducted to describe community structure and assess the environmental quality of river waters. Macrozoobenthos is increasingly used as a bioindicator due to its sensitivity to changes in the physical and chemical parameters of water and its ability to reflect local ecological conditions (Rosyadi & Ali, 2020; Bai'un et al., 2021). Index values such as diversity (H'), evenness (E), and dominance (D) play a crucial role in identifying community stability and the potential for ecological stress resulting from anthropogenic activities (Afifatur, 2021). The ecological index values for macrozoobenthos community structure are presented in **Table 2**.

Table 2. Ecological Index Values for the Macrozoobenthos Community at Palaes Waterfall

Ecological Index	Index Value	Index Category
Diversity Index (H')	1,29	Moderate
Dominance Index (D)	0,36	Moderate
Evenness Index (E)	0,45	Moderate

The macrozoobenthos diversity index value at Palaes Waterfall, H' = 1.29, indicates a moderate level of diversity, suggesting that the community consists of several species with a relatively uneven distribution of individuals. This value is influenced by the dominance of the genus Neritina; thus, although the number of species is relatively high, the distribution of individuals among species is not yet balanced. This condition is reflected in the dominance index (D) value of 0.36, which is related to the high abundance of *Neritina asperulata* (226 individuals) and *Neritina pulligera* (128 individuals) compared to other species. This dominance pattern aligns with the findings of Jalil et al. (2020), who noted that one or two gastropod species often dominate fast-flowing, rocky habitats. Furthermore, the evenness index (E) value of 0.45 indicates moderate evenness, suggesting that the community is still relatively stable but shows a tendency toward dominance by certain species (Maith et al., 2015; Gitarama et al., 2017). The ecological conditions of the waterfall, characterized by a relatively high flow velocity (0.43 m/s), a temperature of 26°C, and a substrate dominated by rocks and gravel, support the presence of rheophilic taxa such as *Neritina asperulata*.

Conclusion

Research at the Palaes Waterfall identified a macrozoobenthos community with moderate diversity (H' = 1.29) influenced by relatively strong currents and a rocky substrate. These conditions favor the dominance of rheophilic gastropods, particularly Neritina, resulting in an uneven distribution of individuals across species. These results confirm that current velocity, temperature, and substrate characteristics play a significant role in shaping the structure of macrozoobenthos communities in fast-flowing river ecosystems.

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