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Macrozoobenthos Diversity as Bioindicator of Water Quality in Candi River, Sidoarjo Regency, Indonesia

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***Abstract*— *The Candi River, located in Candi District, Sidoarjo Regency, Indonesia, plays a crucial role in the hydrological cycle and the lives of the surrounding communities. The presence of numerous industries, residential areas, and agricultural activities around the Candi River has the potential to degrade its water quality. This study aims to evaluate the diversity of macrozoobenthos as bioindicators of water quality in the Candi River. The research was conducted in the Candi River, located in Candi District, Sidoarjo Regency, Indonesia. Macrozoobenthos sampling was carried out at three sites, representing the upstream, middle, and downstream areas of the river. Macrozoobenthos were analyzed using the Shannon-Wiener index. Based on the diversity index values at the three sites—Site 1 (1.98), Site 2 (1.87), and Site 3 (1.39)—the water quality can be categorized as showing moderate diversity, which corresponds to moderate levels of pollution. Higher diversity index values at Sites 1 and 2 indicate slightly better water quality compared to Site 3, where the lower value reflects higher pollution and environmental stress.*

***Keywords*— *Candi river: macrozoobenthos:water quality.*

I. INTRODUCTION

Rivers are vital aquatic ecosystems that support diverse biota and human activities, including household use, fisheries, agriculture, industry, and transportation. However, the utilization of rivers for these various purposes often impacts water quality negatively. This decline is primarily due to the discharge of waste generated by human activities directly into river bodies, either fully or partially, without adequate treatment. Consequently, untreated waste leads to pollution, degrading the health and sustainability of river ecosystems. A previous study by Zhou et al (2022) evaluated the impact of urbanization, agriculture and industry on the water quality of the Bonsa River and the quality of life of downstream residents. It highlights that most freshwater pollution is due to these human activities, which degrade water quality and affect public health. Another research finding in Indonesia highlighted that agricultural practices, particularly improper land management and fertilizer application, significantly influence water quality parameters such as nitrate and phosphate levels (Yustika *et.al*, 2019).

The Candi River in Candi District, Sidoarjo Regency, Indonesia, is vital to both the hydrological cycle and the local communities' livelihoods. It supports domestic, agricultural, and industrial activities, but faces significant environmental challenges. Industrial effluents, residential waste, and agricultural runoff threaten its water quality, leading to issues like eutrophication, chemical contamination, and bacterial pollution.

The decline in water quality due to the introduction of pollutants into river systems can pose a significant threat to the survival of various organisms inhabiting these ecosystems. One key group of aquatic organisms commonly used to assess general water quality is macroinvertebrate. Previous studies have shown that monitoring macroinvertebrate provides a reliable parameter for evaluating the overall health of river ecosystems (Yudhistira *et.al*, 2022; Anastasia *et.al*, 2022; Munfarida & Munir, 2023). Macrozoobenthos, a subset of macroinvertebrates that specifically live on or in the substrate of aquatic environments (the benthic zone), are ideal indicators of water quality. Their relatively sedentary (sessile) habitats, limited mobility, and consistent response to environmental changes make them particularly effective for monitoring the health of aquatic ecosystems. These characteristics allow macrozoobenthos to reflect long-term water quality conditions, providing valuable insights into the ecological state of water bodies. Previous studies have been conducted on the role of macrozoobenthos as bioindicators due to their relatively sedentary nature and sensitivity to environmental changes, making them reliable for monitoring river health (Sueb *et.al*, 2021). Macrozoobenthos communities also reflect changes in water quality and their composition varies with environmental conditions (Rachman *et.al*, 2018). The diversity, abundance, and uniformity of macrozoobenthos as indicators of water quality in the River Kundur as the tools for environmental monitoring (Winarti & Harahap, 2021). This research aims to assess the diversity of macrozoobenthos to use them as bioindicators for evaluating water quality in the Candi River.

II. RESEARCH METHOD

A. *Study Area*

The research was conducted at the Candi River, located on Jalan Raya Candi in the Candi District of Sidoarjo Regency (Fig. 1). The identification and analysis of macrozoobenthos was conducted in the Environmental Technology Laboratory, Sunan Ampel State Islamic University, Surabaya. Meanwhile the sediment identification was carried out at the Oceanography Laboratory of Sunan Ampel State Islamic University Surabaya.

Macrozoobenthos sampling was conducted at three distinct sites along the river, representing the upstream, midstream, and downstream areas. The specific conditions at each sampling site are detailed in Table 1.

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TABLE 1. Site Situation

Site	Area Description
1	an area without human activity
2	activity area of Candi sugar factory
3	community activity / residential area

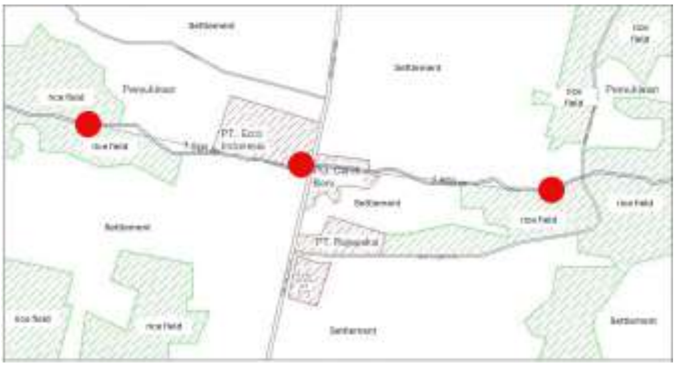

Fig. 1. Sampling Site (1: upstream, 2: middle, and 3: downstream areas of the river.

B. *Diversity Index*

Macrozoobenthos were analyzed using the Shannon-Wiener index (1).

$$H' = -\sum(\frac{n_i}{N}.ln(\frac{n_i}{N})) \quad (1)$$

n_i—total number of individuals of particular species N—total number of individuals (Shannon & Weaver 1964).

III. Results and Discussion

A. *Sediment and Macrozoobenthos Characteristics*

Table 2 encompasses sediment grain size measurements from three different sites along the Candi Sidoarjo River.

TABLE 2. Sediment Identification Results

Grain Size of Sediment	Sampling Site		
	1	2	3
Moderate mud	0,40%	1,60%	30,80%
Coarse silt	0,60%	7,60%	30,60%
Very fine sand	7,60%	8,60%	26,00%
Fine sand	7,20%	32,60%	9,80%
Moderate sand	8,60%	38,60%	1,60%
Coarse sand	52,00%	6,60%	1,20%
Very coarse sand	18,60%	3,40%	0,20%
Very fine gravel	2,40%	0,40%	0,00%
Moderate Gravel	2,60%	0,60%	0,00%

At sampling site 1, the most abundant sediment type is very coarse sand. At sampling site 2, it is moderate mud, while at sampling site 3, the predominant sediment type is moderate sand. Sediment type significantly affects biodiversity, particularly the distribution and behavior of benthic macrofauna. Table 3 illustrates the macrozoobenthos findings, while Table 4 details the species and their respective counts at each sampling site.

TABLE 4. Macrozoobenthos Characteristics

No	Research Findings	Characteristics	Species Name
1		Characteristics This species features a conical shell with a short apex and a smooth outer surface. Habitat It inhabits shallow waters and can be found at depths of up to approximately 40 meters.	*Natica sp.*[1]
2		Characteristics This species has a thin shell with a moderately elevated apex and two distinct spiral ridges on the exterior. Habitat It is typically found in shallow waters and can inhabit depths up to approximately 30 meters.	*Natica sp.*[2]
3		Characteristics This species features a thin, conical shell with an oval operculum. The outer shell color ranges from white to purplish, adorned with brown line-shaped patterns. The shell size is approximately 3-4 cm in length. Habitat It inhabits shallow waters with substrates ranging from muddy to sandy.	*Littoraria sp.*
4		Characteristics This species has a rounded, expanding shell. The outer shell surface is solid and features horizontal lines. Habitat It resides beneath the surface of the substrate.	*Anodontia sp.*
5		Characteristics This species has a shell that protrudes slightly forward, with a line pattern along its elongated surface. Habitat It lives in muddy waters and is one of the most common commercially harvested shellfish in Indonesia.	*Anadara sp.* [1]
6		Characteristics This species features a prominent cephalopod. Each valve has 21 ribs, and each rib is adorned with several round nodules. Habitat It is typically found in mud and sand environments.	*Anadara sp.* [2]

7		Characteristics This species has an elongated shell with rounded edges. Its outer surface is adorned with numerous concentric protrusions and features a narrow border. Habitat It occurs in sandy to muddy areas.	*Tapes sp.*
8		Characteristics This species has a shell with a smooth, tighter outline. Habitat It inhabits shallow waters and is commonly collected by coastal communities in Indonesia for consumption.	*Marcia sp.*
9		Characteristics This species has a reddish body, reaching up to 4 cm in length with an average diameter of 0.5 mm. The red coloration is due to the presence of erythrocruorin, a protein that dissolves in the blood. Habitat This species thrives in polluted waters and can survive in low oxygen conditions due to its ability to respire efficiently even at low oxygen pressures.	*Tubifex sp.*

TABLE 4. Macrozoobenthos Abundance

No	Class	Species	Number of The Species at each Site		
			1	2	3
1	Gastropoda	*Natica sp.*[1]	23	11	0
2		*Natica sp.*[2]	27	8	0
3		*Littoraria sp.*	10	2	0
4	Bivalvia	*Anodontia sp.*	40	22	5
5		*Anadara sp. [1]*	37	26	3
6		*Anadara sp. [2]*	28	9	1
7		*Tapes sp.*	10	3	0
8		*Marcia sp.*	22	9	1
9	Oligochaeta	*Tubifex sp.*	0	1	6
Total Number			198	93	19

We identified three classes of macrozoobenthos: Gastropoda, Bivalvia, and Oligochaeta. The Gastropoda class includes species such as *Natica sp.*[1], *Natica sp.*[2], and *Littoraria sp.* The Bivalvia class comprises *Anodontia sp.*, *Anadara sp.*[1], *Anadara sp.*[2], *Tapes sp.*, and *Marcia sp.* Lastly, the Oligochaeta class is represented solely by *Tubifex sp.* The total number of species identified at each site is as follows: Site 1 hosts 198 species, Site 2 contains 93 species, and Site 3 has 19 species. The species with the highest abundance at each site are as follows: *Anodontia sp.* at Site 1, *Anadara sp.*[1] at Site 2, and *Tubifex sp.* at Site 3.

Sediment characteristics play a critical role in influencing the distribution of species in aquatic environments. Different species are adapted to specific sediment types. Coarse-grained sediments, like sand and gravel, provide habitats for organisms that require spaces to burrow or attach. Fine-grained sediments, such as silt and clay, are more suitable for species that can burrow into compact substrates. For example, based on research findings, *Anadara sp.* [1], a species within the genus Bivalvia, is generally well-adapted to moderate sand habitats. Previous research has shown that Bivalvia species are frequently found in moderate sand habitats. These environments provide the necessary conditions for their feeding, respiration, and overall survival (Wiesebron *et.al*, 2021). *Tubifex sp.*, commonly known as sludge worms or tubificid worms, are particularly well-suited to habitats with moderate mud, as supported by our findings. Recent research has found that tubifex worms are well-adapted to environments with moderate mud and organic matter. They typically inhabit the top layers of mud where they create burrows, allowing them to thrive in sediments rich in organic detritus. Their ability to tolerate low oxygen levels and polluted environments makes them particularly resilient in such habitats. In terms of their ecological role, Tubifex worms are significant indicators of water quality and pollution levels. Their presence and population density in aquatic ecosystems are often used to assess environmental health. Studies have shown that these worms can survive in both anoxic (oxygen-depleted) conditions and environments with varying levels of pollution, making them valuable for biological monitoring and early warning systems (Lee *et.al*, 2024).

B. Diversity Index

Table 4 represents the diversity index of macrozoobenthos in each site.

TABLE 4. Diversity Index of Macrozoobenthos

NO	Diersity Index (pi ln pi)		
	1	2	3
1	-0,25	-0,26	0,00
2	-0,27	-0,21	0,00
3	-0,15	-0,08	0,00
4	-0,32	-0,34	-0,36
5	-0,31	-0,36	-0,31
6	-0,28	-0,23	-0,17
7	-0,15	-0,11	0,00
8	-0,24	-0,23	-0,17
9	0,00	-0,05	-0,37
∑	-1,99	-1,87	-1,39
H	**1,99**	**1,87**	**1,39**

Based on the diversity index values at the three sites—Site 1 (1.98), Site 2 (1.87), and Site 3 (1.39)—the water quality can be categorized as showing moderate diversity, which corresponds to moderate levels of pollution. Higher diversity index values at Sites 1 and 2 indicate slightly better water quality compared to Site 3, where the lower value reflects higher pollution and environmental stress. Despite the upstream site being an area free from human activity, the midstream site being near the Candi sugar factory, and the downstream site being a residential area, all three locations have shown moderate pollution levels. This pollution likely originates from surrounding activities or upstream sources before entering the Candi River. Contaminants can infiltrate the soil and be carried by runoff, accumulating from upstream to downstream.

Recent studies highlight the use of diversity indices like the Shannon-Wiener index to evaluate water quality based on biological indicators. Higher diversity indices generally indicate better water quality, while lower values correspond to higher levels of pollution and environmental stress. For instance, a study assessing the Hongmen Reservoir found that the Shannon-Wiener diversity index ranged from 2.05 to 2.85, indicating a state of clean to mildly polluted water. The relationship between diversity indices and water quality was further supported by the observation that higher indices reflected more stable phytoplankton communities and better water quality (Liu et.al, 2021; Nguyen & Huynh, 2023). This demonstrates the utility of diversity indices as reliable indicators of water quality and pollution levels.

IV. Conclusion

This research focused on assessing the macrozoobenthos diversity as bioindicators to determine the water quality of the Candi River. The findings revealed that the diversity index values were 1.98 at Site 1, 1.87 at Site 2, and 1.39 at Site 3. These values suggest that the water quality exhibits moderate diversity, indicative of moderate pollution levels. Sites 1 and 2 showed higher diversity indices, suggesting relatively better water quality compared to Site 3, where the lower index reflects higher pollution and greater environmental stress. This study underscores the importance of regular monitoring and management to mitigate pollution and preserve the ecological health of the Candi River.

References

[1] L. Zhou, R. Appiah, E.B. Boadi, E.C. Ayamba, E. Larnyo, & H.A. Antwi, “The Impact of Human Activities on River Pollution and Health-Related Quality of Life: Evidence from Ghana,” *Sustainability*, vol. 14 issue 20, pp. 1-11, 2022.

[2] D.R. Yustika, H. Somura, B.S Yuwono, & T. Masunaga, “Impact of Human Activities and Natural Processes on the Seasonal Variability of River Water Quality in Two Watersheds in Lampung, Indonesia,” *Water*, vol. 11 issue 11, pp. 1-17, 2019.

[3] L. Yudhistira, I. Munfarida &Rr. D. N. Setyowati, “Korelasi Kualitas Air dengan Keanekaragaman Keseragaman Makroinvertebrata sebagai Bioindikator di Sungai Tambak Cemandi Desa Kalanganyar Sidoarjo,” *Jurnal Sains dan Teknologi Lingkungan*, vol. 14 issue 1, pp. 1-15, 2022.

[4] S. Anastasia, I. Munfarida, & D. Suprayogi, “Penilaian Kualitas Air Menggunakan Indeks Makroinvertebrata FBI dan Biotilik di Sungai Buntung Sidoarjo,” *Serambi Engineering*, vol. 7, issue 3, pp. 3617-3623, 2022.

[5] I. Munfarida, & M. Munir, “Comparative assessment of river water quality based on macro-invertebrate community structures as biological indicators in three rivers of East Java,” *SICBAS*, Palembang, Indonesia, pp. 1-7, 2023.

[6] S. Sueb, J. Damayanti & F. Rohman, “Macrozoobenthos diversity as bioindicator water quality of Metro River, Malang City” *ICoLiST*, Malang, Indonesia, pp. 1-8, 2021.
H. Rachman, A. Priyono & Y. Wardiatno, “Macrozoobenthos as Bioindicator of River Water Quality in Ciliwung Hulu Sub Watershed,” *Media Konservasi*, Vol. 21 issue. 3, pp. 261-269, 2018.

[7] Winarti & A. Harahap, “The Diversity of Makrozoobenthos as Bio-Indicators of Water Quality of the River Kundur District Labuhanbatu,” *BIRCI-Journal*, vol. 4 issue 1, pp. 1027-1033, 2021.

[8] C.E. Shannon & W. Weaver, *The mathematical theory of communication*. Urbana Univ Illinois Press, Urbana, pp. 49-64, 1964.

[9] L.E. Wiesebron, N. Steiner, C. Morys, T. Ysebaert, & T.J. Bouma, “Sediment Bulk Density Effects on Benthic Macrofauna Burrowing and Bioturbation Behavior,” *Frontiers in Marine Science*, vol. 8, issue 705582, pp. 1-16, 2021.

[10] D.S. Lee, H. Kang, & Y.S. Park, “Analyzing retraction responses of Tubifex tubifex (Oligochaeta: Naididae) colonies to copper treatments through a digital image analysis approach for developing early biological warning systems,” *Environmental Science and Pollution Research*, vol. 31 issue 16, pp. 24559-24566, 2024.

[11] C. Liu, X. Sun, L. Su, J. Cai, & L Zhang, “Assessment of phytoplankton community structure and water quality in the Hongmen Reservoir,” *Water Quality Research Journal*, vol. 59 issue 1, pp. 83-92. 2021.

[12] T.G. Nguyen, & N.T.H. Huynh, “Evaluating Surface Water Quality Using Indexes of Water Quality and Plankton Diversity,” *Civil Engineering Journal*, vol. 9 issue 5, pp. 1153-1163, 2023.

Aldentio Emir Russo, Ida Munfarida, and Rr Diah Nugraheni Setyowati, “Macrozoobenthos Diversity as Bioindicator of Water Quality in Candi River, Sidoarjo Regency, Indonesia,” *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 7, Issue 2, pp. 194-197, 2024.