Jurnal ILMU DASAR (JID)
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Using the Benthic Macroinvertebrates Species Diversity Index to Determine the Water Quality of Antirogo River, Jember Regency

Retno Wimbaningrum[1*)], Eva Tyas Utami[1)], Rizka Agustina[1)], and Rendy Setiawan[1)]
[1)]*Biology Department, Faculty of Mathematics and Natural Sciences, University of Jember*

Article info

Keywords
Antirogo River;
Benthic, Diversity Index;
Macroinvertebrats;
Water Quality

Article history
Received 02-09-2025
Accepted 29-09-2025

*)***Correspoding author**
wimbaningrum.fmipa@unej.ac.id

ABSTRACT

The Antirogo river, as one of the rivers across the Jember regency, East Java, plays an important role and is used for various activities such as agriculture, domestic, and industrial activities. These anthropogenic activities could affect the water quality of the river and the biota within. A group of river biota affected by anthropogenic activities is the benthic macroinvertebrates. Benthic macroinvertebrates can be used as bioindicators of river water quality. This study aimed to assess the water quality of the Antirogo River using the Shannon Wiener species diversity index (H') based on benthic macroinvertebrate data. Benthic macroinvertebrate sampling was conducted using a Surber net at three research stations. This research found 1703 individuals of benthic macroinvertebrates, which were classified into 16 families, 10 orders, and five classes. The most abundant family was the Heptageniidae, while the least abundant was the Simuliidae. The benthic macroinvertebrates' diversity index (H') value was 1.67, with the evenness index (E) value at 0.60. Based on the diversity index (H') value, the water quality in this river was lightly polluted with pollutants that can be in the form of solid materials and toxic compounds.

INTRODUCTION

The river is one of the terrestrial aquatic ecosystems that holds critical roles in providing water that supports the sustainability of any organism nearby (Sahidin et al., 2021). The rivers and streams are closely linked, carrying precipitation, organic and inorganic materials downstream (Hildrew & Giller, 2023b). As an ecosystem, rivers provide organisms within the water bodies and nearby with high biodiversity, and they consist of microorganisms, vascular plants, invertebrates, fish, amphibians, birds, and semi-aquatic mammals. The most abundant animals are often insects, both as larvae, nymphs, and fully aquatic insects (Hildrew & Giller, 2023a). Benthic macroinvertebrates live on the surface or in water sediments (mud, sand, gravel, stone, or organic waste) and are critical in energy flow and material circulation. The benthic macroinvertebrates help detect changes in water quality due to their immobility or limited mobility, and some families are sensitive and intolerant to pollutants, both organic and inorganic, from natural and anthropogenic activities (Xue et al., 2019; Mir et al., 2021; Kostanda et al., 2025).

Anthropogenic activities could impact the water quality, which affects the physicochemical and biological properties, by agricultural activities, industry, domestic activities, littering, and discharging wastewater into the river (Basuki et al., 2024; Sidabutar et al., 2017; Sudia et al., 2020). In 2018, the water in 34 provinces of Indonesia did not meet the quality criteria. It was categorized as highly polluted, resulting in various health problems in multiple regions (Basuki et al., 2024). The poor water quality in this river was already causing health problems for humans, and needed to be evaluated to maintain the water quality. Water quality evaluation or assessment could be conducted using physicochemical and biological indicators.

As mentioned above, benthic macroinvertebrates can use biological indicators to assess water quality; their characteristics (immobility or limited mobility and their sensitivity to pollutants) could be important tools. The water river quality could be assessed and monitored by observing and evaluating the diversity of the benthic macroinvertebrates and the biotic indices such as FBI (Family Biotic Index), BMWP (Biological Monitoring Working Party), and ASPT (Average Score Per Taxon), which have been used worldwide (Abu Sama et al., 2024; Saad et al., 2025; Vikriansyah et al., 2025). In addition to biotic indices, the species diversity index can determine river water quality. Hawkes' research (1978) showed that the diversity index is suitable for indicating physical and toxic pollution. One diversity index often used to determine the quality of the river water in the world was the Shannon-Wiener species diversity index (H'). The physical and toxic pollution categories in a river can be identified based on the H' diversity index value. Based on these findings, the river water quality and the diversity of benthic macroinvertebrates need to be assessed and monitored to define whether the water quality needs to be improved in the short or long term.

One of the rivers that flows in Jember regency is the Antirogo river, which was used for various activities such as agriculture, domestic, and industrial. The Antirogo River recorded a pollution load of 81.043 kg/day (Wahyuningsih et al., 2020). This high input of pollution could affect the water quality in both the short and long terms by affecting the physicochemical and biological properties. The Antirogo River has not yet been assessed for its water quality, and this research aims to determine the water quality of the Antirogo River by evaluating the biological properties using the benthic macroinvertebrates. The results of this research could serve as a basis for the government and society to maintain the river water quality.

MATERIALS AND METHODS

Study Area

This research took place in the Antirogo River, which flows through the Jember regency, with geographically coordinates of 8° 9’ 17.56” S – 113 ° 44’ 22.13” E and 8° 10’ 37.96” S (Figure 1). This research was conducted in June 2023. The identification and data analysis process was conducted in the Biology department of the Mathematics and Natural Sciences faculty at the University of Jember.

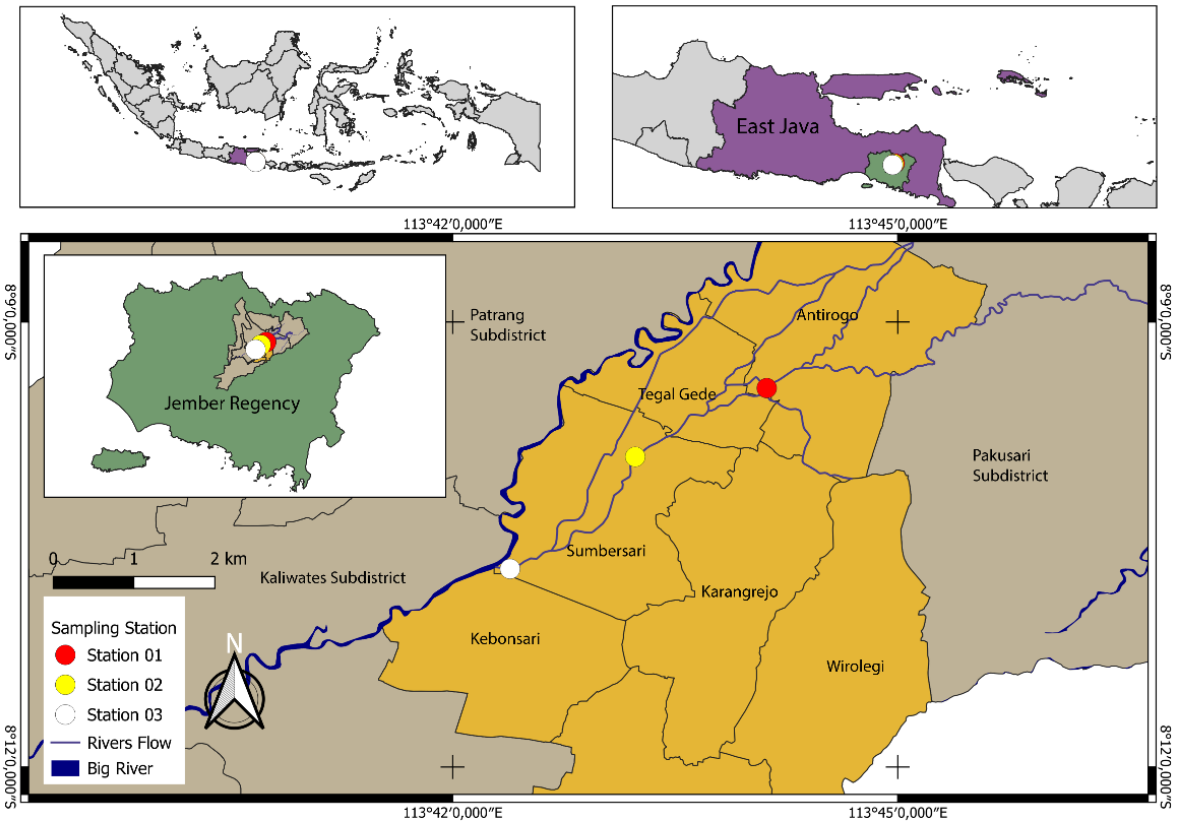

Figure 1. Research sampling stations

Field Data Collection

The Antirogo River was divided into three sampling stations, and each sampling station was identified as upstream, midstream, and downstream before joining with the bigger river to obtain

information about the whole Antirogo River. Each sampling station was divided into five sampling sub-stations with a length of 15 m and nine sampling points. The distance between each sampling station was 2.6 km, while the sampling sub-stations were 10 m apart. The field data collection was the biological parameter in this river. On the other hand, the biological parameter was collected by collecting the benthic macroinvertebrates using the method of Wimbaningrum et al. (2016). The benthic macroinvertebrates were collected using a Surber net with a mesh of 0.5 mm², 40 cm length, and 25 cm width. The surber net was positioned against the current flow and at the bottom of the river. The basal substrate of the river was stirred, and the debris was separated from the net using a pinset or a pipette. The water containing benthic macroinvertebrates was stored in labelled bottles with 70% Alcohol. The benthic macroinvertebrate samplings were repeated three times for each substation. The water samples were observed in a stereo microscope, and the characteristics of each found benthic macroinvertebrate were recorded. The found benthic macroinvertebrates were identified using Edmondson (1959), Needham & Needham (1962), Merritt & Cummins (1995), Yule & Sen (2004), and Kriska (2022). Each species was counted for abundance and classified into the same family to obtain the family richness.

Data Analysis

The benthic macroinvertebrates were counted and classified to obtain the abundance of the species and the family. The diversity of the benthic macroinvertebrates was analyzed using the Shannon-Wiener diversity index (H'), and the distribution of individual numbers was analyzed using the Evenness index (E). The diversity index (H') and the evenness index (J') were analyzed using the equation below. The diversity index (H') value determines the water river quality based on the Lee et al. (1978) shown in Table 1.

$$H' = -\sum(pi\ log\ pi)$$ (Shannon & Weaver, 1949; Odum, 1971)

$$J' = \frac{H'}{H'max} = \frac{H'}{\ln S}$$ (Pielou, 1966)

Explanation:
H': the Shannon-Wiener species diversity index;
pi: the number of individuals each species divided by the total number of individuals;
J': Pielou's Evenness Index;
S: the number of species.

Table 1. The classification of the water river quality based on the Diversity Index (H') value (Lee et al., 1978)

The Diversity Index (H') Value	Water River Quality
> 2.0	Not polluted
2.0 – 1.6	Lightly polluted
1.5 – 1	Moderately polluted
< 1.00	Heavily polluted

RESULTS AND DISCUSSION

The research result in the Antirogo River in Jember regency revealed the presence of five classes of benthic macroinvertebrates. The five classes include Clitellata (2 families), Crustacea (1 family), Gastropoda (2 families), Insecta (10 families), and Turbellaria (1 family). The research revealed benthic macroinvertebrate population densities ranging from 419 to 766 individuals/m2. The Heptageniidae is the most abundant, with 430 individuals /m2 in Station 1. Table 2 provides detailed information on the composition of benthic macroinvertebrates in the Antirogo River, Jember regency.

Table 2. The composition of benthic macroinvertebrates in Antirogo River

Class	Order	Family	St1	St2	St3	Total
Clitellata	Hirudinea	Erpobdellidae	0	0	7	7
		Glossiphoniidae	0	1	6	7
Crustacea	Decapoda	Potamidae	3	4	0	7
Gastropoda	Caenogastropoda	Pachychilidae	22	45	43	110
		Thiaridae	5	15	17	37
Insecta	Coleoptera	Elmidae	19	5	3	27
	Diptera	Chironomidae	17	1	7	25
		Simuliidae	5	0	0	5
	Ephemeroptera	Baetidae	107	6	38	151
		Caenidae	37	10	23	70
		Heptageniidae	430	107	292	829
	Lepidoptera	Crambidae	7	2	0	9
	Tricoptera	Glossosomatidae	0	4	2	6
		Hydropsychidae	93	202	58	353
		Polycentropodidae	3	0	4	7
Turbellaria	Tricladida	Planariidae	18	17	18	53
TOTAL			766	419	518	1703
Shannon-Wiener Diversity Index (H')			1.52	1.54	1.59	1.67
Evenness Index (J')			0.59	0.60	0.62	0.60

The Antirogo River is a habitat for dominant families such as Heptageniidae, Hydropsychidae, Baetidae, and Pachychilidae (Table 2). The abundance of Heptageniidae suggested that this species can inhabit various environmental conditions. The Heptageniidae were abundant under the rocks in river beds as they could attach themselves to the rocks' surface. These findings are in line with Boonsoong & Braasch (2013), who stated that the Heptageniidae family is one of the ordinary benthic families with an abundant number of their larvae inhabiting the rocks, logs, vegetation, and leaves in the slow to fast flowing streams. The Heptageniidae larvae inhabit fast streams by attaching themselves to the surface of the rocks, logs, and leaves to overcome the strong currents and consume the periphyton as their food source (Resh & Cardé, 2009). As they inhabit the rocks and vegetation in the river bed, the Heptageniidae are the decomposers in this Antirogo river and help purify the water. This statement is supported by Jacobus et al. (2019), who stated that the Heptageniidae's roles in the streams are as decomposers and purifiers of the water through filter feeding, which provide indicators of the streams.

The presence of Hydropsychidae in the Antirogo River also indicates the water quality condition. The Hydropsychidae are commonly found in unpolluted rivers and can indicate the pollution influx into the water (Kubendran et al.,2017; Akyildiz & Duran, 2021). Wiggins (2004) stated that Hydropsychidae is known to be quite sensitive to the heavily polluted waters. The Hydropsychidae in this research were found around the settlements and indicated that the water was not heavily polluted. These findings aligned with Purdyaningrum et al. (2013), who stated that the river around the settlement was categorized as slightly polluted, and only the Hydropsychidae was found. Wakhid et al. (2021) also found that the Hydropsychidae were more abundant in water near the village than in the forest and the tea plantation. The Hydropsychidae was known to have an adaptation to the gradients of environmental changes up to the downstream (Ficsór & Csabai, 2021). These studies indicated that the Hydropsychidae indicated the Antirogo river was unpolluted to slightly polluted water.

On the other hand, the Simuliidae, one of the least abundant families in this stream, inhabits the stream from unpolluted (clean streams) to moderately polluted (Rustam et al., 2019). The Simuliidae are found almost everywhere, with running water suitable as a habitat for immature stages (Hadi & Takaoka, 1991). Both studies stated that running water in clean or unpolluted conditions or moderately polluted conditions could be the habitat for the Simuliidae. Ciadamidaro et al. (2016) noted that the presence of the Simuliidae indicates significant levels of organic pollution-induced disturbances. These studies showed that the Simuliidae could define whether the water is good or unpolluted. Based on the most abundant families (Heptageniidae, Hydropsychidae, and Baetidae) and one family of the least

abundance (Simuliidae), it is indicated that the condition of the Antirogo river was a pretty clean river with a small amount of pollution.

The water quality of the Antirogo River was assessed to obtain information about the water quality using the Shannon-Wiener species diversity index (H'). Based on H' value, the Antirogo River overall had 1.67 and was categorized as lightly polluted. Each sampling station's diversity index (H') ranged from 1.52 to 1.59, classified as moderately polluted (Table 1 and Table 2). The characteristics of each sampling station were identical, as this river flowed around the settlements and agricultural areas. This moderate diversity of benthic macroinvertebrates is allegedly due to the disturbances and pollution influx from settlements and agricultural areas around the rivers. The disturbances and the pollution influx could affect and change the river's water quality and biota composition.

The distribution of each family in this research was analyzed by calculating the evenness index (J'). The evenness index (J') value overall in this research was 0.60, and in each sampling station, it ranged from 0.59 to 0.62, indicating that some species had a higher number than the others (Table 2). The evenness index (E) value indicated that in the Antirogo River, the number of individuals of each family was distributed evenly, and only some families with dominance number, especially the Heptageniidae and Hydropsychidae, were most abundant in this river. Both the evenness index (E) and the diversity index (H') indicated that this Antirogo river was lightly polluted, with moderately diverse and evenly distributed communities. As a comparison, some studies of macroinvertebrates showed that their diversity index value was lower than this study, such as in Surabaya river with 1.01 of H' (Maulana & Kuntjoro, 2023) and in Semarang river with a range of 0.68 – 1.41 of H' (Purdyaningrum et al., 2013).

The benthic macroinvertebrates' diversity (H') value can indicate the pollution influx into the river water. The pollution in the water bodies and sediments was affecting and contaminating every aquatic organism, especially the organisms with slow mobility, such as the benthic macroinvertebrates. Abdillah et al. (2025) stated that the Gastropods, as organisms with slow movements and inhabiting the river's sediments, can accumulate the chemical compounds of the pollution and have a negative correlation between the pollutant and the Gastropods. The pollutant from anthropogenic activities in the river could be toxic and affect the river's numbers and diversity. Based on the diversity index (H') value, the pollutants contained in the Antirogo River can be suspended solids and toxic at low levels. According to Hawkes (1978), the diversity indices are suitable for indicating physical and toxic pollution, which stresses most species in a community without encouraging replacement species. Sudarso et al. (2016) and Lestari & Rahmanto (2020) stated that the sediment had higher pollutant concentrations, and the higher concentration was correlated to the lower macrozoobenthos diversity. These studies supported that the diversity of the macrozoobenthos could indirectly be used as an indicator of the pollution influx into the river water, with the increase of the pollutant concentration in the water and sediment decreasing the diversity of the benthic macroinvertebrates.

CONCLUSIONS

The benthic macroinvertebrates in the Antirogo River were found in 1703 individuals, which were classified into 16 families, 10 orders, and five classes. The most abundant families were the Heptageniidae and the Hydropsychidae, while the least abundant were the Simuliidae. The diversity (H') and the evenness (E) of the benthic macroinvertebrates in this river overall were 1.67, which was categorized as moderately diverse, and 0.60, which was pretty evenly distributed. Based on the diversity index (H') value, the water quality of the Antirogo River in this research was categorized as lightly polluted.

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