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BIOMONITORING OF MACROINVERTEBRATE DIVERSITY AS AN INDICATOR OF POLLUTION IN DEKET RIVERS LAMONGAN REGENCY

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ABSTRACT

Macroinvertebrates are aquatic organisms that live at the bottom of the water, have relatively slow movements, and have a relatively long life span so that they can respond to river water conditions, changes in water quality, and the substrate in which they live significantly affecting their composition and abundance. This research aims to determine the diversity value, macroinvertebrate dominance, and the river water quality based on the Family Biotic Index (FBI) in the Deket River, located in the Lamongan Regency. The sampling method used a purposive sampling method, sampling was carried out at 3 stations and 4 replications, macroinvertebrates were taken using an Ekman grab tool, and river water quality values were measured using the family biotic index (FBI). Based on the research results, there is a moderate pollution level in the Deket River, as shown by the results of the FBI value with the water quality category being rather poor, with a high pollution level with a large population. The diversity index value for macroinvertebrates in the Deket River is between 1.27 and 1.57, included in the medium category. Meanwhile, the macroinvertebrate dominance index value in the Deket River is relatively poor.

Keywords: Macroinvertebrates; Pollution; Family Biotic Index (FBI); Deket River

INTRODUCTION

Maintaining good water quality in the river is vital for a healthy aquatic ecosystem. According to Wimbaningrum *et al*. (2016) that physical, chemical, and biological properties determine water quality. The biological factor includes living organisms that can serve as bioindicators. Macroinvertebrates are aquatic organisms that live at the bottom of the water, move slowly, and have a long lifespan. They can react to the river water conditions (Nangin *et al*., 2015).

The residents' livelihood activities depend on the Deket River. However, the river is currently facing a problem of water hyacinth blooming at several points due to the accumulation of organic waste (Ulpiana & Wulandani, 2021). Despite this issue, the Deket River is considered suitable for its flow location and falls under the dense community environment category (Wan *et al*., 2013).

Biomonitoring is a method for monitoring water quality by studying the biological parameters of groups of organisms living in it (Sripanya *et al*., 2023), Biomonitoring involves using indicators present in the water to assess its quality. Various groups of macroinvertebrates serve as excellent indicators of human impacts, particularly pollution. Most of them have specific ecological requirements, making them highly useful as bioindicators for assessing the characteristics of aquatic environments (Benetti & Garrido, 2010).

Plankton, periphyton, microbenthos, nekton, macrophytes, and macroinvertebrates are commonly used as indicator organisms in estimating water quality (Chazanah *et al*., 2020). Macroinvertebrates are aquatic organisms without backbones that live in muddy waters. They are particularly useful in detecting changes in water quality due to human activities such as industrial waste, fisheries, rice fields, and tourism, etc (Prajoko *et al*., 2021).

Deket Village has several rivers that originate from Bengawan Solo. The residents use these rivers as a source of water and for collecting water from the pond rice fields. However, there are indications that the river water is being polluted due to the discharge of factory waste, wastewater from pond rice fields, and the community's waste (Prihatini *et al*., 2019). This research aims to determine the diversity value, macroinvertebrate dominance, and the river water quality based on the Family Biotic Index (FBI) in the Deket River, located in the Lamongan Regency

RESEARCH METHODS

This research was conducted from January to February 2023 in the Deket River, Lamongan Regency. In this study, macroinvertebrate samples were collected from three stations—rice fields, residential areas, and water hyacinth areas—which were selected based on their varying levels of human influence and ecological conditions. At each station, sampling was conducted at four repetition points, resulting in a total of 12 samples (3 stations × 4 points). The rice fields represent agricultural influences, the residential areas reflect domestic and urban runoff, and the water hyacinth areas indicate the impact of aquatic vegetation on macroinvertebrate communities.

Using the Ekman grab (15x15x15 cm) tool, the purposive random sampling method was used to collect samples at a depth of 10 cm, ensuring representative data collection from the sediment. The Ekman grab is opened and sunk into the bottom of the water to collect the substrate. The collected substrate was placed on a baking sheet for sorting macroinvertebrates and then photographed. The Global Biodiversity Information Facility (GBIF) website was used to identify them.

Water quality measurements were taken for physical, chemical, and biological parameters. Physical parameters include temperature, brightness, and current speed. Chemical parameters include pH, DO, nitrate, phosphate, and ammonia. Biological parameters were determined through macroinvertebrate sampling by calculating values based on the Family Biotic Index (FBI) developed by (Hilsenhoff, 1988). The formula used to calculate FBI values was also utilized:

$$FBI = \Sigma \frac{Xi.ti}{n} \quad \text{.. (1)}$$

Note: i= represents the order in which family groups are arranged within the macroinvertebrate community; xi= represents the number of individuals within family group i; ti= represents the tolerance level of family group i; n= represents the total number of individuals within the macroinvertebrate community

The Shannon-Wiener diversity index is a measure of biodiversity that considers the number of species present and the abundance of each species in a given habitat. This index can be calculated using a formula that takes into account the species richness and the proportion of abundance of each species, and it is formulated below:

$$H' = -\sum_{i=1}^{s} Pi\ In\ Pi \quad \text{.. (2)}$$

Note: H'= represents The Shannon-Wiener diversity index; pi= represents number of individuals of one type with the entire sample size (ni/N); ∑= sum of calculation; s= represents number of species

Meanwhile, the Dominance Index is determined by utilizing Simpson's dominance index formula (Pamungkas, 2016) and it is formulated below:

$$D = \Sigma(ni/N)2 \quad \text{.. (3)}$$

Note: D = represents the Simpson Dominance Index; Ni= represents the number of individuals per species; N= represents the total number of individuals across all species.

The dominance index ranges from 0 to 1. A smaller index indicates no species dominates, while a larger index indicates a dominant species (Pamungkas, 2016).

RESULT AND DISCUSSION

Result

Macroinvertebrates in The Deket River

The macroinvertebrates found during the study were identified up to the genus level. 127 species from 3 classes and 6 genera were obtained from all stations. Details of the macroinvertebrates found at each station are provided in Table 1.

Table 1. Water Quality Classification Based On The Family Biotic Index

Family Biotic Index	Water Quality	Pollution Level
0.00 – 3.75	Excellent	Does not contain any organic material
3.76 – 4.25	Great	Slightly contain any organic material
4.26 – 5.00	Good	Contain any organic material
5.01 – 5.75	Quite good	Contains quite a lot of organic material
5.76 – 6.50	Quite poor	Contains a lot of organic material
6.51 – 7.25	Poor	Contains a huge amount of organic material
7.26 – 10.00	Terrible	Contain heavy organic material

Source: (Hilsenhoff, 1988).

Macroinvertebrate Results Based on Family Biotic Index (FBI)

The research revealed that the macroinvertebrate family Thiaridae was the most commonly found organism at each station, from 1 to 3. The FBI calculations showed that stations 1, 2, and 3 had relatively poor water quality with high pollution levels. Station 1 scored 6.31, station 2 scored 6.09, and station 3 scored 6.01 (Table 2).

Table 2. FBI Calculations Results of Station 1

No.	Family Name	Amount (xi)	Tolerance (ti)	xi. ti
Station 1				
1.	Parathelphusidae	5	6	30
2.	Thiaridae	20	7	140
3.	Viviparidae	64	6	384
4.	Lymnaeidae	29	6	174
5.	Tubificidae	5	10	50
6.	Napidaes	4	6	24
Total Amount		127	41	802
Station 2				
1.	Parathelphusidae	4	6	24
2.	Thiaridae	60	7	420
3.	Viviparidae	25	6	180
4.	Lymnaeidae	30	6	150
5.	Tubificidae	5	10	50
6.	Napidaes	3	6	18
Total Amount		127	41	774
Station 3				
1.	Lymnaidae	9	6	54
2.	Thursday	300	7	1,800
3.	Viviparidae	8	6	48
4.	Parathelphusa	2	6	12
5.	Tubificidae	3	8	24
6.	Lymnaidae	9	6	54
Total Amount		322	33	1,938

Not many species or macroinvertebrate organisms are found in the Deket River from stations 1-3. Those with high tolerance values dominate macroinvertebrates in the Deket River. The results of the Shannon-Whienner Diversity Index (H') values are shown in Table 3.

Table 3. Diversity Index Value

Station	Diversity Index Value	Category
I	1,50	Average
II	1,27	Average
III	1,57	Average

According to the Shannon-Whienner formula, station I has a diversity value of 1.50, station II has a value of 1.27, and station III has a value of 1.57. Table 3 shows that station III has the highest diversity index value. This could be because station III has more abundant nutrients, allowing macroinvertebrates to thrive there.

Meanwhile, station II located in the middle of the river flow, has the lowest diversity index value. This is due to the large amount of waste from the market and Kaputren River, and household and agricultural waste. The pollution caused by these wastes prevents many macroinvertebrates from surviving in the area.

Dominance Index

The Simpson formula was used to calculate the dominance index, and the results are presented in Table 6.

Table 4. Dominance Index Value

Station	Dominance Index Value	Category
I	0,27	Poor
II	0,33	Poor
III	0,22	Poor

According to the Simpson formula calculations, the dominance value at station I is 0.27, at station II it is 0.33, and at station III it is 0.22. Station III has the lowest dominance value while Station I has the highest (Table 4). Both of these values fall within the low dominance category, defined as 0.00<C<0.50.

The results of the dominance index analysis are consistent with those of the diversity analysis. Low dominance index values and vice versa usually accompany high diversity index values. Based on these results, the Deket River can be classified as moderately polluted.

Water Parameter

Physical Parameter

The results of the measurement of physical parameters in this study including temperature, brightness, current speed are presented in Table 5.

Table 5. Physical Parameter

No	Parameter	Station 1	Station 2	Station 3
1	Temperature (°C)	28.4	28.6	28.7
2	Brightness (cm)	32.75	35.25	40.25
3	Current Speed (m/sec)	0.03	0.04	0.04

After researching the temperature parameters of the Deket village river, it was discovered that the highest temperature recorded was 28.7°C at station 3 and the lowest temperature recorded was 28.4°C at station 1.

It is important to note that temperature variations can be influenced by exposure to sunlight and weather conditions during the study. As a result, there may be temperature differences among research stations. However, it is worth mentioning that the temperature at each station still falls within the range suitable for macroinvertebrates' survival.

After analyzing the brightnes parameter of the Deket River, station 1 recorded the lowest value of 32.75 cm, while station 3 recorded the highest value of 40.25 cm.

The brightness of a body of water can be affected by its color, turbidity, and the particle presence. When there are too many particles in the water, it becomes harder for light to penetrate it, reducing its productivity for photosynthesis. In this case, the sampled river is located right beside a pond where the owners dispose of their wastewater directly into the river, which can hurt the quality of the river water.

After measuring the current speed, it was between 0.03 m/sec and 0.04 m/sec, indicating a pretty slow current in the Deket River.

Chemical Parameter

The results of the measurement of physical parameters in this study including pH, Dissolved Oxygen, Nitrate, Phosphate, Ammonia are presented in Table 6.

Table 6. Chemical Parameter

No	Parameter	Station 1	Station 2	Station 3
1	pH	7	7.2	7.2
2	Dissolved Oxygen (mg/l)	0.15	2.91	2.15
3	Nitrate (mg/l)	2.45	1.55	1.2
4	Phosphate (mg/l)	5.95	1.56	0.84
5	Ammonia (mg/l)	0.34	0.16	0.20

According to the research on pH parameters, station 1 has the lowest pH value of 7, while stations 2 and 3 have the highest pH value of 7.2. The research results indicate that the pH value of the Deket River at stations 1-3 is still suitable for acroinvertebrate habitat.

The research shows that the dissolved oxygen levels in the Deket River are alarmingly low due to multiple factors. Based on the Lamongan Regency Fisheries Service laboratory results, station 1 had the highest nitrate value of 2.45 mg/l, while station 3 had the lowest value of 1.2 mg/l. It seems that station 1 has a high nitrate value due to its proximity to residents' homes.

According to the Lamongan Regency Fisheries Service Laboratory results, station 1 had the highest phosphate value of 5.95 mg/l, while station 3 had the lowest value of 0.84 mg/l. Based on the Lamongan Regency Fisheries Service laboratory results, the ammonia value ranged from 0.16 mg/l to 0.34 mg/l at stations respectively.

Discussion

The Thiaridae family is known for its high resistance to pollution (Widiyanto & Sulistayarsi, 2014). Similarly, the

Tubificidae family also exhibits a notable tolerance to polluted environments. The Tubificidae family, a type of macroinvertebrate with moderate to high pollution tolerance, can survive in waters affected by pollution (Hendrasarie, 2019). According to Zulkifli & Setiawan (2012), this group of macroinvertebrates is highly tolerant and can withstand environmental conditions with high organic matter levels, enabling them to adapt to extreme conditions.

Tubificidae can be found in environments with low oxygen concentrations, as noted by Hettige *et al*. (2022). Their study highlights the adaptability of Tubificidae to oxygen-depleted conditions, which is relevant to the Deket River, where Stations 1-3 exhibit low dissolved oxygen concentration values, aligning with the typical Tubificidae habitat (Table 6). In contrast, the Lymnaeidae family, another type of macroinvertebrate, is known for its potential to contribute to water pollution, as reported by Badawy *et al*. (2013). These macroinvertebrates are also present at each station. The Lymnaeidae family can be found on rock surfaces or river banks using their abdominal muscles, as stated (MDFRC, 2013).

According to Gayosia *et al*. (2015), waters that have not been polluted will show a balanced number of individuals.In contrast, in polluted waters the number of individuals is not evenly distributed and tends to be a species that dominates.

Poor water quality conditions are believed to be the main reason for the low diversity index (H') (Sirait *et al*., 2018). This is supported by the physical condition of the water, where a significant amount of rubbish accumulates at the bottom of the river. Human activities around the river, including dense housing, rice fields, and trade, further contribute to pollution, which disrupts aquatic ecosystems and inhibits the growth and survival of aquatic biota.

The impact of this pollution is reflected in the diversity values at each station, which vary due to differences in environmental characteristics and community activities (Hidayah & Ambarwati, 2021). As pollution increases, certain species become dominant while others decline. According to Mushthofa *et al*. (2014), Station II has a higher dominance value than Stations I and III, suggesting potential water pollution. This dominance shift occurs because species have different tolerance levels to environmental stressors. Organisms that cannot withstand pollution decrease in population, while more tolerant species thrive, altering the dominant species composition.

Sampling data show that the genus Melanoides dominates at Station II, indicating its resistance to household waste contamination. Physicochemical parameters that determine water quality include temperature, brightness, current speed, pH, dissolved oxygen, nitrate, phosphate, and ammonia. Seminar *et al*. (2020) suggest that the ideal temperature for the survival of these organisms is between 26°C-31°C. According to Mustofa (2017), the entry of pond wastewater into public waters can also affect the physical quality of the water, mainly its brightness. Ratih *et al*., (2016), reported that water clarity of at least 22 cm is required to survive macrozoobenthos. Leatemia *et al*. (2017), suggest that slow-flowing rivers harbor a greater diversity of macroinvertebrate organisms than fast-flowing rivers. Yunitawati *et al*., (2012), swift currents flow at a rate of 0.5-1 m/sec, medium currents flow at a rate of 0.2-0.5 m/sec, slow currents flow at a rate of 0.1-0.2 m/sec, and prolonged currents flow at a rate of less than 0.1 m/sec.

According to Rosalina and Maipauw (2019), that leaves and roots that fall to the ground undergo weathering and form a layer of organic material that enters the water. The sampling location has trees on both sides, leading to the accumulation of rotten tree trunks and fallen leaves in the water. The decomposition of this organic matter can influence water quality, including pH levels. According to Junaidi *et al*. (2009), pH values below 5 or above 9 are not ideal for macroinvertebrate life, which may impact their presence and diversity in the area. A pH ranging from 7 to 8.5 still allows macroinvertebrates to survive. According to Effendi (2003), The Deket River has a relatively slow current speed, which contributes to the low dissolved oxygen levels. As shown in Figure 5, lower current velocity reduces oxygen diffusion and mixing in the water. According to Effendi (2003) also explains that dissolved oxygen is inversely related to temperature, meaning higher temperatures further decrease oxygen availability. This relationship highlights the combined effect of physical factors on dissolved oxygen concentration in the river. Figure 1 confirms that the high-temperature parameter value is around 28°C. Ibrahim *et al*. (2020), suggest that a dissolved oxygen content of 2 mg/I in water is sufficient to support the life of aquatic biota. The elevated nitrate concentration is likely due to the direct discharge of household waste into the river, as also observed by Hamuna *et al*. (2018) in similar riverine environments. According to Effendi (2003) states that nitrate levels exceeding 5 mg/L indicate anthropogenic pollution, primarily from domestic wastewater and animal feces. This aligns with the conditions at the study site, where residential areas contribute to nutrient enrichment in the water.

According to Yuliandari (2018) stated that nitrate does not harm macroinvertebrates. Meanwhile, Gayosia *et al*. (2015) found that phosphate originates from household waste disposal, including organic and inorganic waste, detergent waste, and agricultural runoff, leading to high phosphate levels in water. The elevated phosphate concentration at Station 1 is due to its proximity to residential areas where household waste is directly discharged into the river.

Excessive phosphate, however, can disrupt aquatic organisms' metabolic systems, making survival difficult (Patty, 2013). Similarly, Sudaryanti *et al*. (2021) reported that an ammonia concentration of 1.0 mg/L impairs haemoglobin's ability to transport oxygen, potentially causing aquatic organism mortality. The high ammonia levels at Station 1 result from household organic waste entering the river. Gayosia *et al*. (2015) further noted that ammonia mainly originates from human and animal waste in riverine environments. Kadim *et al*. (2017) also identified high NH_3 levels as a clear indicator of water dominates. The research confirms that macroinvertebrates can serve as biological indicators for assessing changes in water quality and river ecosystem conditions.

CONCLUSION

The Deket River has few of macroinvertebrate organisms, and the dominant families at each station are Lymnaeidae, Tubificidae, Viviparidae, and Thiaridae. These families have a high tolerance for pollution and are resistant to it. Based on the FBI calculations, the water quality at station 1, station 2, and station 3 is relatively poor, with high levels of pollution. The score for station 1 is 6.31, which falls under the relatively poor water quality category. Station 2 scored 6.09, and station 3 scored 6.01, both of which are also in the poor water quality category with high pollution levels.

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