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Assessment of Water Quality in the Upper Brantas River Using Macrozoobenthos as Bioindicators

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ABSTRACT

Given the observed decline in water quality in the upstream region of the Brantas River, which passes through Batu City to Blitar, this study aims to use the abundance and diversity of macrozoobenthos as bioindicators for water quality assessment. Macrozoobenthos is analyzed with Shannon-Wiener's index of abundance and diversity. The purpose of this research is to monitor the water quality conditions in the upstream region of the Brantas River. The results of this study showed a fairly even abundance value, with the lowest being 1.3% and the highest being 62.4%, while the macrozoobenthos diversity index obtained ranged from 1.28 to 2.02, which is included in the moderate diversity category. These results fall into mild to moderate pollution according to Shannon-Wiener's index. The results of water quality measurements when compared to Indonesia water quality standards for fish farming in PP RI no. 22 of 2021, temperature, DO (Dissolved Oxygen), pH, and COD (Chemical Oxygen Demand) meet the quality standards, while BOD (Biochemical Oxygen Demand) and TSS (Total Suspended Solids) do not meet the quality standards.

1. INTRODUCTION

Macrozoobenthos animals play a very important role as a key component in the food web, functioning as predators, suspension feeders, detritivores, and parasites. Macrozoobenthos is also utilized as a bioindicator of water quality, as they are very sensitive to changes in the aquatic environment they inhabit [1]. The presence of macrozoobenthos can be seen from the substrate of the aquatic bottom, which greatly determines the development of these organisms [2]. Fast-flowing rivers with rocky substrates are more often found in the Phylum Arthropoda and Mollusca. Substrates consisting of sand and mud are more commonly encountered in the Phylum Annelida and Mollusca.

The Brantas River is one of the rivers that plays an important role for the community, especially in East Java. The upper Brantas River area passes through the Batu City area to Blitar [3]. The upstream area of the Brantas River has experienced a land-use change from forest to vegetable agricultural land [4] This has caused the downstream area of the Brantas River to become an appropriate place for business in the field of fisheries. There are several types of aquacultures carried out in the upstream area of the Brantas River, with still water pond culture being the most common type of aquaculture, reaching 14,000 farmers. The highest aquaculture production in Batu City is tilapia, which reached a production volume of 29,814 tons in 2021. The commodity with the highest production volume in Blitar is catfish, which reached 9,923,300 tons in 2021 [5]. This is in contrast to what was found at the Rombok Banangar River located in Serimbu Village, Landak Regency. This river is very close to a waterfall. The Banangar River has different flow rates based on the substrate at the bottom of the water, resulting in a highly diverse type of macrozoobenthos [6].

According to the East Java Environmental Agency, statistical measurements of water quality using the STORET method showed that the Brantas River in the upstream and transition areas (starting from the Pendem Bridge in Batu City to the Lengkong DAM) was in a moderately polluted condition. However, aquaculture activities require good water quality and are suitable for fish commodities. Therefore, water quality testing and monitoring need to be carried out to ensure the quality of water from the upstream areas of the Brantas River. In addition to physical and chemical parameters, water quality can also be measured using biological parameters (bioindicators). Macrozoobenthos are animals that settle on the bottom of the waters with limited movement and are sensitive to changes in water quality, so that they can be used as bioindicators of water quality [7]. Each of the macrozoobenthos species shows a different level of tolerance to different contaminants [8]. The preferred habitat for each type of macrozoobenthos also affects the distribution of abundance and diversity [9].

Research conducted in China found that concentrations of dissolved oxygen were closely related to the community structure of macrozoobenthos in the Cao Chu River, China [10]. Meanwhile, macrozoobenthos found in in Brantas River are Buccinidae, Hydrophilidae, Lumbricidae, Macromiidae, Pachychilidae, Parathelpusidae, Thiaridae, and Veneridae. The result also found that macrozoobenthos is correlated with dissolved oxygen [11]. Many macrobenthos are sensitive to low oxygen levels, for example, Ephemeroptera, Plecoptera, and Trichoptera (EPT) [12].

Given these challenges, the objective of this study is to evaluate the water quality of the Brantas River using the abundance and diversity of macrozoobenthos as bioindicators, to determine its suitability for ongoing aquaculture activities

2. METHODOLOGY

This research was conducted from April 2023 to May 2023 in the transition season from the rainy season to the dry season. The sampling location was determined in the upstream area of the Brantas River, which includes Batu City and Blitar Regency (Figure 1).

2.1 Materials

Equipments and materials used in this study include a hand net (diameter 43 cm) with netting 0.5 mm, Secchi disk, DO meter, pH pen, thermometer, bottle sample 1 L and 50 mL, plastic clip, microscope stereo, magnifying glass, pinset, petridish, ruler, pipet, coolbox, GPS, Macrozoobenthos samples, water, formalin 4%, alcohol 70%, identification guidebook.

2.2 Sample collection

Sampling was carried out in the upstream area of the Brantas River; two stations were chosen: Station 1 in Batu City and Station 2 in Blitar Regency. Based on topographical considerations of environmental conditions, there are 5 points at each station to collect samples. Macrozoobentos sampling was carried out at two stations, each region consisting of 5 points. Sampling is carried out at each point every 2 weeks.

The first point at the first station, Batu, is at the Kekep River, the second one is at the Brantas Tulungrejo River, the third point is at the Lanang River, and fourth point is at the Sidomulyo River, and the last point at Station 1 is at the Pendem River. The first point in Station 2, Blitar Regency, is the Telaga Rambut Monte River as the first point, then the second one at the Bantaran area, the river in the Sanggrahan area as the third point, and the Jalan Tangkis Lahar Gn. Kelud, as well as the fourth point and the fifth one, is the Lekso River.

2.3 Pearson correlation

Correlation analysis was carried out between the diversity of macrozoobenthos and the physical and chemical parameters of water. The data normality test was carried out first using the Shapiro-Wilk test because the number of samples was only <50. If the significance value was >0.05, the data was normally distributed and tested with Pearson Correlations, while if the significance value was <0.05, the data was abnormally distributed and tested with Spearman's rho. The following is the table of coefficient intervals in Table 1.

Table 1. Level of relationship, interval of correlation coefficient

Coefficient Interval	Relationship Level
0 - 0.199	Very Low
0.20 -0.39	Low
0.40 - 0.59	Currently
0.60 - 0.79	Strong
0.80 - 1	Very Strong

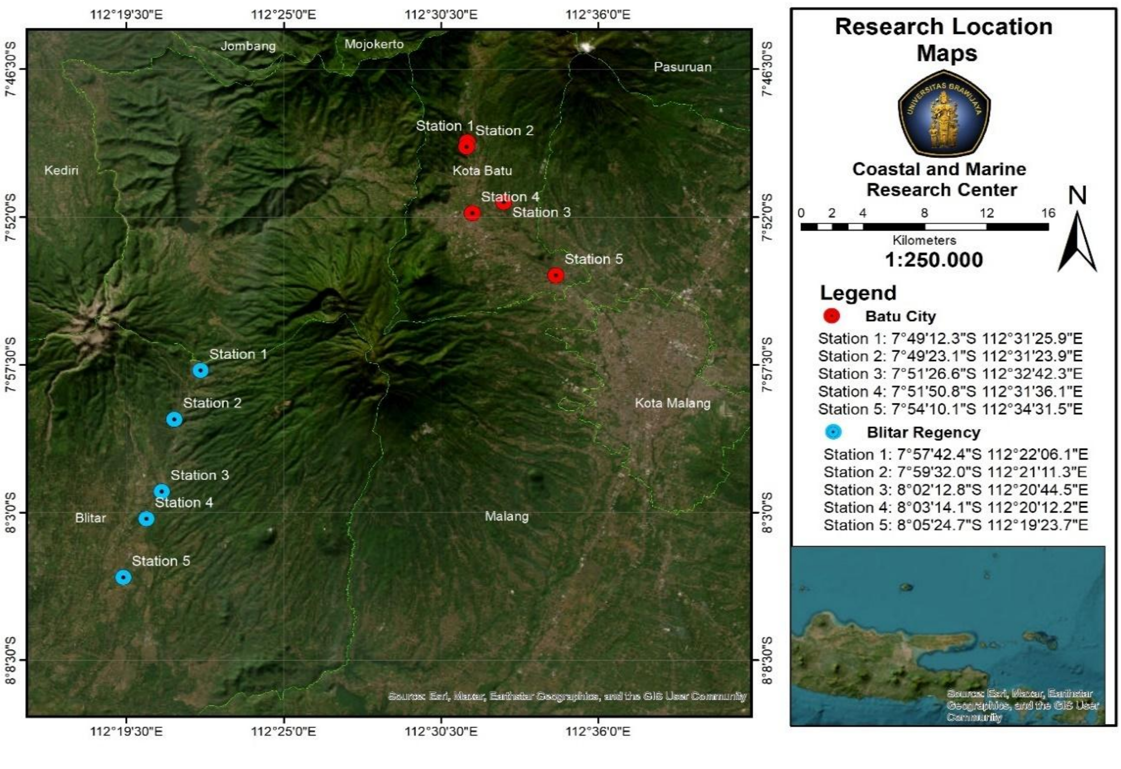

Figure 1. Map of sampling locations at Batu and Blitar

Macrozoobenthos sampling was carried out at two stations, each area consisting of 5 points. Macrozoobenthos sampling was carried out by kicking and jabbing techniques. The kicking technique was carried out in shallow rivers, the net was placed in front of the person holding the net with the mouth of the net facing the direction of where the water flow come from, then the substrate was stirred and kicked with the person's feet in front of the net for 1 minute or 10 meters long with rotating feet motion. This technique is done to stimulate animals or benthos hiding at the bottom of the river to get out and drift into the net. The jabbing technique can be carried out on the banks of shallow and deep rivers by placing a net at the bottom of the riverbank, then moving the net forward towards the source of the water flow for 10 meters. The substrate (sediment and gravel) that enters the net is sorted, then cleaned in a plastic bowl. The macrozoobenthos attached to the substrate were taken as samples. The sorted macrozoobenthos samples were transferred into a plastic sample bag, which had been labeled based on station points, and then given 4% formalin solution to preserve the macrozoobenthos for identification.

Water sampling and measurement were carried out in the same place as macrozoobenthos sampling. Parameter measurements were carried out in situ and ex-situ. Parameters examined in situ were temperature with a thermometer, pH with a pH meter, and DO (Dissolved Oxygen) using a DO meter. Furthermore, 1.5 liters of water samples were taken at each location for ex-situ testing, namely for BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), and TSS (Total Suspended Solids) parameters.

Sampling of base substrate sediment was carried out in the same place as macrozoobenthos and water quality sampling. Sediment samples were tested ex-situ in the laboratory. Sediment samples were stratified to obtain data on sediment grain size. After that, the results are used to determine the type of substrate based on Shepard's triangle.

2.4 Data analysis

Collected macrozoobenthos and then analyzed for its abundance and diversity. Macrozoobenthos abundance is analyzed with Shannon-Wiener's:

$$D = \frac{Ni}{N} \times 100\% \quad (1)$$

where,

D = Abundance

Ni = Number of individuals of a species

N = Total number of individuals found

The diversity of macrozoobenthos was also analyzed with Shannon-Wiener's:

$$H' = -\sum_{I=1}^{s} Pi \ln Pi \quad (2)$$

where,

H' = diversity index

Pi = the number of individuals of each species

S = number of types

Ni = the number of the i-th type

N = Total number of individuals found

If the diversity index shows a value of more than 3, then the level of diversity is high; if the value is between 1-3, then the level of diversity is moderate, and if the value is less than 1, then the level of diversity is low. The diversity index value can be used to determine the level of pollution, waters with macrozoobenthos diversity value that is more than 3 is categorized as not polluted, diversity value ranging 2-3 is categorized as lightly polluted, diversity value ranging 1-2 Is categorized moderately polluted, and diversity value less than 1 is categorized as heavily polluted [8].

Correlation analysis was carried out between macrozoobenthos diversity and water physical and chemical parameters. The data normality test was carried out first using the Shapiro-Wilk test because the number of samples was only <50. If the significance value is > 0.05, then the data is normally distributed and tested with Pearson Correlation, whereas if the significance value is <0.05, then the data is not normally distributed and tested with Spearman's rho.

3. RESULT

3.1 Macrozoobenthos abundance

Macrozoobenthos abundance in the upstream area of the Brantas River is found at Station 1 (Batu), with the highest abundance at point 5, with the Thiaridae family of 52.9%, and the lowest abundance was at point 1, with the Gomphidae family of 6.3%. At station 2 (Blitar), the highest abundance was at point 5, with the Thiaridae family as much as 62.4%, while the family that had the smallest abundance was the Perlidae family, which was as much as 1.3%. The results obtained for abundance values can be seen in Table 2.

3.2 Macrozoobenthos diversity

Based on the data obtained on macrozoobenthos diversity in the upstream area of the Brantas River, Station 1 (Batu) has a diversity index value ranging from 1.29 to 2.02. These results indicate that Station 1 shows moderate diversity and falls into the category of lightly and moderately polluted. Station 2 (Blitar) shows a diversity index value ranging from 1.28-1.83, which is included in the moderate diversity category, so that this water is included in the moderately polluted category. The results of the calculation of the diversity index analysis can be seen in Table 3.

Based on the data from the abundance of macrozoobentos in the upper reaches of the Brantas River, at Station 1 (Batu), the highest abundance is found at point 5, namely the Thiaridae family as much as 52.9% which is included in the high abundance, and the lowest abundance is at point 1, namely the Gomphidae family as much as 6.3%. At Station 2 (Blitar), the highest abundance is found at point 5, which is in the Thiaridae family, as much as 62.4%, while the family with the smallest abundance is in the Perlidae family, which is 1.3%. The results of macrozoobentos types in addition to being analyzed for abundance, the diversity index was also calculated (Figure 2).

3.3 Physical and chemical parameters

Based on the results of water quality measurements in the upstream area of the Brantas River, temperature parameters ranged from 20.3-23.7°C, pH between 7.7-8.6, DO between 7.6-8.4 mg/L, BOD between 5-15 mg/L, COD between 11-22 mg/L, and TSS between 33-150 mg/L. The results of the water physical and chemical parameter data were then compared with the second class of water quality standards set by PP RI No. 22 year 2021. The results of the physical and chemical parameters of water measurement can be seen in Table 4.

Table 2. Macrozoobenthos abundance

Class	Family	Abundance									
		Batu					Blitar				
		St. 1	St. 2	St. 3	St. 4	St. 5	St. 1	St. 2	St. 3	St. 4	St. 5
Citellata	Erpobdellidae	-	-	-	-	-	-	2.1	-	-	-
	Lumbriculidae	-	10.8	7.4	11	7.7	-	2.8	1.4	-	-
Gastropoda	Lymnaeidae	-	-	-	-	-	5.7	-	-	-	-
	Planorbidae	7.4	-	-	-	13.7	-	-	-	-	-
	Thiaridae	-	-	9.8	33.5	52.9	29.3	26.4	6.9	51	62.4
Insecta	Amphipterygidae	-	-	-	-	-	3.5	1.8	1.4	-	-
	Baetidae	18.6	18.3	-	-	-	-	25.4	19.7	8.7	4.1
	Chironomidae	14.8	15.2	38.5	29		3.9	24.7	36.5	23.1	5.6
	Coenagrionidae	9.5	15.2	-	-	11.8	4.8	-	-	-	-
	Gomphidae	6.3	-	-	-	-	7.4	-	-	-	-
	Hydropsychidae	12.7	19.5	14.1	17.9	-	32	8.2	28.6	-	2.8
	Perlidae	15.9	-	-	-	-	-	3	1.3	3.9	1.8
	Tipulidae	14.7	21.1	21.8	-	-	-	5.1	1.6	3.1	2.5
Malacostraca	Palaemonidae	-	-	-	-	-	7.4	-	-	-	-
	Sundathelphusidae	-	-	-	-	13.7	-	-	-	7.4	17
Tubbellaria	Dugesiidae	-	19	32.2	8.3	-	5.7	-	2	-	3.7

Table 3. Macrozoobenthos diversity

Station	Point	H'	Category
Batu	1	2.02	Moderate diversity (lightly polluted)
	2	1.76	Moderate diversity (moderately polluted)
	3	1.70	
	4	1.48	
	5	1.29	
Blitar	1	1.83	Moderate diversity (moderately polluted)
	2	1.77	
	3	1.57	
	4	1.34	
	5	1.28	

Table 4. Physical and chemical parameters

Parameter	Station										Water Quality Standard (2nd Class)
	Batu					Blitar					
	1	2	3	4	5	1	2	3	4	5	
Temp (°C)	21.5	20.3	21.5	22.3	22.9	23.4	23.7	23.7	22.2	22.6	18-30
pH	8.5	8.5	8.5	8.2	8.2	8.6	8.1	8.3	8.4	7.7	6-9
DO (mg/L)	8.4	8.1	8.2	7.9	7.6	8.3	8.2	8	8	7.7	>4
BOD (mg/L)	5	10	10	10	15	7	9	10	12	13	<3
COD (mg/L)	11	17	19	18	21	13	16	17	19	22	<25
TSS (mg/L)	33	50	52	79	150	50	52	73	98	130	<50

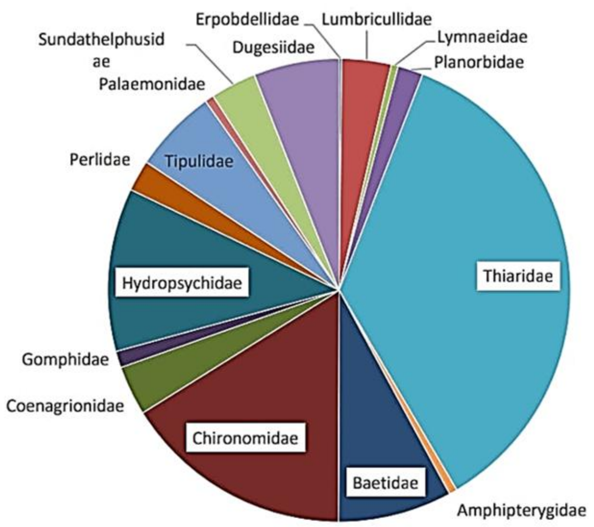

Figure 2. An abundance of macrozoobenthos in the upstream region of the Brantas River

Table 5. Base substrate texture

Station	Point	Texture (%)				Category
		Gravel	Sand	Silt	Clay	
Batu	1	63	37	0	0	Gravel
	2	71	29	0	0	Gravel
	3	80	11	9	0	Gravel
	4	45	25	30	0	Gravelly sediment
	5	0	48	37	15	Silty sand
Blitar	1	28	28	44	0	Gravelly sediment
	2	56	13	25	0	Gravelly sediment
	3	67	10	23	0	Gravelly sediment
	4	0	71	9	20	Clayey sand
	5	0	64	25	11	Silty sand

3.4 Base substrate sediment

The base substrate varied quite at the two stations. Station 1 has a substrate texture of gravel, gravelly sediment, and silty sand. Substrate conditions at Station 2 consist of gravelly sediments, clayey sand, and silty sand. The type of substrate that is dominated by gravel is thought to be due to the geographical location of the stations, both of which are located upstream of the river. The upstream region has a substrate that is generally in the form of rocks, gravel, and sand. The difference in the type of substrate from each station is also thought to be due to geographical location, namely the distance between the stations, which are far apart. The results of the base substrate texture classification based on the soil triangle in the upstream area of the Brantas River can be seen in Table 5.

4. DISCUSSION

Diversity index (H') and abundance (D) are index studies that are often used to predict the condition of an aquatic environment and community stability based on biological components. The environmental condition of water is said to be good or stable if a high diversity index is obtained. If diversity is equal to zero (0), then the community will consist of a single species or species. The diversity value will be close to the maximum if all species are evenly distributed in the community [13, 14], so it can be concluded that the diversity index value is strongly influenced by the number of types of organisms; therefore, the abundance of each species is also analyzed.

Diversity of macrozoobenthos can provide information about water quality. At Station 1 (Batu), the diversity values ranged from 1.29 to 2.02; these values can be categorized as lightly and moderately polluted [13]. This is due to the evenly distributed abundance of macrozoobenthos, especially at point 1, which has the highest diversity value, so that it is included in the lightly polluted category. The highest abundance at that point was only 18.6% in the family Baetidae, while the lowest was 6.3% in the Gomphidae family. Baetidae is categorized as a macrozoobenthos that is tolerant to a lightly polluted environment, meanwhile Gomphidae is categorized as being tolerant to a very lightly polluted environment [15]. Baetidae is a species that is sensitive to pollutants such as insecticides [16]. As stated, Baetidae only live in clean water habitats [17].

Conditions of diversity and abundance are quite different at Station 2 (Blitar). Station 2 has diversity values ranging from 1.28 to 1.83. This difference is sufficient to categorize Station 2 in the moderately polluted category. The highest abundance value at Station 2 was found in the Thiaridae family of 62.4% which was found at point 5, which also had the lowest diversity value of all station points. The lowest abundance value at point 3 is in the Perlidae family, which has an abundance value of only 1.8%. However, at this value of abundance and diversity, the waters of Station 2 in the upstream of the Brantas River can still be categorized as moderately polluted. Thiaridae is an indicator species for high TSS [18]. Thiaridae is categorized as a macrozoobenthos that is tolerant to a moderately polluted environment, meanwhile Gomphidae is categorized as being tolerant to a very lightly polluted environment [15]. Thiaridae is a type of gastropod that is tolerant of contaminants. Macrozoobenthos such as Thiaridae, which are very abundant in waters, are influenced by agricultural waste in river water ecosystems and are tolerant to a high TSS value [19].

The results of the diversity and abundance of these macrozoobenthos were then compared with the physical and chemical parameters of water quality. The diversity results appear to be directly proportional to the TSS and BOD values. The TSS value appears to be outside the class II quality standard according to PP RI no. 22 of 2021 for almost all station points except for point 1, Station 1. Point 1 at Station 1 is also the only point that shows results of diversity values, which are categorized as lightly polluted. TSS can affect the composition of macrozoobenthos in an aquatic environment [20]. Waters with lower TSS values have higher diversity of macrozoobenthos.

BOD values at all station points show values that are outside the second-class quality standard according to PP RI No. 22 of 2021. This fact is thought to be directly proportional to the results of macrozoobenthos diversity, which still shows that the condition of these waters is polluted. In accordance with the results of diversity at point 1, Station 1, which shows moderate diversity values, is still in the lightly polluted category. Increased BOD in waters can be caused by the entry of organic and inorganic materials into the waters and can cause loss of macrozoobenthos, which are intolerant to these changes [21].

After obtaining these results, Pearson correlation was used to further understand the correlation between macrozoobenthos diversity and chemical and physical parameters of water. After we found that all the data obtained had a normal distribution, we could continue with the Pearson correlation test. In the first correlation test between macrozoobenthic diversity and temperature parameters, the results obtained were that there was no significant correlation ($P > 0.05$) between macrozoobenthic diversity and temperature. The results also show that the relationship between the two is low and opposite.

In the correlation test between the second parameter between macrozoobenthos diversity, and DO, the results showed that there was a significant correlation between macrozoobenthos diversity and DO ($P <0.05$). In addition, the results show that the relationship between DO and macrozoobenthos diversity is very strong. There are other parameters that show the same conclusion as DO, namely BOD, COD, and TSS, all three of which showed significant correlation results and very strong and contradictory relationships with macrozoobenthos diversity. Meaning the higher the diversity value, the lower the value of the water parameters will be. Meanwhile, the pH parameter also shows a significant correlation with macrozoobenthos diversity, but only has a strong correlation with the in-line relationship.

Waters that show a reduction in DO will cause the BOD value to increase, because the BOD value increases, the COD value also increases. The increased COD value is also caused by the entry of organic and inorganic materials into the water, and causes the loss or reduction of macrozoobenthos, which are intolerant to these changes [20]. TSS can affect the penetration of light into the waters, and can affect DO in the waters, and sedimentation in the waters, and where macrozoobenthos are located, so that they can affect their abundance and diversity [22]. In aquaculture, if the BOD and COD values increase in waters, it can result in anoxia in fish or a lack of oxygen, as well as high TSS values, which affect DO values.

Still water pond cultivation is a type of cultivation that is mostly carried out in the cultivation activities carried out around the upstream area of the Brantas River, reaching 14,000 cultivators. Cultivation at both stations, namely Batu and Blitar, is famous for cultivating goldfish, and this commodity has become a superior product [23]. The highest aquaculture production in Batu City is in tilapia, which will reach a production volume of 29,814 tons in 2021, while the volume of tilapia production in Blitar will reach 411,500 tons in 2021. Therefore, these two commodities are included in the commodities most frequently cultivated in the region. around the headwaters of the Brantas River.

The cultivation of still water ponds for carp is regulated by SNI 01-6131-1999, while for tilapia it is regulated by SNI 7550-2009. In the SNI for goldfish cultivation in still water ponds, the optimal temperature for cultivating is 25°C, while in the SNI for tilapia, it ranges from 25-32°C. The temperature of the waters of the Brantas River is slightly below the SNI quality standard, which is in the range of 20.3-23.7°C. This is thought to be caused by the upstream area of the Brantas River, which is generally located in mountainous areas that have a cooler climate than the lowlands.

The pH parameter for carp and tilapia culture in still water ponds is 6.5-8.6, while the PP RI no. 22 of 2021 for class 2 water quality standards, the quality standards for the pH parameter are 6-9. There are slight differences between the three quality standards, but the pH measurement results obtained in the upstream area of the Brantas River ranged from 7.7 to 8.6, so they are still included in the three quality standards.

The DO parameter for goldfish farming in still water ponds is more than 5 mg/L, while for Tilapia, the optimal level is more than 3 mg/L, and in PP RI No. 22 of 2021 for class 2 water quality standards, the quality standard for the DO parameter is more than 4 mg/L. There are slight differences between the three quality standards, but DO measurements obtained in the upstream area of the Brantas River ranged from 7.7 to 8.6, which are still included in the three quality standards.

After obtaining the data results, a Pearson correlation was performed between the diversity of macrozoobenthos and the chemical and physical parameters of water. Since it was found that all the data had a normal distribution, the Pearson correlation test was continued. In the first correlation test, which is the correlation test between the diversity of macrozoobenthos and the temperature parameter, the result obtained was that there was no significant correlation ($P > 0.05$) between the diversity of macrozoobenthos and temperature. The results also indicate that the relationship between the two is weak and inverse. In the correlation test between the second parameter, namely the correlation between macrozoobenthic diversity and DO, the results showed that there is a significant correlation between macrozoobenthic diversity and DO ($P < 0.05$). Furthermore, the results indicate that the relationship between DO and macrozoobenthic diversity is very strong, with opposing characteristics. There are other parameters that show the same conclusion as the DO parameter, namely BOD, COD, and TSS, all of which indicate significant correlation results and very strong and opposing relationships with macrozoobenthic diversity. The pH parameter also shows a significant correlation with macrozoobenthic diversity, but only has a strong relationship that is direct.

The results of the diversity and abundance of macrozoobenthos in the upstream area of the Brantas River show that the upstream waters of the Brantas River are categorized as lightly and moderately polluted. The same results were found in the Citarum Hulu River Basin (DAS), indicating that the macrozoobenthos bioindicator shows levels of pollution ranging from light to heavy [24]. When compared with class II quality standards, PP RI No. 22 of 2021 is thought to be closely related to TSS and BOD. One of the most important cultivation commodities in the upstream of the Brantas River is carp and tilapia, so that the results of water quality obtained in the upstream area of the Brantas River are also compared with SNI 01-6131-1999 concerning carp cultivation in still water ponds and SNI 7550-200 regarding the cultivation of tilapia in still water ponds. The results obtained were that the temperature parameter was slightly below the quality standards of SNI 01-6131-1999 and SNI 7550-200, but other parameters, such as DO and pH, were still sufficient for cultivation in the upstream area of the Brantas River.

5. CONCLUSIONS

Macrozoobenthos found in the upstream areas of the Brantas River are from Erpobdellidae, Lumbriculidae, Lymnaeridae, Planorbidae, Thiaridae, Amphitretidae, Baetidae, Chironomidae, Coenagrionidae, Gomphidae, Hydropsychidae, Perlidae, Tipulidae, Palaemonidae, Sundathepusidae, and Digesiidae. Families with the highest abundance in both stations are from the Thiaridae family, and families with the lowest abundance are from the Gomphidae at the first station and the Perlidae at the second station. Thiaridae is categorized to be tolerant to a moderately polluted environment; meanwhile, both Gomphidae and Perlidae are categorized to be tolerant to a very lightly polluted environment. Thiaridae is tolerant of an environment with a high TSS and therefore could be found in waters that are influenced by agricultural wastes. The abundance of macrozoobenthos in the upstream area of the Brantas River is fairly even, with the macrozoobenthos diversity index obtained ranging from 1.28 to 2.02 and belonging to moderate diversity and these results fall into the category of mild to moderate pollution. That is because if the value is between 1-3, then the level of diversity is moderate, and diversity values ranging from 2-3 are categorized as lightly polluted, and diversity values ranging from 1-2 are categorized as moderately polluted. The use of biota (macrozoobenthos) to determine the water quality of rivers is more accurate compared to the use of physical and chemical parameters.

Pearson correlation result shows that the water parameters of DO, BOD, COD, and TSS all showed significant correlation results and very strong and contradictory relationships with macrozoobenthos diversity. When compared to water quality standards for aquaculture in PP RI no. 22 of 2021 (second class), temperature, DO, pH, and COD meet the quality standards, while BOD and TSS do not meet the quality standards. When compared with the SNI, the Indonesian standard for cultivating carp and tilapia in still water ponds, the DO and pH parameters still meet the standards.

TSS appears to be outside the second-class quality standard according to PP RI no. 22 of 2021 for almost all station points except for point 1, Station 1. Point 1 at Station 1 is also the only point that shows results of diversity values, which are categorized as lightly polluted. Waters with lower TSS values have higher diversity of macrozoobenthos.

BOD at all station points shows values that are outside the second-class quality standard according to PP RI No. 22 of 2021. This fact is thought to be directly proportional to the results of macrozoobenthos diversity, which shows that the condition of these waters is still polluted. Increased BOD in waters can be caused by organic and inorganic materials that flowed into the waters and can cause loss of many macrozoobenthos types that are intolerant to these changes.

Waste treatment should be done, and using materials that are more environmentally friendly should be normalized, especially for all parties that contribute directly or indirectly to the pollution load to the Brantas River. In addition, the government can tighten regulations regarding waste treatment and the use of materials that are not environmentally friendly, so that the water quality in the upstream areas of the Brantas River can be improved and maintained in accordance with quality standards for freshwater fish farming water sources. Further research about the correlation between macrozoobenthos diversity and other chemical water parameters that are more related to pollution, like ammonia, phosphate, and nitrate, could be done to further understand the macrozoobenthos' role as bioindicators of water pollution. In this study, pesticides and heavy metals are not studied in detail, because this research focuses on macrozoobenthos as bioindicators.

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NOMENCLATURE

D	Abundance, %
Ni	Number of individuals of a species, ind

N	Total number of individuals found, ind
H'	Diversity index
Pi	Number of individuals of each type, ind
S	Number of types