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Benthic macroinvertebrates as bioindicators to detect the level of water pollution in the upstream segment of Brantas River Watershed in Malang, East Java, Indonesia

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Abstract. *Hertika AMS, Sudaryanti S, Musa M, Amron K, Putra RBDS, Alfarisi MA, Hidayat MR, Pertiwi M, Halimah MF. 2024. Benthic macroinvertebrates as bioindicators to detect the level of water pollution in the upstream segment of Brantas River Watershed in Malang, East Java, Indonesia. Biodiversitas 25: 632-643.* The Brantas River is the second longest river on the island of Java after the Bengawan Solo River. The current condition of the Brantas River is facing a worrying decline in water quality due to community activities in the surrounding area. This decline can have a negative impact on both aquatic biota and community welfare. To assess water quality, one method involves the use of biological indicators, specifically benthic macroinvertebrates. The objective of this research is to assess the water quality upstream of the Brantas River by using benthic macroinvertebrate as bioindicators. The assessment is based on the community structure, Biological Monitoring Working Party-Average Score Per Taxon (BMWP-ASPT) method and physico-chemical water parameters. This research was conducted at 10 sampling stations with 5 stations located in Batu City and 5 stations located in Malang City. The benthic macroinvertebrate result consists of 8 classes, 53 families. namely Bivalves (2 families), Clitellata (2 families), Gastropoda (5 families), Hirudinea (1 family), Insecta (35 families), Malacostraca (4 families), Oligochaeta (2 families), Polychaeta (1 family), and Turbellaria (1 family). The abundance of macroinvertebrates ranged from 181-2879 individuals/m^2, while the diversity index ranged from 0.563-2.988. The evenness index ranged from 0.208-0.870, while the Simpson dominance index ranged from 0.061-0.799. The ASPT range of the upstream segment of Brantas River was found to be between 2.80-6.19, indicating a variation in water conditions from poor to excellent. The physico-chemical water as supporting parameters is still optimal, except for ammonia, total organic matter, and total dissolved parameters that exceed the quality standard. The results of this research show that based on benthic macroinvertebrates as bioindicators, the BMWP-ASPT index and water quality parameters as support, upstream to downstream the Brantas River watershed in Malang City has poor to very good quality. This is due to anthropogenic activities in land use which can disrupt the quality of aquatic ecosystems. Therefore, local governments need to manage waterfall ecosystems well by controlling human activities around them.

Keywords: Aquatic insect, bioassessment, BMWP-ASPT, pollution, water quality status

INTRODUCTION

Rivers are freshwater ecosystems that are constantly changing due to the unidirectional flow of water from higher to lower elevations. In tropical regions, these ecosystems are home to a diverse range of biota that can adapt to changes in food availability and habitat (Koning et al. 2020). Unfortunately, rivers are often polluted, making them susceptible to environmental degradation. Pollution can result from various human activities within river basins (Pardamean et al. 2021). Domestic, agricultural, and industrial operations can all have a discernible impact on the quality of river water, leading to adverse consequences (Gomes et al. 2019). Rivers offer several benefits to nearby communities, including urban centers and their surroundings. Rivers are a crucial source of water for fulfilling basic human needs, including drinking, domestic activities, tourism, agriculture, fisheries, and economic needs such as industrial applications and housing provision (Gunton et al. 2017). The Brantas River is one of the primary sources of water for people in East Java (Hasan et al. 2023).

The Brantas River is the second longest river on the island of Java, after the Bengawan Solo River. The Brantas River watershed covers an estimated size of 12,000 km^2, which is approximately one-quarter of the total land area of the East Java province (Hayati et al. 2017). According to Arsad et al. (2021), the Brantas watershed traverses various areas, including Batu, Malang, Blitar, Tulungagung, Kediri, Jombang, and Mojokerto. The Brantas River plays an important role in facilitating rice cultivation in the East Java region, as it serves as a major source of water for irrigation purposes (Raymond et al. 2021). In addition, the river serves as a vital domestic water supply for the cities located along its course (Roestamy and Fulazzaky 2022). The ecological condition of the upper reaches of the Brantas River is significantly influenced by anthropogenic activities. This anthropogenic pressure comes mainly from organic waste, household waste, agricultural waste, and industrial waste (Sueb et al. 2021). The implementation of monitoring and management strategies for the Brantas River is important in order to preserve its quality and prevent pollution from exceeding the established threshold.

Various methods can be used to monitor water quality, one of which is the use of benthic macroinvertebrate as biological indicators (Tan and Beh 2015; Liyana et al. 2019). Benthic macroinvertebrates refer to organisms that are large enough (macro) to be visually identified without the use of magnification. Characterized by the absence of a backbone, invertebrates exhibit a benthic lifestyle, living partially or entirely within the substrate of an aquatic environment (Raphahlelo et al. 2022). Benthic macroinvertebrates serve as bioindicators of water quality due to their high sensitivity to alterations in water conditions (Al et al. 2022). An advantage of using benthic macroinvertebrates for biomonitoring purposes is their universality, which allows them to be applied to different aquatic systems (Edegbene et al. 2021). In addition, these organisms have remarkable species diversity and abundance, making them valuable indicators. They indicate the response to a wide range of environmental stressors and sampling cost-effectiveness (Tampo et al. 2021). Furthermore, the sedentary or benthic nature of these species, along with their extended life cycle compared to other freshwater aquatic organisms such as algae and plankton, make them valuable markers for assessing water quality (Sumudumali and Jayawardana 2021).

This study promotes the monitoring of river health in the areas of Malang City, Batu City, and Malang District through the utilization of biological indicators, specifically macroinvertebrates. These indicators include the assessment of composition, diversity index, evenness index, dominance index, and the Biological Monitoring Work Party-Average Score Per Taxon (BMWP-ASPT) index. The selection of macroinvertebrates as the focus of study is justified by their ecological significance as organisms inhabiting river ecosystems. Each type of macroinvertebrate has a different sensitivity and tolerance to changes in water quality caused by the introduction of waste into the river. In addition, the monitoring of physico-chemical parameters is carried out as a means of assessing the pollution state of the Brantas River.

MATERIALS AND METHODS

Study area

This research was located along the upstream segment Brantas River watershed from Batu-Malang City, East Java, Indonesia (Figure 1). The research was conducted from May to July 2023 with two replications and two-week intervals. The objective of this research was to assess the extent of pollution in the aforementioned river by using macroinvertebrate biomarkers and physico-chemical water parameters. The sample sites for macroinvertebrates and water quality were categorized into ten stations. The ten research stations were determined using the purposive sampling method. This method was chosen by considering data on land use characteristics of the Brantas River watershed, so that it can be used to represent the current conditions of the Brantas River. The station consists of five sampling points located in the Batu City area, and another five sampling points located in the Malang City area. The geographical coordinates of the sampling stations and the detail of land-use characteristic data in the Brantas River watershed are shown in Table 1.

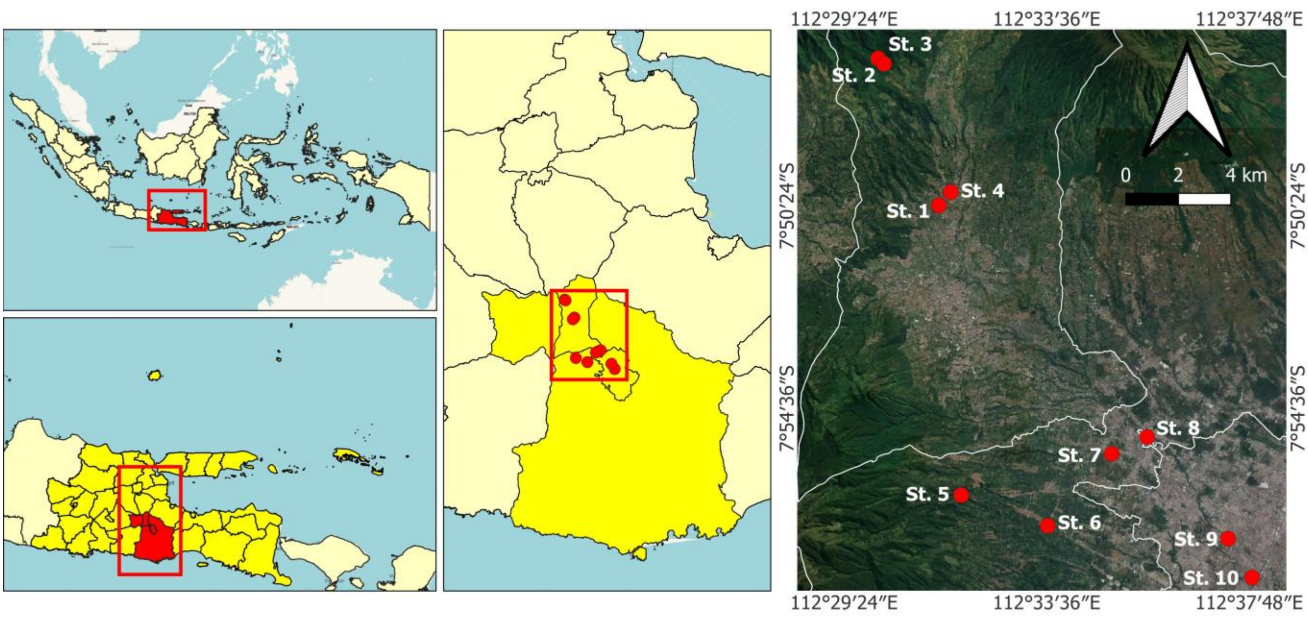

Figure 1. Sampling location station in Brantas River Watershed, Malang District, East Java, Indonesia

Table 1. Characteristic of sampling stations

Sampling station	GPS coordinates	Location	Land use
Station 1	112°31'22.00"E, 07°50'22.99"S	Temas	Farm, Settlement
Station 2	112°30’13.7”E, 07°47’27.0”S	Coban Talun Waterfall (Bottom)	Tourist area
Station 3	112°30’06.3”E, 07°47’20.3”S	Coban Talun Waterfall (Upper)	Forest, Tourist area
Station 4	112°31’36.6”E, 07°50’06.6”S	Punten	Agricultural, Settlement
Station 5	112°31’49.9”E, 07°56’23.6”S	Bedengan	Forest, Tourist area
Station 6	112°33'37.34"E, 07°57'1.71"S	Dau	Agricultural, Settlement
Station 7	112°34’56.9”E, 07°55’32.0”S	Sengkaling	Tourist area, Settlement
Station 8	112°35’40.9”E, 07°55’11.3”S	Tlogomas	Campus area, Settlement
Station 9	112°37’21.7”E, 07°57’17.7”S	Dinoyo	Settlement, Home industry
Station 10	112°37’51.6”E, 07°58’06.0”S	Mayjend Panjaitan	Campus area, Settlement

Table 2. Methods and instruments for assessing water quality

Parameter	Unit	Method/instrument
Temperature	°C	Dissolved Oxygen Analyzer type DO9100
pH	-	Water Quality Tester tipe EZ-9901
Dissolved Oxygen (DO)	mg/L	Dissolved Oxygen Analyzer type DO9100
Ammonia (NH_3)	mg/L	Spectrofotometre UV-Vis
Total Organic Matter (TOM)	mg/L	Titrimetre
Total Dissolved Solid (TDS)	mg/L	Water Quality Tester tipe EZ-9901
Current velocity	m/s	Current meter

Procedures

Sampling and identification of benthic macroinvertebrates

Purposive sampling was used to collect macroinvertebrate samples. Benthic macroinvertebrates samples were collected using the modification method of a published article (Wimbaningrum et al. 2016). A Surber Bottom Sampler with a mesh size of 0.5 mm, measuring 30 cm by 30 cm, was used to collect macroinvertebrate samples. At each sampling point, ten subsamples were collected within a stretch of approximately 20 m, with each subsample being approximately 1 m away from each other (Wakhid et al. 2021). The front of the Surber Bottom Sampler enters the substrate ±10 cm after being oriented to face the opposite direction of the river current. Macroinvertebrates are agitated with the foot on the front of the Surber Bottom Sampler so that the current sweeps them into the sampler. The samples obtained were placed in labeled vials and preserved in a 70% alcohol solution until the entire sample was submerged. The samples were then taken to the Hydrobiology Laboratory, Faculty of Fisheries and Marine Sciences, University of Brawijaya for identification and calculation.

Physico-chemical parameters

The assessment of physico-chemical water quality as a supporting parameter is carried out using two different approaches, namely ex-situ and in-situ methods. Table 2 shows the water parameters analyzed based on human activities around the watershed and the possible pollutants released by each activity. On ex-situ methods, a water sample was collected using a series of sterilized polyethylene bottles. This process follows the methodology outlined by Olasoji et al. (2019). Once the bottles were filled, they were transported to the laboratory in a coolbox that was pre-filled with ice cubes. The purpose of this transportation was to conduct further analysis at the Hydrobiology Laboratory, which is part of the Division of Environment and Aquatic Biotechnology at the Faculty of Fisheries and Marine Sciences, Brawijaya University in Malang, Indonesia. The Total Organic Matter (TOM) and Ammonia (NH_3) were measured based on the 06-6989.22-2004 and SNI 06-6989.30-2005. The optimal water quality level refers to the Government Regulation Number 82 of 2001 concerning Water Quality Management and Water Pollution Control. Meanwhile, water quality parameters were measured directly on the site, such as pH and Total Dissolved Solid (TDS) measured using an Automatic Calibration Digital water quality meter (Water Quality Tester type EZ-9901). On the other hand, the Dissolved Oxygen (DO) and temperature were measured using a Dissolved Oxygen Analyzer type DO9100. Lastly, the current velocity was measured using a conventional current meter referring to the Indonesian National Standards (SNI) 8066:2015.

Data analysis

After identification and quantification of benthic macroinvertebrates, several indices were calculated, including the Diversity Index (H'), Evenness Index (E), Dominance Index (C), and BMWP-ASPT Index. Apart from that, physico-chemical parameters are also measured and analyzed and then all data is processed and represented visually through the use of Microsoft Excel in the form of graphs or tables. This representation is then subjected to descriptive analysis, where the data is examined in relation to field conditions and related references.

Diversity index of macroinvertebrate (H')

The diversity index value is used to determine the level of macroinverterbrate diversity in a population. The macroinvertebrate diversity index uses the Shannon-Wiener formula (Shannon 1948; Yazdian et al. 2014; Magurran 2021).

$$H' = -\sum \left(\frac{ni}{N}\right) ln \left(\frac{ni}{N}\right)$$

Where :
H' : Shannon-Wiener Diversity Index
ni : Number of individuals/species
N : Total number of individuals

Evenness Index of macroinvertebrate (E)

The evenness index is used to express the total number of individuals distributed within each species found in the study. The evenness index is calculated using the Pielou's index (Pielou 1966; Custodio et al. 2018; Magurran 2021) as follows:

$$E = \frac{H'}{LnS}$$

Where:
E : Evenness Index
H' : Shannon-Wiener Diversity Index
LnS : Natural log of the total number of species

Dominance Index of macroinvertebrate (C)

The dominance index is used to see how much an organism dominates other organisms in an ecosystem. The dominance index is calculated using the formula of Simpson's Day Index Of Dominance (Simpson 1949; Custodio et al. 2018) as follows :

$$C = \sum \left(\frac{ni}{N}\right)^2$$

Where:
C : Dominance Index
ni : Number of individuals of each type
N : Total number of Individuals

Biological Monitoring Work Party-Average Score Per Taxon (BMWP-ASPT) Index

The standard used in Europe for assessing biological indicators of water quality is the BMWP (Biological Monitoring Working Party) index based on macroinvertebrate assemblages. The index is designed to allow rapid data collection in the field and therefore rapid assessment of water quality and problem development. Each of the taxa collected in a sample must be identified, usually to the family level, and assigned a value for each family (from 1 to 10) based on its known tolerance to oxygen tension. The individual scores for each of the taxa are then summed to give a total score for the entire sample and the BMWP value is obtained. The lower limit for this score is 0 (no organisms), with higher scores indicating improved water quality (Frid and Dobson 2013).

According to Galbrand et al. (2007), the macroinvertebrates found are assessed using the BMWP index and calculated using the ASPT index then the results can be categorized according to the ASPT value. The ASPT index describes the tolerance level of all taxa in a community. ASPT is calculated by dividing the value of the number of 1 family by the number of all families in one sample. The following ASPT is categorized into 5 groups (Table 3).

$$ASPT = \frac{\text{Total BMWP index score}}{\text{Number of families found and have a score}}$$

RESULTS AND DISCUSSION

Macroinverterbrate community

The result of the research conducted in the upstream waters of the Brantas River Watershed, namely in Malang Raya, revealed the presence of four different phyla of benthic macroinvertebrates. These phyla include Mollusca, Annelida, Arthropoda, and Platyhelminthes. The phyla in question are divided into eight distinct groups, namely Bivalvia (with 2 families), Clitellata (with 2 families), Gastropoda (with 5 families), Insecta (with 35 families), Malacostraca (with 4 families), Oligochaeta (with 2 families), Polychaeta (with 1 family), and Turbellaria (with 1 family). The study revealed wide diversity of benthic macroinvertebrate groups, with population densities ranging from 181 to 2879 individual/m^2. Baetidae is the phylum with the highest abundance of 2220 individuals/m^2 obtained at station 5 during the first sampling. Table 4 provides comprehensive information on the macroinvertebrate composition found in the upstream waters of the Brantas River Watershed, particularly in the region of Malang Raya. Meanwhile, Figure 2 shows the observed case of benthic macroinvertebrates.

The upper reaches of the Brantas River in Malang are home to several dominant families of macroinvertebrates, including Baetidae, Lepidostomatidae, Hydropsychidae, Chirinominae, Orthocladiinae, and Lumbriculidae. The prevalence of the Baetidae family suggests that this particular species is capable of thriving in a wide range of environmental conditions. Empirical evidence shows that Baetidae specimens were present at each of the sample locations. Baetidae and Hydropsychidae are families of aquatic insects commonly found in unpolluted rivers. Kubendran et al. (2017) found that Baetidae are sensitive to environmental changes. Akyildiz and Duran (2021) observed that the prevalence of the Hydropsychidae could serve as an early indicator of heightened anthropogenic waste influx into aquatic environments. This family appears to be sensitive to waters that are significantly polluted, indicating a possible correlation with waters that are only slightly polluted and capable of creating micro-environments that are resistant to water.

Table 3. Average Score Per Taxon

ASPT value	Water quality
>6.0	Excellent water quality
5.5-6.0	Very good water quality
5.0-5.5	Good water quality
4.5-5.0	Moderate water quality
4.0-4.5	Moderately-poor water quality
<4.0	Poor water quality

Note: Assessment biological integrity using aquatic macroinvertebrate by Galbrand et al. (2007)

Table 4. Macroinvertebrate individual composition at the upstream of Brantas River Watershed, Malang, Indonesia

Family	**Station 1**		**Station 2**		**Station 3**		**Station 4**		**Station 5**		**Station 6**		**Station 7**		**Station 8**		**Station 9**		**Station 10**	
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Bivalves																				
Sphaeriidae	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Thiaridae	-	-	-	-	-	4	6	52	-	-	-	1	-	-	1	1	7	-	-	5
Clitellates																				
Glossiphoniidae	-	1	-	-	-	-	12	5	-	-	-	-	-	-	1	-	-	1	1	1
Haplotaxidae	-	-	-	1	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-
Gastropods																				
Hydrobiidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	1	1	2	2	-
Lymnaeidae	-	-	-	-	-	-	3	4	-	-	8	22	-	-	1	-	1	-		7
Physidae	-	-	-	-	-	-	1	4	-	-	23	104	-	-	-	-	-	-	1	-
Planorbidae	1	-	-	-	3	3	-	9	-	-	-	-	-	-	2	-	-	-	1	
Viviparidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Hirudinea																				
Richardsonianidae	-	-	-	-	-	-	171	163	2	1	17	32	7	1	3	2	7	4	5	8
Insect																				
Amphipterygidae	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Athericidae	-	-	2	-	1	1	-	-	2	2	-	-	-	-	-	-	-	-	-	1
Baetidae	118	128	121	57	199	34	127	584	2220	1140	1448	230	27	21	5	2	2	21	9	4
Blephariceridae	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Caenidae	23	15	6	19	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Ceratopogonidae	3	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	5	3	1	3	76	18	85	84	-	-	3	17	11	7	10	17	9	53	10	60
Elmidae	118	43	17	14	70	49	6	34	76	42	8	126	16	7	51	57	17	147	57	65
Empididae	46	80	20	35	1	14	-	1	10	4	2	1	-	-	-	-	-	-	-	-
Gerridae	4	-	1	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-
Glossosomatidae	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptageniidae	23	28	37	38	-	-	-	-	5		-	-	-	-	-	-	-	-	-	-
Hydrophilidae	86	125	31	30	-	-	-	-	6	9	-	-	-	-	-	-	-	-	-	-
Hydropsychidae	-	1	2	2	-	-	-	-			-	-	-	-	-	-	-	-	-	-
Lampyridae	33	33	26	19	4	9	12	44	132	58	54	88	349	67	58	118	459	233	673	175
Lepidostomatidae	-	-	1	3	-	-	-	-	8	1	-	-	-	1	-	-	-	-	-	-
Leptoceridae	41	41	28	22	-	-	-	-	196	157	-	-	-	-	-	-	-	-	-	-
Limoniidae	88	66	1	19	-	-	-	-	46	39	-	-	-	-	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	3	4	1	2
Muscidae	10	5	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Noctuidae	-	-	1	3	-	-	-	-	3	1	1	-	-	-	-	1	-	-	-	-
Orthocladiinae	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perlidae	22	18	2	6	287	44	-	76	12	17	5	46	6	24	7	37	5	319	13	102
Perlodidae	39	48	14	21	-	-	-	-	74	58	-	-	-	-	-	-	-	-	-	-
Polycentropodidae	26	39	15	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philopothamidae	25	17	-	8	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Prosopistomatidae	9	6	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psephenidae	8	7	3	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psychodidae	17	22	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scirtidae	-	-	2	1	-	-	1	-	-	-	-	1	-	-	-	-	1	4	1	8
Simuliidae	10	8	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tabanidae	46	84	18	14	-	-	-	-	31	8	34	82	11	1	-	1	-	-	-	-
Tanypodinae	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
Tipulidae	4	5	2	-	42	6	14	9	1	4	3	4	-	18	3	3	-	2	1	2
Malacostraca																				
Gammaridae	-	-	1	1	-	-	-	-	2	-	-	-	-	-	-	-	1	-	2	-
Grapsidae	24	20	4	17	-	-	3	1	-	-	-	-	-	2	-	-	-	-	3	-
Onicidae	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-
Sundathelphusidae	-	-	-	-	-	1	5	-	-	-	-	-	3	5	1	-	2	-	2	2
Oligochaeta																				
Lumbriculidae	8	1	2	-	4	5	11	64	1	4	7	8	49	29	3	2	34	38	58	274
Naididae	-	-	-	-	-	1	73	3	-	-	-	-	-	-	-	-	2	22	-	4
Polychaeta																				
Nereididae	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbellaria																				
Planaridae	10	7	28	19	3	5	2	2	42	35	9	12	-	-	-	-	-	-	-	-
Total	860	865	417	458	691	194	534	1139	2879	1584	1622	774	482	183	181	263	561	863	853	722

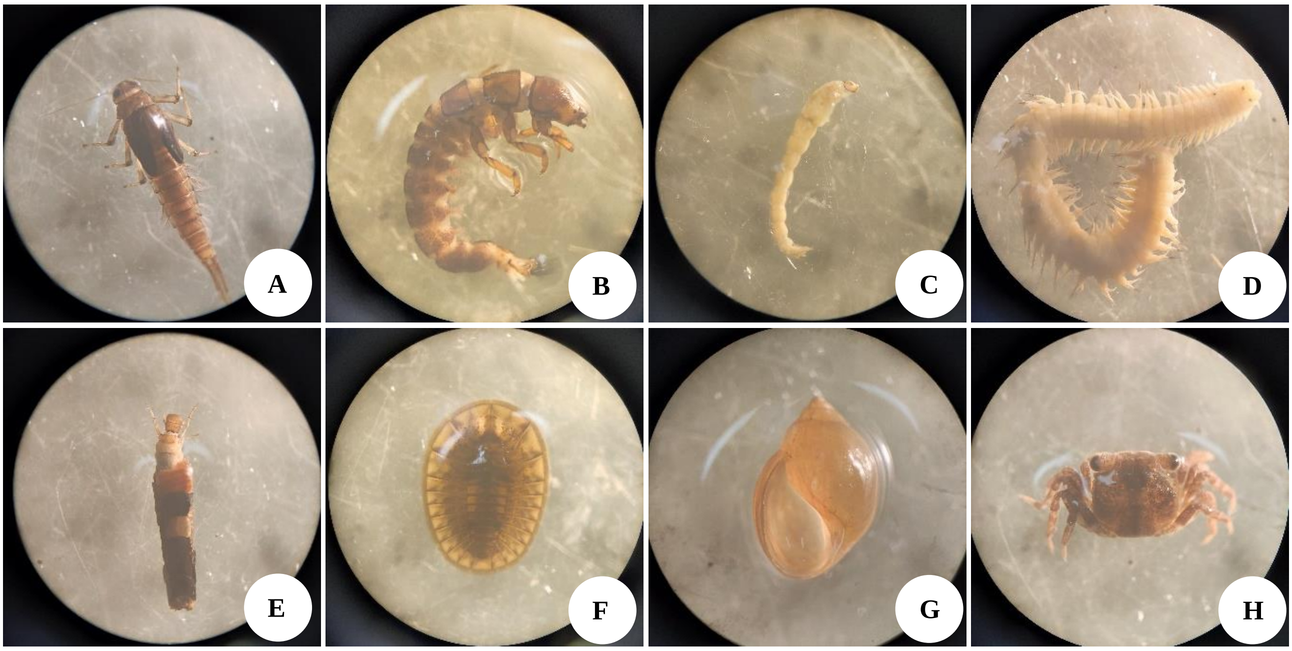

Figure 2. Examples of benthic macroinvertebrate in the upstream of Brantas Watershed River During Observations: A. Baetidae, B. Hydropsychidae, C. Orthocladinae, D. Nereididae, E. Lepidostomatidae, F. Psephenidae, G. Physidae, H. Grapsidae

The presence of Simuliidae is an indicator of significant levels of organic pollution-induced disturbances (Ciadamidaro et al. 2016). Simuliidae, Lumbriculidae, and Hydrophilidae are known to inhabit aquatic environments characterized by stony substrates, abundant organic matter decomposition, and flora. These organisms can be found in a range of water bodies, including both smaller streams and larger rivers. Psephenidae inhabit fluvial environments characterized by shallow depths, rapid water currents, and surfaces composed of rock and gravel. This study identifies the presence of Lepidostomatidae, Glossosomatidae, Elmidae, Perlidae, Heptagenidae, Philopotamidae, Leptoceridae, and Limnephilidae in the river ecosystem as indicator of water body health (Sudaryanti 2022). Thiaridae, Lymnaeidae and Chironomidae are families that indicate water pollution (Xu et al. 2014). The Chironomidae and Lymnaeidae groups include species that range from sensitive to tolerant of environmental changes, allowing them to inhabit both pristine and polluted habitats (Lencioni et al. 2012; Nicacio and Juen 2015).

Some species are always found at all research stations, while other species are only found at certain stations. This is because macrobenthic fauna have different adaptation abilities. The variation in habitat quality across different study stations has a significant impact on the population size of macroinvertebrates. The number of organisms is also affected by fluctuations in the physical and chemical characteristics of aquatic environments, such as water conditions, substrate composition, and currents (Odountan et al. 2019). An instance of the basic substrate's condition, characterized by muddy sand and a high amount of organic substrate, leads to a diminished presence of benthic macroinvertebrate (Hettige et al. 2023). In the context of aquatic ecosystems, it has been observed that the river riffle characterized by substantial rock and gravel substrates exhibits the most pronounced abundance and productivity of macroinvertebrate species. The decline in species diversity and population size is a reaction of the macrozoobenthos community to various disturbances, sometimes referred to as stressors (Brysiewicz et al. 2022).

Physicho-chemical parameters

Figure 3 shows the water quality measurements (water temperature, pH, DO, TOM, ammonia, TDS and current velocity) at 10 stations carried out in the upstream of Brantas River Watershed. The water quality of the upstream of Brantas River can be classified as normal to lightly polluted. The temperature obtained at the first sampling ranged from 15.4-25.4°C with the sampling time at 06.00 to 10.00 WIB. Then the temperature at the second sampling ranged from 14.5-24.3°C. The temperature results obtained tend to increase at each station and are quite stable at each sampling. Temperature values tend to increase due to the geographical location of each different station. Apart from that, the time of measurement and the canopy factor (coverage by vegetation) of trees growing nearby also influence the temperature value. According to Koniyo (2020), the increase in water temperature can be influenced by the intensity of sunlight that falls on the water surface and is then reflected back into the atmosphere, where some of it is absorbed in the form of heat energy. Apart from that, changes in water temperature can also be influenced by geographical location, differences in measurement time, weather and climate conditions, hydrological regimes, and land use. The temperature range obtained still supports benthic macroinvertebrate life. Within the suitable temperature range, the growth rate of macroinvertebrates may be enhanced, leading to a reduction in turnover rate, as well as an increase in productivity and species variety, as temperature rises (Bonacina et al. 2023).

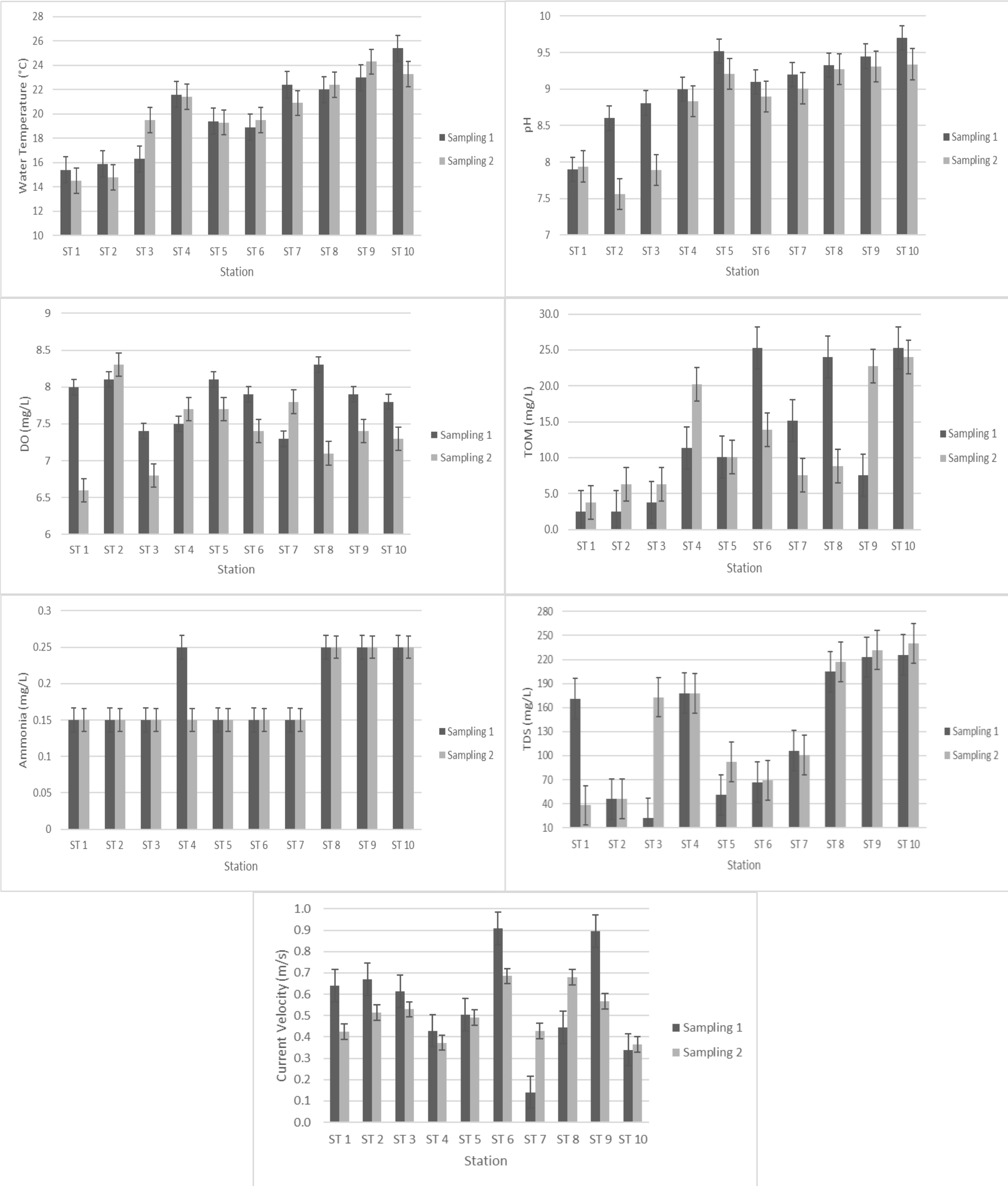

Figure 3. Water quality measurement results (Water temperature, pH, DO, TOM, ammonia, TDS, and current velocity)

Furthermore, the reduction in water pH observed during the second sampling can be attributed to precipitation that occurred on the day preceding the second sampling event. According to Maulud et al. (2021) the typical pH range of freshwater river is between 6.5 and 9.0. Multiple factors can affect the pH levels in aquatic environments, such as the introduction of other substances, photosynthetic activity, presence of aquatic creatures, concentrations of dissolved oxygen and carbon dioxide, temperature variations, and discharge of waste materials (Sudinno et al. 2015). The birth rate and survival rate of macroinvertebrates are influenced by alterations in pH levels, leading to subsequent modifications in biodiversity (Walag and Canencia 2016). When the pH fluctuates (pH <5.0 or pH>10.0), the reproductive capacity of macroinvertebrates is substantially diminished, perhaps leading to mortality in severe instances, accompanied by a decline in biomass and diversity. The decline in pH levels may also initiate the liberation of heavy metals, resulting in the toxication of macroinvertebrates. Consequently, this has implications for the community composition and spatial arrangement of macroinvertebrates (Hou et al. 2020).

DO plays a crucial role in the survival of aquatic organisms as it is utilized for respiration and osmoregulation. Differences in DO levels among all stations were influenced by many factors, including water temperature, varying levels of total organic matter, and the land cover surrounding the water surfaces (Ahmed and Lin 2021). The obtained DO readings at all stations were classed as within the usual range. However, there were comparable changes observed across all stations. According to Government Regulation Number 82 of 2001, the minimum acceptable level of dissolved oxygen is ≥4 ppm. In the event that the observed value is lower than the anticipated value, it will have a detrimental impact on the survival rate of aquatic organisms. Water quality is positively correlated with the concentration of dissolved oxygen in the water. DO is typically not considered a significant macroinvertebrate biological element in clear and unaltered river systems due to its limited drop in concentration. However, in the context of contaminated waterways, the scenario is reversed (Sudaryanti 2022).

TOM refers to the collective amount of organic substances present within aquatic environments. Clean waters are classified as having TOM content below 10 mg/L, whereas fertile waters are characterized by TOM levels exceeding 26 mg/L (Astriana et al. 2022). The presence of TOM can be observed at stations 1, 2, and 3, which are classified as clean water sites due to their elevated locations. These stations experience less organic material intake from the surrounding environment. The elevated TOM value arises from the breakdown or decomposition of organic substances by microbes, resulting in the release of Carbon dioxide (CO_2) and potential reduction in pH levels (Yasmin et al. 2022). Elevated TOM concentrations have the potential to induce eutrophication, a phenomenon characterized by the proliferation and overgrowth of aquatic organisms. This excessive growth can have detrimental effects on both the biota and the overall quality of water bodies (Czerwińska-Kayzer et al. 2023).

The presence of ammonia in water predominantly arises from the metabolic processes of aquatic organisms, wherein it is generated as a metabolic by-product. Additionally, the decomposition of organic matter, such as domestic garbage, facilitated by bacteria transported by water currents, also contributes to the production of ammonia. The presence of ammonia in water can be attributed to the decomposition of inorganic and organic nitrogen compounds, including protein and urea (Putro et al. 2021). According to Wahyudi et al. (2017), the typical concentration of ammonia in river waters is less than 0.5 mg/L. In unpolluted waters, the ammonia concentration is below 1 mg/L, whereas in polluted waterways, it can exceed 10 mg/L. The analysis yielded ammonia levels within the range of 0.15 mg/L to 0.25 mg/L, which fall within the classification of normal water. The elevated levels of ammonia seen at stations 8, 9, and 10 can be attributed to the proximity of residential and educational facilities, which contribute to the accumulation of domestic waste and subsequently amplify the concentration of ammonia in the surrounding environment.

On the other hand, total dissolved solids are closely related to turbidity of the waters. TDS is the amount of dissolved solids measuring ≤1 μm, where a greater increase in the TDS value indicates that the waste organic material has not been completely degraded into gas (Prismayanti et al. 2021). The elevated TDS levels observed at Stations 8, 9, and 10 can be attributed to the sampling sites being situated in areas characterized by significant anthropogenic activity, including the presence of institutions and residential areas. The fluctuations in TDS levels in natural aquatic systems are mostly attributed to three main factors: discharge of industrial effluents, heightened precipitation patterns, and the encroachment of seawater (Onifade et al. 2023). An increase in TDS concentration in waters is associated with an increase in BOD and COD which will then reduce dissolved oxygen levels (Zhang et al. 2017). Referring to Government Regulation Number 82 of 2001, the maximum amount of TDS allowed for class I-water quality is 1000 mg/L (Hertika et al. 2021). In the upstream Brantas Watershed area, the concentration of TDS remained within the range of 22-240 mg/L. Therefore, it continues to adhere to the criteria for class I-water quality and would not have any detrimental effects on the state of aquatic creatures.

Moreover, within river ecosystems, the velocity of the stream plays a crucial role in governing the occurrence and population sizes of macroinvertebrates. The tolerance of macroinvertebrates towards high current speeds is expected to be limited due to the potential hindrance it poses on their developmental and reproductive processes. There are five distinct categories of current speed that can be identified: very slow current (with a range of 0.1 m/s), slow current (with a range of 0.1-0.25 m/s), medium current (with a range of 0.25-0.5 m/s), fast current (with a range of 0.5-1 m/s), and very fast current (with a range more than 1 m/s) (Sudaryanti 2022). The Brantas River exhibits favorable current conditions that support the viability and growth of macroinvertebrate populations. The reduced velocity observed at Station 7 can be attributed to the local topography and water depth at the sampling site. The velocity of a river is subject to various factors, encompassing land friction, wind patterns, river morphology, geographical placement, as well as potential disruptions arising from the presence of vegetation, debris, or algal growth within the river system (Putra and Hendrasarie 2023).

Macroinvertebrate biology index

The macroinvertebrate biology index is one of the parameters used in this study to measure diversity, evenness and dominance indices. The macroinvertebrate biological index is presented in Figure 4. Based on the results found, it shows that the Shannon-Wiener Diversity Index (H') measured during the initial sampling exhibited a range of 0.563-2.913, with the maximum value observed at station 1 and the minimum value recorded at station 6. In the second sampling, the observed range of values spanned from 1.173 to 2.98. Station 2 recorded the highest value, while station 5 recorded the lowest value. The Evenness Index (E') value ranges from 0.208 to 0.848, with the highest value observed at station 1 and the lowest value recorded at station 6. In the second sampling, the observed range spanned from 0.374 to 0.870, with the maximum value recorded at station 2 and the minimum value observed at station 5. Moreover, the Dominance Index (C) value acquired during the initial sampling period ranged from 0.074 to 0.7999, with the highest value observed at station 6 and the lowest value recorded at station 1. In the subsequent sample event, the observed range spanned from 0.061 to 0.532, with the maximum value recorded at station 6 and the minimum value observed at station 2.

According to Subhan et al. (2022), the Shannon-Wiener Diversity Index (H'), a value of H' less than 1 indicates a low species diversity, which in turn implies a low community stability and association with a significantly contaminated condition. If the value of H' falls within the range of 1 to 3, it can be inferred that the level of species variety is moderate, and the water conditions can be considered moderate as well. If the value of H' is greater than 3, it indicates a high level of diversity, characterized by a significant dispersion of individuals across different species. Additionally, it suggests that the aquatic environment is not contaminated. The analysis of H' values across all stations during the first and second sampling periods indicates that the diversity of benthic macroinvertebrate families observed in this study is within the medium category. However, it is worth noting that stations 6, 9, and 10 exhibited low species diversity during the first sampling period. The low diversity index observed in the first sampling at station 6 was attributed to the prevalence of the Baetidae family. Similarly, at stations 9 and 10, the Hydropsychidae family exhibited the highest abundance compared to other families, contributing to the low diversity index. Furthermore, the distribution of individuals across species was found to be uneven. The diversity of species within a given area is determined by various factors, including the characteristics of the substrate, the number of available food sources, the presence of competition among species, and the level of disturbance originating from the surrounding environment (Bendary et al. 2023).

The Pielou Evenness Index was categorized as low (E<0.4), medium (0.4<E<0.6), and high (E>0.6) (Melati et al. 2021). Stations 1, 2, 3, 4, and 8 exhibited comparatively elevated levels of evenness during both the initial and subsequent sampling periods. In addition to this, stations 6, 9, and 10 in the second sampling had high values of evenness (E>0.6). Station 5 exhibited low evenness values in both the first and second sampling events, while stations 9 and 10 displayed low evenness values only in the first sampling event (E<0.4). Station 7 achieved a moderate evenness value during the initial sampling period. The evenness index value serves as a measure of the degree of evenness exhibited by the various species within a given ecological community. The species Evenness Index (E) often has a numerical range between 0 and 1. A value of evenness that approaches 1 or is comparatively high signifies a reasonably uniform distribution of individuals across species and the absence of a dominant species within the community (Triyadi and Toni 2023).

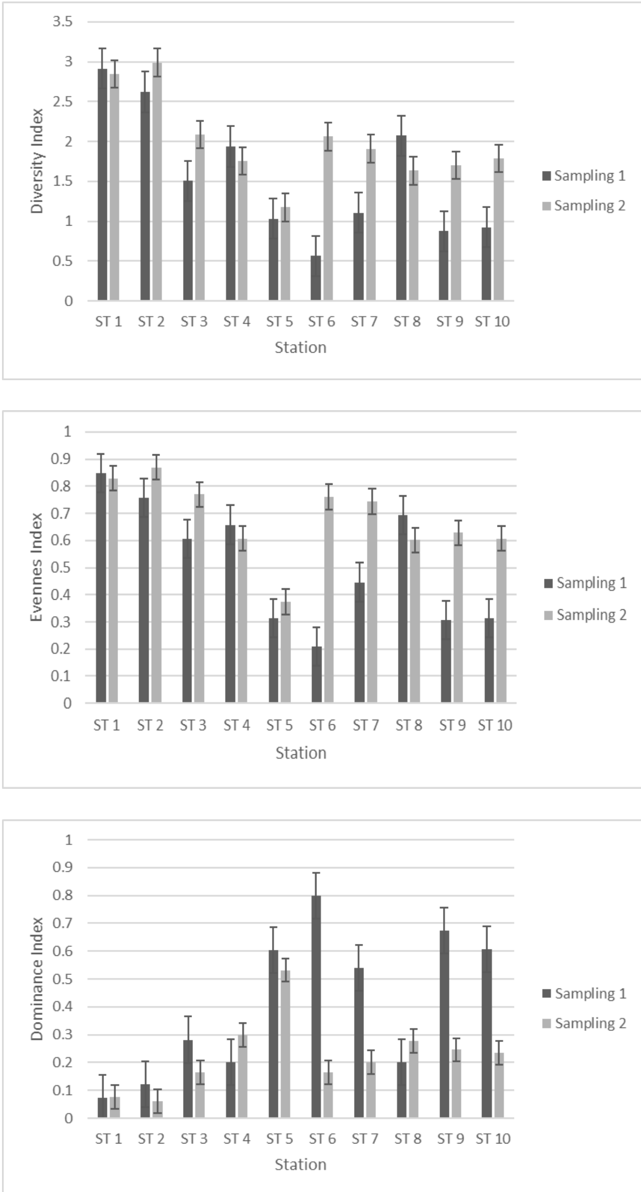

Figure 4. Macroinvertebrate biology index (diversity index, evenness index, dominance index) in Brantas River

Table 5. ASPT Index Value

Station	Sampling 1		Sampling 2	
	ASPT value	Water quality	ASPT value	Water quality
1	6.19	Excellent	6.19	Excellent
2	5.96	Very good	5.96	Very good
3	4	Moderately-poor	3.7	Poor
4	3.06	Poor	3.15	Poor
5	6.13	Excellent	5.63	Very good
6	3.7	Poor	3.8	Poor
7	3.44	Poor	3	Poor
8	3.6	Poor	3.8	Poor
9	3.53	Poor	2.8	Poor
10	3.42	Poor	3.6	Poor

Simpson's Dominance Index is categorized as low (C<0.5), medium (0.5<C<0.75), and high (C>0.75) (Fitriya et al. 2023). The Dominance Index (D) for stations 1, 2, 3, 4, 7, and 8 throughout the first and second sampling periods, as well as for stations 9 and 10 during the second sampling period, exhibited a classification of low dominance (C<0.5). The Dominance Index (D) observed at station 5 during the first and second sampling periods falls within the medium dominance category (0.50<C<0.75), whereas station 6 exhibits a high dominance category (0.75<C<1). The elevated dominance index seen at station 5 can be attributed to the prevalence of the Baetidae family, which emerged as the dominating taxonomic group in the area. A high level of dominance is indicative of a low level of species richness characterized by an unequal distribution. An unpolluted aquatic ecosystem will have a diverse assemblage of individuals representing a wide range of species. Conversely, within aquatic environments that are contaminated with pollutants, there is an observable disparity in the distribution of individuals, with a tendency for a single species to exhibit dominance (Rizal et al. 2022).

Biological Monitoring Work Party-Average Score Per Taxon (BMWP-ASPT) Index

The results of the research carried out, obtained river water quality conditions at 10 stations in the greater Malang area, starting from excellent water quality, very good water quality, good water quality, moderate water quality, moderately-poor water quality and poor water quality. The water quality conditions from the BMWP and ASPT index calculations carried out can be seen in Table 5.

Station 1 from the first and second sampling obtained the same ASPT results, namely 6.19, which indicates the water quality status is Excellent water quality. Station 2, taking the first and second samples, obtained an ASPT value of 5.96, which interprets the water quality status as Very good water quality. Station 3, the first sampling, obtained results 4 which interpreted the water quality conditions as moderate-poor water quality and sampling; secondly, a result of 3.7 was obtained which interpreted the water quality condition as poor water quality. Station 4 for the first and second sampling obtained ASPT results with values of 3.06 and 3.15 respectively, which interpreted the water quality condition as poor water quality. Station 5, the first sampling obtained an ASPT value of 6.13 which interpreted the water quality as Excellent water quality and the second sampling obtained an ASPT value of 5.63 which interpreted the water quality condition as Very good water quality. Station 6 from the first and second sampling obtained ASPT values of 3.7 and 3.8 respectively, which interpreted the water quality conditions as poor water quality. Station 7 from the first and second sampling obtained ASPT values of 3.44 and 3 respectively which interpreted the water quality conditions as poor water quality. Station 8 from the first and second sampling obtained ASPT values of 3.6 and 3.8 respectively, which interpreted the water quality conditions as poor water quality. Station 9, the first and second sampling, obtained ASPT values of 3.53 and 2.8 respectively, which interpreted the water quality condition as Poor water quality. Station 10, the first and second sampling, obtained ASPT values of 3.42 and 3.6 respectively, which interpreted the condition of the water quality as Poor water quality.

The water quality status of Excellent water quality and Very good water quality is found at station 1, station 2 and station 5. These three sampling locations are in primary forest areas and are in areas where the forest conditions are still very good so that the condition of the river waters is still very well maintained. The macroinvertebrate scores found at these three stations were classified as types with high scores, namely glossosomatidae, heptageniidae, lepidostomatidae, leptoceridae, perlidae, perlodidae with a score of 10. According to Matlou et al. (2017), perlidae are macroinvertebrates that are sensitive to pollution. Water quality status: Excellent water quality and Poor water quality is found at station 3, station 4, station 6, station 7, station 8, station 9, and station 10. Generally these stations are located in densely populated residential areas and agricultural areas. Allows input of domestic waste and agricultural waste directly into water bodies. This is based on research by Khan et al. (2021), who stated that the condition of heavily polluted water is mostly caused by the presence of rubbish and liquid waste along rivers which usually come from residential waste such as detergents, cleaning materials, waste from packaging materials, and so on. Water conditions are worsened by the input of agricultural waste, causing an increase in organic waste as waste from agricultural activities.

In conclusion, the upstream waters of the Brantas River watershed in Malang Raya contain benthic macroinvertebrate community consisting of 8 classes, 53 families. namely Bivalves (2 families), Clitellata (2 families), Gastropoda (5 families), Hirudinea (1 family), Insecta (35 families), Malacostraca (4 families), Oligochaeta (2 families), Polychaeta (1 family), and Turbellaria (1 family). The abundance of benthic macroinvertebrates ranged from 181-2879 individuals/m2. Benthic macroinvertebrate diversity is classified as low to moderate, with Shanon Wiener index values ranging from 0.563-2.988. The evenness index value ranges from 0.208 to 0.870, while the Simpson Dominance Index ranges from 0.061 to 0.799. The range of ASPT values for the upstream segment of Brantas River was found to be 2.80-6.19, indicating varying water conditions from poor, very good, to excellent depending on the station location. The results of measurements of physico-chemical parameters including temperature, pH, DO, TOM, ammonia, TDS, and current speed, were measured at all research stations. The results indicate that the water quality ranges from very good to lightly polluted.

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