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Macroinvertebrates as a Bioindicator of Water Quality in the Jangkok River, Lombok Island

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Abstract: Rivers are water bodies in open ecosystems where activities in the environment have an impact on river water quality. Monitoring of water quality is necessary to preserve aquatic resources. One of the river basins on Lombok Island is the Jangkok River. This river has a high utility, so water quality monitoring is needed. Macroinvertebrates are one of the best biological indicators for water quality monitoring. The objective of this study is to determine the diversity of macroinvertebrates and the quality of Jangkok River waters by using macroinvertebrates as bioindicators so that the results of this study can be used as a reference basis for the future use of Jangkok River water in the allocation of community needs. The method used in this research is biomonitoring with macroinvertebrate bioindicators, and the technique used in sampling is purposive sampling. Sampling was conducted at three stations, namely the upstream, middle, and downstream parts of the Jangkok River. The data analysis used was the *Family Biotic Index* (FBI) supported by physical-chemical parameters. The results of this study showed that the macroinvertebrates identified were 721 individuals consisting of 5 classes, 17 orders, and 36 families. The water quality of the Jangkok River, based on the FBI value in the upstream and middle sections, is still included in the good category, while in the downstream section, it falls into the very bad category.

Keywords: Bioindicator; FBI; Jangkok River; Macroinvertebrates; Water Quality.

Introduction

Jangkok River is one of the major rivers in Lombok Island, West Nusa Tenggara [1]. This river has a very important ecological and economic role in life. The water utilization of Jangkok River covers the areas of West Lombok Regency, Central Lombok, and Mataram City. This condition reflects that the utility of the Jangkok River is high. In addition, the complex level of water use, such as for irrigation, rice fields, fish ponds, cages, clean water supply, domestic needs/delivery of residents, growth of kale plants, and other small businesses, shows the high use or utility of the Jangkok River [2].

The complex use of the Jangkok River can pollute the waters if not managed properly. So, if the input of dissolved materials from various activities is still within certain limits, this will not reduce the quality of the waters. However, if the input of dissolved materials exceeds the ability of the waters to clean themselves (self-purification), it will cause environmental pollution problems [3], which will affect and certainly have an impact on the surrounding community and have a direct impact on the lives of organisms that inhabit the river waters.

The latest data on the water quality of the Jangkok River in 2022 based on physical, chemical and biological testing (E. *coli* and total coliform) is that the upstream and middle parts are still mildly polluted [4]. Meanwhile, the water quality of the downstream Jangkok River in 2020 was still declared heavily polluted [5]. This is closely related to community activities around the river, such as bathing, washing and toilet (MCK) and disposing of domestic waste directly into the river. The most common environmental condition of the Jangkok River is that the river is used as a place to throw garbage, which can damage the river's physical structure, so the river does not function optimally [6]. The Jangkok River is important for the community and the organisms that inhabit these waters, so it must always be monitored.

Monitoring water quality is important to determine water suitability and sustainability [7]. River water quality monitoring can be determined by a combination of physical-chemical and biological parameters [8], one of which is biomonitoring. Water quality biomonitoring is an effort to monitor water quality biologically by observing the response of indicator organisms (bioindicators) living in water to control and assess environmental quality changes repeatedly [9].

Bioindicators are groups or communities of organisms whose existence or behaviour in nature is related to environmental conditions. If there is a change in water quality, it will affect the existence and behaviour of these organisms so that it can be used as a pointer to environmental quality. One of the bioindicators of water quality is using macroinvertebrates [10].

Macroinvertebrates are a group of invertebrate animals with a fairly large size (>1 mm). These organisms can provide an overview of a body of water's physical, chemical, and biological conditions, so they can be bioindicators of river water quality [11]. The presence of macroinvertebrates can be used to evaluate the quantity of pollution that occurs because some macroinvertebrates have different tolerances [12].

The composition and number of aquatic organisms, such as macroinvertebrates, can change depending on the water quality in which they live, as water quality and the presence of aquatic organisms are interrelated. A decrease in water quality due to pollution will disturb organisms and impact the diversity of aquatic organisms that occupy the aquatic ecosystem [13]. Therefore, macroinvertebrates are a good choice as bioindicators of water quality in the Jangkok River. So this research aimed to determine the diversity of macroinvertebrates

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and the quality of the Jangkok River waters using macroinvertebrates as bioindicators. So, monitoring the water quality of the Jangkok River can provide factual information about the current condition or status of water quality and can be used as a reference for planning, evaluating, controlling, and environmental supervision.

Research Methods

This research was conducted in July-August 2023 in the Jangkok River on Lombok Island (Figure 1). Sampling was conducted during the dry season, consisting of three stations (upstream, middle, and downstream). Research stations were determined by purposive sampling, which considered community activities around the river and the river's different physical characteristics. Each station has two sampling points with 3 repetitions of each point.

Station I is the upstream part of the river located in Sesaot Village, Narmada District, West Lombok Regency. Station II is the middle part of the river in Saribaye Village, Lingsar District, West Lombok Regency. Station III is the downstream part of the river located in Ampenan, Ampenan District, Mataram City.

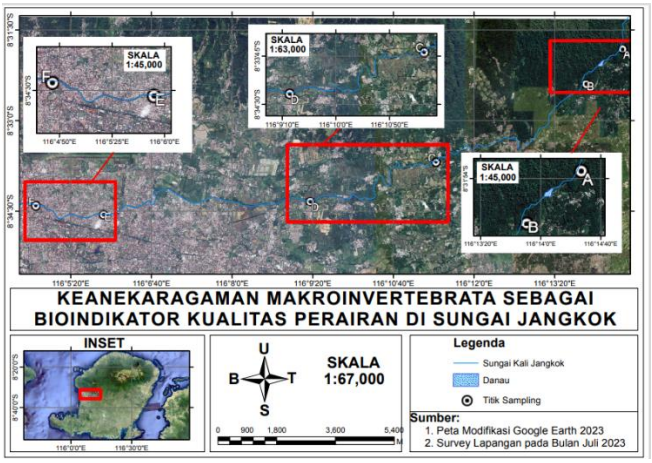

Figure 1. Research location map

Macroinvertebrate sampling was carried out using a net, which was placed opposite the direction of the river flow along 10 meters measured using a transect rope. Sampling was done using kicking and jabbing techniques. The kicking technique was carried out by entering the shallow river and placing the net in front with the mouth of the net facing the direction of the water flow, then stirring the substrate in front of the net by moving the legs around to stimulate the animals hiding at the bottom of the river to be washed into the net. Then, the jabbing technique is carried out by placing the net on the surface of the riverbed, then moving forward towards the upstream or source of water while sweeping the net to touch the surface of the riverbed, especially under aquatic plants. Samples were also taken from the overhanging river wall, branches, rocks, roots on the river wall, and macroinvertebrates moving above the water surface. Next, put the samples taken into the tray and then sorted. The samples obtained were put into plastic clips containing 70% alcohol and identified to the family level by referring to [14, 15, 16, 17].

In addition to biological water quality monitoring, physical and chemical monitoring is necessary to strengthen the research results. The physical-chemical parameters include water temperature, river width and depth, current speed, substrate, acidity (pH), and dissolved oxygen (DO).

Aquatic macroinvertebrate data are calculated using the Family Biotic Index (FBI). Physical-chemical parameters of waters as supporting data were calculated using Principal Component Analysis (PCA) using SPSS 23.0.

The Family Biotic Index (FBI) method is a method of calculating the level of pollution of a body of water by using indicators in the form of the presence of macroinvertebrates based on their family, as for the formula used [18], namely:

$$FBI = \Sigma \frac{Xi \; x \; ti}{n}$$

Information:
FBI =Benthic macroinvertebrate index
Xi = Number of individuals of the i-th family group
ti = Tolerance level of the i-th family group
n = Number of orgasms in 1 sample plot

Table 1. Water Quality Assessment Criteria Using Hilsenhoff's FBI (1988)[19].

FBI Value	Water quality	Pollution Level
0.00-3.75	Very good	Not polluted by organic materials
3.76-4.25	Very well	Slightly polluted by organic materials
4.26-5.00	Good	Polluted with some organic materials
5.01-5.75	Enough	Polluted quite a lot of organic materials
5.76-6.50	Quite bad	Polluted with lots of organic materials
6.51-7.25	Bad	Very much polluted
7.26-10.00	Very bad	Heavily polluted by organic materials

Results And Discussion

Aquatic macroinvertebrates can be used as bioindicators of river water quality [11] because macroinvertebrates are very sensitive to environmental changes, found in almost all waters, have limited movement to facilitate observation, relatively many types with different responses, and are easy to identify [20].

Table 2. Macroinvertebrates found in Jangkok River, Lombok

Class/subclass	Order	Family	Research Location		
			Upstream	Middle	Downstream
Insects	Ephemeroptera	Baetidae	5	0	0
		Leptophlebiidae	3	36	0
		Heptageniidae	10	0	0
	Plecoptera	Perlidae	2	0	0
	Trichoptera	Hydropsychidae	1	44	0
		Limnephilidae	3	0	0

		Polycentropodidae	2	3	0
		Glossosomatidae	0	11	0
		Philopotamidae	0	4	0
	Hemiptera	Gerridae	31	25	0
		Vellidae	7	18	0
		Nepidae	3	0	0
	Diptera	Limoniidae	8	1	0
		Tipulidae	0	4	0
		Chironomidae (blood red)	0	5	35
	Odonata	Coenagrionidae	7	0	0
		Libellulidae	10	0	1
		Corduliidae	11	0	0
		Gomphidae	10	0	0
		Euphaeidae	2	0	0
	Coleoptera	Psephenidae	5	0	0
		Noteridae	1	0	0
		Elmidae	0	3	0
	Lepidoptera	Pyralidae	1	0	0
		Crambidae	0	3	0
Gastropods	Heterobranchia	Lymnaeidae	1	1	0
	Caenogastropoda	Viviparidae	1	11	0
		Thiaridae	4	4	140
	Mesogastropods	Ampullariidae	1	7	0
	Archaeogastropods	Neritidae	0	0	8
Bivalves	Veneroids	Shpaeriidae	0	17	51
	Unionida	Unionidae	0	0	1
Malacostraca	Decapoda	Palaemonidae	0	0	41
		Sesarmidae	0	0	15
Clitellates	Oligochaeta	Tubificidae	0	0	69
	Hirudinea	Glossiphonidae	0	34	0
Total Individuals			129	231	361

This study showed that macroinvertebrates found in Jangkok River consisted of 5 classes, namely Insect, Gastropoda, Bivalve, Malacostraca, and Clitellata. These five classes consist of 17 orders and 36 families, as presented in Table 2. The macroinvertebrates were obtained from three different sampling stations. Based on the identification results, intolerant macroinvertebrate groups were found, namely several families from the EPT order (Ephemetoptera, Plecoptera, Trichoptera) and groups that are very tolerant of pollutants, namely several families from the Gastropoda, Bivalvia, Clitellata classes.

In this study, physical and chemical parameters of waters were measured as supporting data for river water quality research. The physical-chemical conditions of the Jangkok River waters can be seen in Table 3.

Table 3. Physical and chemical conditions of Jangkok River waters, Lombok

Parameters	Research Location		
	Upstream	Middle	Downstream
pH	7.3	7.5	7.6
Water temperature (℃)	23.25	25.5	27.35
Dissolved oxygen (DO) (mg/L)	5.65	5.84	3.18
Current speed (m/s)	0.28	0.39	0.24
Depth (cm)	36.85	55.9	85.65
River width (cm)	15.21	20.5	25.5
Substrate type	Rocky and sand	Rocky, sand, and muddy	Sand and muddy
Color	Clear	Somewhat murky	Murky

Table 4. River water quality standards based on PP No. 22 of 2021[21].

Parameters	Class			
	I	II	III	IV
Water temperature (^{0}C)	Dev 3	Dev 3	Dev 3	Dev 3
pH	6-9	6-9	6-9	6-9
Dissolved oxygen (DO) (mg/L)	6	4	3	1

Based on the results of measuring the physical-chemical parameters of the waters in Table 3, the pH of the Bangkok River water is neutral, with a pH range of 7. Based on the measurement results, the pH value in the Jangkok River upstream to downstream is still by the macroinvertebrate habitat, because the pH value for aquatic organisms can live in waters ranging from 7-8.5 [22]. If the pH value exceeds the pH range needed by macroinvertebrates to live, then the number of individuals in these waters will decrease directly [23]. The average water temperature from upstream to downstream ranges from 23.25^0C-27.35^0C. The temperature range can still support the life of macroinvertebrates. Temperatures that have a range of 35-40^0C can endanger macroinvertebrate life if the water temperature is too high, which exceeds the temperature that is good for macroinvertebrate life so that macroinvertebrates automatically experience a decrease in macroinvertebrate diversity or uniformity until death occurs in macroinvertebrates [24]. Temperature has a close relationship with dissolved oxygen levels in water because temperature is one factor that affects dissolved oxygen levels in water.

Dissolved Oxygen (DO) shows the number of mg/l of oxygen gas dissolved in water. Flowing water will have more dissolved oxygen content when compared to stagnant water [25]. From the test results, oxygen levels in the downstream part of the river are reduced and the lowest of the other parts of the river. Reduction in dissolved oxygen levels can be caused by the decomposition of organic matter in the waters, aquatic animal activity, and various chemical reactions of the waters. The lower dissolved oxygen level in the water shows low water quality [26]. Then the current speed is grouped into categories, namely very fast flowing waters (>1 m/s), fast (0.5-1 m/s), medium (0.25-0.5 m/s), slow (0.1-0.25 m/s), and very slow (<0.1 m/s) [27]. From this grouping, the current speed in the Jangkok River in the upstream and middle sections is moderate, while in the downstream section, the current speed is classified as slow. Current speed will affect the water's various physical, chemical, and biological factors. Current speed has a direct effect on the formation of the bottom substrate.

The bottom substrate greatly influences the formation of habitats for organisms that live in water. Substrate is a medium in the form of a place (habitat) for organisms to carry out life activities. The substrate of a water body is different, namely rocky, sandy, or muddy substrates [28]. Based on the observations of macroinvertebrate sampling carried out in various types of substrates, diverse macroinvertebrates are also obtained, as can be seen in Table 2. Furthermore, the average value of the depth of the Jangkok River ranges from 36.85-85.65 cm. The lowest depth is in the upper reaches of the river, and the highest is in the lower reaches of the river, where the increase in river depth causes the intensity of light entering the water to decrease. So that it will indirectly affect the organisms in it; this is reinforced by the statement that the depth of a body of water is one of the factors that affect the presence of an organism, where the deeper the water, the fewer organisms are found [29,30]. So, according to the results of these observations, when compared to deep waters, shallow waters have more diverse or high macroinvertebrates. This is because, in shallow water conditions, the intensity of the sunlight can penetrate the entire water body to reach the bottom of the water to support the photosynthesis process in waters that cause high water productivity [31].

The results of the measurement of physico-chemical parameters of waters adjusted based on PP No. 22 of 2021, the upstream and middle parts of the Jangkok River still meet the class II water quality standards, which means that the designation of Jangkok River water can be used for water recreation infrastructure/facilities, freshwater fish farming, animal husbandry, water for irrigating crops, and or other designations that require the same water quality as these uses. Then, the downstream part of the river falls into class III water quality standards, meaning that its designation can be used for freshwater fish farming, animal husbandry, water for irrigating crops, and other designations requiring the same water quality as these uses [21]. River water quality standards based on PP No. 22 of 2021 can be seen in table 4.

Based on the exposure of the physicochemical parameters above, it can be seen that the upstream and middle of the river have closer similarities than the downstream of the river. This is done by analysing each station's relationship to or similarity to environmental parameters. The analysis results using Principal Component Analysis (PCA) can be seen in Figure 3.

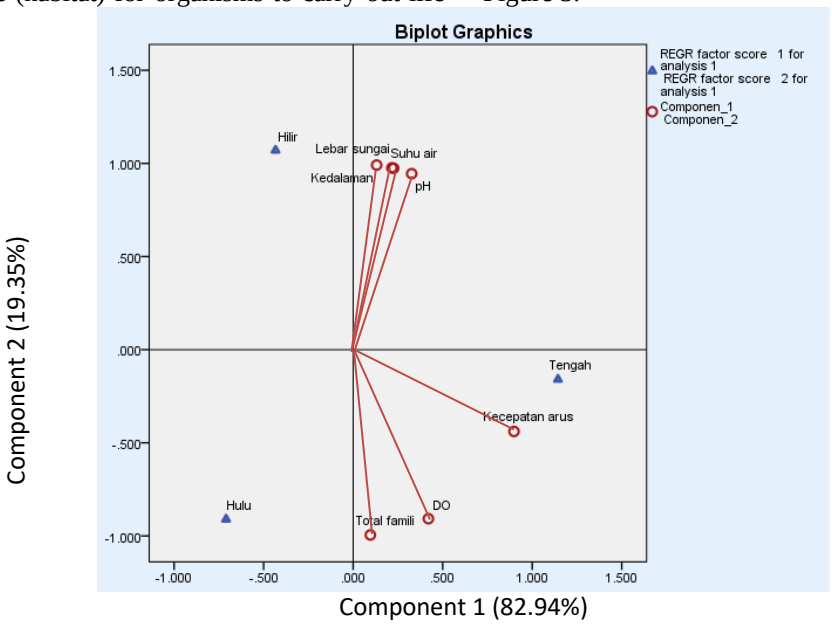

Figure 2. Graph of each station's relationship to environmental parameters

Based on the Principal Component Analysis (PCA) results, each station has different environmental conditions or characteristics. It can be seen from the graph that the upstream and middle parts of the river have relatively more similar environmental conditions than the downstream, namely having higher dissolved oxygen (DO) and current velocity compared to the downstream. Meanwhile, the river's lower reaches have a deeper depth, wider river width, and higher water temperature and pH compared to the upper and middle reaches of the river. In addition, the upstream and middle sections have almost the same number of families and more than the downstream.

The water quality of the Jangkok River is biologically calculated based on the FBI value. FBI is a calculation of the water quality index based on each family's tolerance value (resistance to environmental changes) [20]. The range of tolerance of macroinvertebrates starts from a score of 0 (very intolerant organisms) to 10 (very tolerant organisms) to pollutants [32]. The results of the calculation of the FBI value can be seen in Table 4.

Table 4. Family Biotic Index (FBI) Calculation Results

Research sites	FBI Value	Category
Upstream	4.53	Good
Middle	4.65	Good
Downstream	7.57	Very bad

Based on the results obtained, the FBI value in the upstream and middle sections is included in the good water quality category, with the level of pollution polluted by some organic matter. This is by the results of the PCA analysis, which states that the upstream and middle sections have similar environmental characteristics that are closer than the downstream of the river, where the upstream and middle of the river have higher current speeds, so dissolved oxygen is higher. The higher the dissolved oxygen level, the better it will be for aquatic organisms [18], so from these aquatic environmental conditions, a family of macroinvertebrates was found in the order Ephemeroptera, Plecoptera, and Tricoptera (EPT). This order is included in the intolerant group, which is a group of organisms that have the ability to grow in clean environmental conditions are rarely found in waters rich in organic matter and cannot adapt to waters that experience changes or decreases in water quality [33].

The family Leptophlebiidae of the order Ephemeroptera has a tolerance level of 2 [15], with 36 individuals out of 721 found in the Jangkok River. This family is an organism that feeds on living plants and dead plant residues or coarse organic matter. This organism is very well used to indicate toxicants attached to organic matter [34]. The Perlidae family of the Plecptera order has a tolerance level of 1 [15] with a presence rate of 2 individuals. The Hydropsychidae family of the Trichoptera order had a tolerance level of 4 [15] with a presence of 44 individuals. The presence of these three families indicates that the water quality in the upper and middle reaches is still good, supported by the physical-chemical parameters of the environment.

The increase in the FBI value downstream indicates that the water quality has changed and is included in the very poor water quality category with a heavy pollution level of organic matter. On the graph, the current velocity line is opposite or away from the downstream of the river, which means that the speed of water flow downstream is slower, which results in the deposition of organic matter, which causes low dissolved oxygen. So that only certain groups of organisms can survive in these aquatic environmental conditions.

Changes in water conditions are also indicated by a decrease or no intolerant organism groups, namely the EPT order. The absence of this family directly indicates a change in the polluted river's status. Strengthened by the presence of families tolerant of pollutants, namely the Thiaridae, Chironomidae, Shpaeriidae, and Tubificidae families.

Downstream, the Thiaridae family was found with 140 individuals, Chironomidae with 35 individuals, Shpaeriidae with 51 individuals, and Tubificidae with 69 individuals. These families are very tolerant of changes in environmental factors, so their dominating presence can be used as bioindicators of poor water quality [18].

Conclusion

Based on the identification results, macroinvertebrates comprised 17 orders, and 36 families with 721 individuals. These organisms have different tolerance values to environmental changes. From the results of the analysis of the water quality of the Jangkok River, it can be seen that the waters of the Jangkok River in the upstream and middle parts are in the category of good water quality or slightly polluted by organic matter, while the downstream part of the river is heavily polluted by organic matter. The presence of organic matter or polluting waste, especially in the downstream part of the river, has greatly affected the presence of macroinvertebrates, which can be seen from the higher FBI value.

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