

MAKROZOOBENTHOS AS A BIOINDICATOR OF WATER QUALITY IN THE MASANG KECIL RIVER IN WEST PASAMAN REGENCY

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ABSTRACT

Sungai Masang Kecil is located in the middle of the PT Andalas Agro Industri (PT AAI) palm oil plantation and mill. This activity will have an impact on aquatic biota, especially benthos. Benthos occupies an important position in the food chain and lives permanently on the substrate to be used as a bioindicator of pollution. This study aimed to determine the Community Structure of Macrozoobenthos and the indicator species of water pollution in the Masang Kecil River around the PT AAI area, West Pasaman Regency. This research was conducted using a purposive sampling method with three sampling points, namely upstream and two downstream points after the Wastewater Treatment Plant (IPAL) and after the confluence of tributaries. Sampling using Surber net size 30x30 cm. The results of identifying the types of Benthos organisms as a whole identified as many as 45 species. Most species are found in Class Insecta. Based on the diversity index, the water quality in PT AAI's river basin was classified as unpolluted, and it could be concluded that the benthic condition was in good condition on a scale of four. In the current study, the Diptera order as an indicator of polluted water was most commonly found among orders from other insect classes, namely, ten species. However, there were nine species from the Order Ephemeroptera as an indicator of clean waters and six species for Trichoptera.

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INTRODUCTION

Oil palm is one of the plantation crops in Indonesia. Oil palm plantations were originally developed in North Sumatra and Nanggroe Aceh Darussalam. However, now it has expanded to various areas including in West Sumatra. Palm oil plantations and mills are developing simultaneously. One of the palm oil industries in West Sumatra is PT

Andalas Agro Industry (PT. AAI). In the PT AAI area, there is a river, namely the Masang Kecil River. The Masang Kecil River will empty into the Big Masang River, located in West Pasaman Regency.

The river has several biotas, including nekton, plankton, neuston, and benthos. Benthos consists of plant organisms (phytobenthos) and animal organisms

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(zoobenthos) (Nyabakken, 1992). Benthos in dynamic environments such as rivers of benthos animals (zoobenthos) can provide an overview of water quality because benthos live relatively sedentary and experience direct contact with waste that enters their habitat. The level of water quality can be determined through a biological approach by analyzing the community structure of organisms that live in these waters. The community of organisms that can be used to predict the quality of the waters where these organisms live is generally macrozoobenthos. This is because macrozoobenthos has a relatively sedentary nature with very limited movement, so it will be directly affected if there is a change in water quality (Asra, 2019). Therefore, macrozoobenthos will remain exposed to environmental pollution to respond continuously to water quality conditions (Indarmawan & Manan, 2011).

Macrozoobenthos can be used as a bioindicator of water quality so that it can make it easier to estimate the state of the aquatic environment (rivers). According to Odum (1994) and Ruswahyuni, (2010), clean water that has not received a pollutant load will show a balanced number of individuals from almost all existing species. Meanwhile, in polluted waters, the distribution of the number of individuals is uneven, and there tends to be a species that dominates. So that it will reduce the diversity index of macrozoobenthos Asra, (2019), Macrozoobenthos will remain exposed to environmental pollution so that it can respond continuously to water quality conditions (Indarmawan & Manan, 2011).

Previous research was conducted in the Masang Kecil River by Izmiarti and Safitri (2018) on the Macrozoobenthos Community as a Biological Indicator of Water Quality in the Masang Kecil River, which Receives Liquid Waste from the Palm Oil Industry in Kinali Pasaman Barat, the results of identifying macrozoobenthos were found in the Masang Kecil River namely found 43 species consisting of 33 species of Insects, four types of Oligochaeta, three types of Gastropods, two types of Hirudinae, one type of Arachnida and one type of Turbellaria. From the research conducted by Izmiarti and

Safitri (2018), it can be seen that macrozoobenthic insect species are a sign of good waters, while only one species is found as an indicator of polluted water. Therefore, after four years, it is necessary to review the composition and structure of the community and determine the species of pollution indicators in the Masang Kecil River, PT Andalas Agro Industry (PT.AAI), West Pasaman Regency.

LITERATURE REVIEW

Macrozoobenthos can be used as a bioindicator of water quality so that it can make it easier to estimate the state of the aquatic environment (rivers). According to Odum (1994) and Ruswahyuni, (2010), clean water that has not received a pollutant load will show a balanced number of individuals from almost all existing species. Meanwhile, in polluted waters, the distribution of the number of individuals is uneven, and there tends to be a species that dominates. So that it will reduce the diversity index of macrozoobenthos. Macrozoobenthos is often used because benthos lives sessile and are exposed to contaminants longer.

According to Vernberg in Fachrul (2007), based on their size, benthos can be divided into three, namely Macrobenthos, Mesobenthos, and Microbenthos. First is macrobenthos live at the bottom of the water and are filtered by a filter with eye sizes of 1.0 x 1.0 mm or 2.0 x 2.0 mm, while adults are 3-5 mm in size. Macrozoobenthos can also be divided into infauna and epifauna under the mud. In contrast, an epifauna is a group of macrobenthos that live on the surface of the substrate. Second is mesobenthos are organisms that have a size of 0.1 - 1.0 millimeters, millimeters, for example, the protozoa group, which is large (cnidaria), small worms and very small crustaceans. Third is Microbenthos Organisms that are less than 0.1 millimeters in size, for example, protozoa.

The resistance and adaptation of the benthic vary from one species to another; that is, some are resistant to the conditions of the local waters, but some are not resistant, so the presence of certain benthos is a guide in assessing the quality of these waters. In contrast, macrobenthos is organisms that reach

a size of at least 3-5 mm at the time of maximum growth. Macrozoobenthos usually includes insects, mollusks, Oligochaeta, crustacean-amphipods, isopods, Decapoda, and nematodes (Nybakken, 1992).

The Kinali community uses the Masang Kecil River for domestic activities, garden irrigation, and a place for prohibited fish. The Masang Kecil River is relatively shallow, with a depth of 30-100 cm and a width of 6-8 m; it has a calm current and a substrate of rock, gravel, sand, and a little silt downstream. Many residents' activities are carried out around the Masang Kecil River, which can affect the quality of river waters. The activities of these residents can disrupt the life of aquatic organisms. One group of organisms directly affected by pollutants in the river ecosystem is macrozoobenthos because these animals live relatively sedentary lives. Macrozoobenthos can be used as a water quality bioindicator to provide an overview of water conditions. Macrozoobenthos are sedentary, live relatively long, and move relatively slowly. The sensitivity of macrozoobenthos to changes that occur in water makes macrozoobenthos an indication of the condition of an aquatic area. Apart from being an indicator of water quality, the contribution of macrozoobenthos is also quite large to aquatic ecosystems in the process of mineralization of sediments and cycles of organic matter and plays a role as a balancer of nutrients in aquatic ecosystems (Nangin et al.,

2015). Based on the many community activities around the river and the negative impacts, it is necessary to analyze the diversity of macrozoobenthos and determine macrozoobenthos as bioindicators of water pollution.

METHODS

Research Methods in the Field

Macrozoobenthos sampling was carried out in a composite manner with three repetitions at three sample stations, namely in the Upper Masang Kecil River, downstream, after WWTP, and the confluence of tributaries using a quantitative descriptive method. Macrozoobenthos sampling was carried out at each station with a predetermined depth of 30-50 cm when the water conditions were stable, meaning there were no traces of flooding. The tool used was a 30x30 cm SURFnet as a plot. The macrozoobenthos sample that has been taken is placed first in a bucket and then crushed using a fine wire brush to release the benthos attached to the substrate. The sample is filtered, put into a plastic bag, given a preservative in the form of 40% formalin, and then labeled so that the samples are not mixed up—labeled samples are stored in a cool box to be taken to the laboratory for identification. The data collection location can be seen in **Figure 1**.

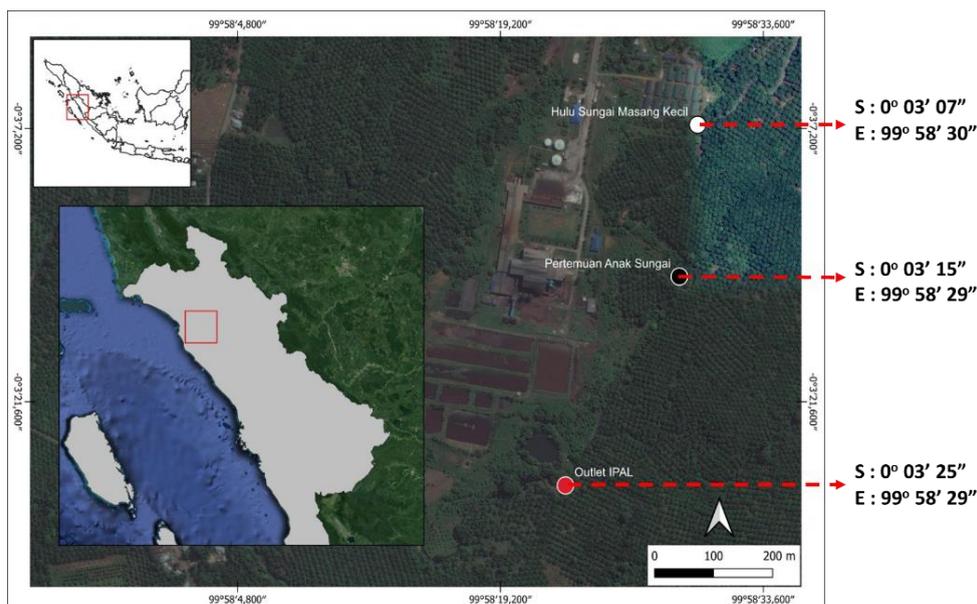


Figure 1. Sampling Locations

Source: Google Earth Pro

Research Methods in the laboratory

The way it works in the laboratory is that the benthos is sorted from the impurities and then rinsed and preserved again. Further identification was carried out with reference to identification books. After that, analysis of density, relative density and diversity index was carried out. Macrozoobenthos abundance was calculated using the formula according to [Brower et al. \(1990\)](#).

1. Density and Relative Density Analysis (KR%)

$$\text{Benthic density } \left(\frac{\text{ind}}{\text{m}^2}\right) = \frac{N_i}{A} \quad (1)$$

Information :

N_i = the average number of benthos (ind)

A = Area (m²)

KR% = Total Individual Density of a Species x 100% Total Individual Density

2. Benthic diversity is calculated using the Shannon Wiener diversity index with the following formula Michael, (1984):

$$H' = - \sum_{i=1}^s \frac{N_i}{N} \ln \frac{N_i}{N}$$

Information :

H' = Shannon Wiener diversity index

n_i = Number of individuals or density value of a species

N = Number of individuals or density value of all species

Table 1. Water Quality According to the Diversity Index of Aquatic Biota

Number	Diversity Index (H') Plankton	Indeks Keanekaragaman (H') Benthos	Category	Scale
1	<0,3	<1	Very ugly	1
2	0,3 - 0,7	1-1,5	Bad	2
3	0,7 - 1	1,6-2	Pretty good	3
4	1 - 5	2-3	Well	4
5	>5	>3	Very good	5

Source: Governor of West Sumatra Regulation Number 78 of 2012.

RESULTS AND DISCUSSION

The macrozoobenthic community in the Masang Kecil river was found to be 45 species with a composition of 31 Insecta class, four types of Gastropods, three types of Oligochaeta, five types of Hirudinea, one type of Tricladida (Table 2). The number of

macrozoobenthos species found at each research station consisted of 23 in station one, 27 in station two, and 15 in station three. According to [Brower and Zar \(1977\)](#), density indicates the number of individuals living in a certain habitat, area, and time.

Table 2. Structure of the Benthos Community in the Masang Kecil River in the PT AAI Area

Class/Type of Benthos Animal	Observation Location					
	Batang Masang Kecil Upstream		Batang Masang Kecil Downstream			
	K (ind/m ²)	KR (%)	After WWTP		After confluence of the creek waters	
		K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)	
GASTROPODA						
<i>Gyraulus</i> sp.	-	-	11,11	1,17	-	-
<i>Melanooides granifera</i>	3,70	1,16	-	-	-	-
<i>Melanooides tuberculata</i>	3,70	1,16	-	-	-	-
<i>Polypilis</i> sp.	-	-	-	-	3,70	2,38
HIRUDINEA						
<i>Alboglosiphonia</i> sp.	3,70	1,16	-	-	-	-
<i>Erphobdella</i> sp.	11,11	3,49	248,12	26,07	18,52	11,90
<i>Gloiobdella</i> sp.	3,70	1,16	-	-	-	-
<i>Helobdella</i> sp.	3,70	1,16	218,50	22,96	11,11	7,14
<i>Placobdella</i> sp.	-	-	3,70	0,39	-	-

Class/Type of Bentos Animal	Observation Location					
	Batang Masang Kecil Upstream	Batang Masang Kecil Downstream				
		After WWTP		After confluence of the creek waters		
K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)	
INSECTA						
O. Coleoptera						
<i>Promoresia</i> sp.	-	-	-	-	3,70	2,38
<i>Stenelmis</i> sp.	7,41	2,33	14,81	1,56	-	-
O. Diptera						
<i>Antocha</i> sp.	-	-	-	-	3,70	2,38
<i>Dixa</i> sp.	-	-	-	-	3,70	2,38
<i>Eukiffriella</i> sp.	3,70	1,16	11,11	1,17	-	-
<i>Chironomus</i> sp.	3,70	1,16	55,55	5,84	18,52	11,90
<i>Cryptochironomus</i> sp.	29,63	9,30	3,70	0,39	3,70	2,38
<i>Limnophila</i> sp.	3,70	1,16	-	-	-	-
<i>Orthocladius</i> sp.	-	-	18,52	1,95	-	-
<i>Pilaria</i> sp.	3,70	1,16	-	-	-	-
<i>Polypedilum</i> sp.	29,63	9,30	33,33	3,50	14,81	9,52
<i>Tany tarsus</i> sp.	-	-	3,70	0,39	3,70	2,38
O. Ephemeroptera						
<i>Baetis chocoaratus</i>	-	-	18,52	1,95	-	-
<i>Baetis</i> sp.	-	-	11,11	1,17	-	-
<i>Caenis</i> sp.	-	-	18,52	1,95	-	-
<i>Centroptilum</i> sp.	-	-	3,70	0,39	3,70	2,38
<i>Heptogenia</i> sp.	-	-	3,70	0,39	-	-
<i>Leptophlebia</i> sp.	3,70	1,16	-	-	-	-
<i>Psephenoides</i> sp.	-	-	7,41	0,78	3,70	2,38
<i>Pseudocloeon</i> sp.	-	-	3,70	0,39	-	-
<i>Thraulius</i> sp.	14,81	4,65	-	-	-	-
O. Hemiptera						
<i>Pelocoris</i> sp.	-	-	3,70	0,39	-	-
O. Lepidoptera						
<i>Eoophyla</i> sp.	-	-	3,70	0,39	-	-
O. Odonata						
<i>Asiagomphus</i> sp.	7,41	2,33	-	-	-	-
<i>Euphaea</i> sp.	3,70	1,16	-	-	-	-
<i>Sympetrum</i> sp.	-	-	3,70	0,39	-	-
O. Trichoptera						
<i>Hydropsyche elisoma</i>	-	-	22,22	2,33	40,74	26,19
<i>Hydropsyche</i> sp.	3,70	1,16	-	-	-	-
<i>Philopotamus</i> sp.	-	-	7,41	0,78	-	-
<i>Polycentropus</i> sp.	14,81	4,65	-	-	-	-
<i>Psychomya</i> sp.	7,41	2,33	3,70	0,39	-	-
<i>Rhyacophyla</i> sp.	14,81	4,65	-	-	-	-
OLIGOCHAETA						
<i>Branchiura</i> sowerby.	-	-	14,81	1,56	-	-
Lumbricidae	11,11	3,49	22,22	2,33	-	-
<i>Tubifex</i> sp.	125,91	39,53	170,35	17,90	11,11	7,14
TRICLADIDA						
<i>Planaria</i> sp.	-	-	-	-	11,11	7,14

Class/Type of Bentos Animal	Observation Location					
	Batang Masang Kecil Upstream		Batang Masang Kecil Downstream			
			After WWTP		After confluence of the creek waters	
	K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)	K (ind/m ²)	KR (%)
Total Density	318,49		951,76		155,54	
Number of Taxa	23		27		15	
Diversity Index	2,35		2,26		2,23	

Source: Analysis Results, 2022

Based on **Table 2**, it can be seen that the highest density of macrozoobenthos was at Station two, namely at the WWTP outlet, with a total density of 951.76 ind/m², followed by Station one in the upper reaches of the Masang River as much as 318.49 ind/m², Station three at the children's meeting. River as much as 155 ind/m². The high density of macrozoobenthos at Station two is likely due to the location at the WWTP outlet, so the substrate's organic content is high and therefore supports the growth of macrozoobenthos because the organic substrate, which is the food ingredient is available **Table 2**. The density of macrozoobenthos (ind/m²) at each study station.

The macrozoobenthic species with the highest density of the three stations were *Stenomelania torulose* from the Gastropod class, with a total density of 122.4 ind/m². [Jailani and Nur \(2012\)](#) state that the ability of gastropods to survive in an environment is caused by favorable environmental conditions, such as the type of substrate and relatively high organic matter content, and

excellent adaptability to live in various places. According to [Hutagalung \(1991\)](#), Gastropods can accumulate polluted materials without being killed, exist in large quantities, are bound in a hard place, and live for a long time.

The Diversity Index is a value that expresses the diversity of several species from various organisms in a community ([Michael, 1994](#)). The highest macrozoobenthos diversity index was found at Station one upstream of the Masang Kecil River (2.35) and then followed by Station two after WWTP (2.26) and station three after the confluence of tributaries (2.26) (**Table 2**). The macrozoobenthos diversity index in the Masang Kecil river ranged from 2.23 -2.35 and was categorized as good diversity. The high macrozoobenthic diversity index at Station one is because, at Station one, riparian plants and rivers are found that are still awake, and relatively many species are found at this station.

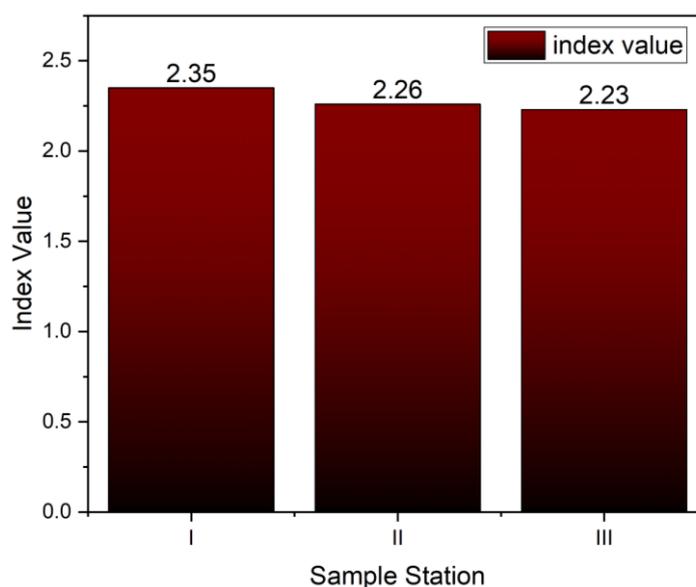


Figure 2. Macrozoobenthos Diversity Index

Source: Research Results, 2022

According to [Rahmawaty \(2011\)](#), the diversity index of macrozoobenthos in river waters is influenced by the conditions of the surrounding environment, so that macrozoobenthos that can adapt have a high diversity index, while macrozoobenthos that are unable to adapt have a low diversity index. According to [Resosoedarmo et al. \(1989\)](#), a community with high diversity is composed of many species with the same or nearly the same abundance. The diversity index of macrozoobenthos at Station two decreased because, at Station two, it was suspected that there were dominating species such as Tubifex sp. Because the sampling point is after the

WWTP because the waters are rich in organic matter. The diversity index at Station three is the lowest. The low diversity index at this station is due to the input of water from residents' housing polluted by domestic waste. With a high level of human activity in the aquatic environment, macrozoobenthos that cannot adapt to these environmental conditions will die ([Pelealu et al., 2018](#)). Several types of benthos found can be seen in the following figure: The Diptera Order is a facultative intolerant species that can survive in an environment with a rather wide tolerance, between waters that have not been polluted to moderately polluted ([Fachrul, 2007](#)).

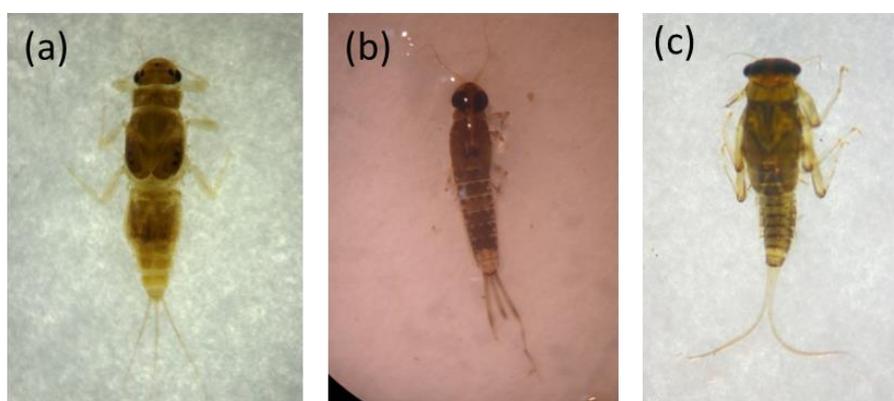


Figure 3. Types of Macrozoobenthos from the Order of Lepidoptera: (a) *Caenis* sp. (b) *Baetis* sp. (c) *Pseudocleon* sp.

Source: Research Results, 2022

Macrozoobenthos, which are intolerant, have a narrow tolerance range for pollution and are not resistant to environmental pressure, so they can only live in clean waters. For example, the order Ephemeroptera (Mayfly) will achieve high abundance in an environment that tends to be cold and cool, with moderate to heavy currents and rocky. Some families of this order are burrowers or diggers in fine sediments above the rocks. The Mayfly is a grass eater; although it is classified as a herbivore, it also consumes large amounts of bacteria ([Odum, 1993](#)). Species *Baetis*, sp from the family Baetidae, is the most tolerant species of this order for light pollution. Usually, animals in this group will experience a decrease in abundance if there is sedimentation and organic pollution; these animals require a lot of oxygen, namely at 4-11 ppm oxygen. Types of mayflies (Ephemeroptera), stone files (Plecoptera), and

Caddies-files (Tricoptera) are commonly found in clear water ([Jhonatan et al., 2016](#)).

According to [Wardhani, \(2007\)](#), insects from the orders Coleoptera, Hemiptera, and Odonata are found in moderate to clean quality waters, while Diptera is often found in polluted waters. In the current study, the order Diptera was most commonly found among orders from other insect classes, namely, ten species. However, there were nine species from the Order Ephemeroptera as an indicator of clean waters and six species for Trichoptera. The number of macrozoobenthos species as an indicator of clean and polluted water balances this.

The Gastropod class, better known as water slugs, is one of the macrozoobenthos found in various glasses of water. Habitat conditions favored by Gastropods are dissolved oxygen levels between 0.5-14 ppm.

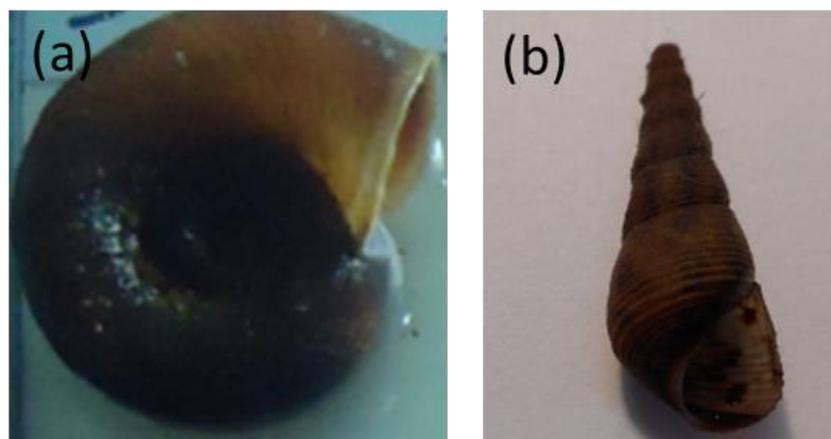


Figure 4. Types of Macrozoobenthos from the Gastropod Class: (a) Gyraulus sp. (b) Melanoides tuberculata

Source: Research Results, 2022

Usually, gastropods also indicate silica-rich waters. Several studies have shown that gastropods can survive in heavily polluted areas, and these contaminants, such as heavy metals, pesticides, and radioactivity, are concentrated in organs and shells. In this study at PT AAI, gastropods were not found much, only upstream and at WWTP outlets.

The research [Putra et al., \(2014\)](#) also found gastropods in the Batang Ombilin River

with the type *Melanoides tuberculata*, which has a Relative Abundance (KR%) of 50%. *Melanoides* is one of the benthos that is tolerant of environmental pollution. In addition, the temperature of the waters can also support the life of *Melanoides*. *Melanoides* can live well in the temperature range of 18-32°C. *Melanoides* can regenerate quickly, produce offspring quickly, and have a long lifetime ([Desmawati, 2019](#)).

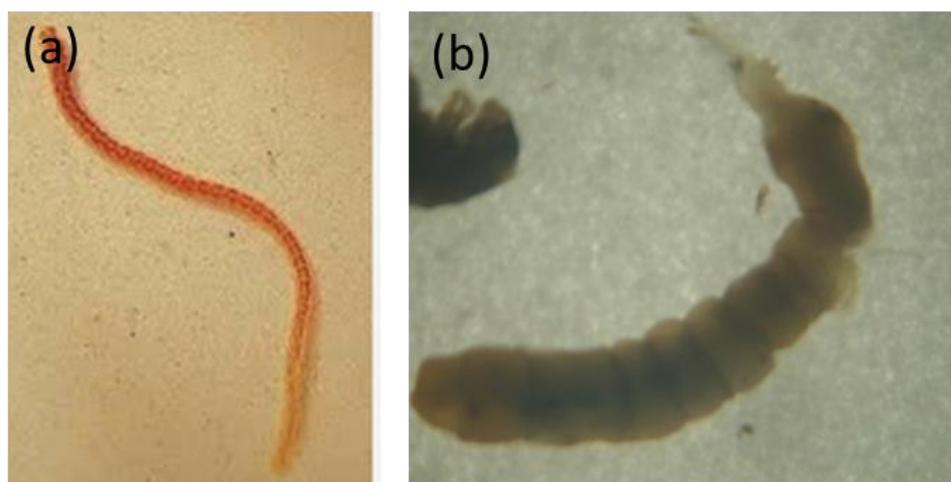


Figure 5. Types of Macrozoobenthos from Oligochaeta and Order Trichoptera: (a) Tubifex sp. (b) Hydropsyche sp.

Source: Research Results, 2022

PT AAI also found the Order of Trichoptera (Caddisfly), one insect order that has complete metamorphosis. It is an insect that is intolerant to pollutants, so it prefers clean waters. Most Trichoptera larvae prefer to live in shallow water types (5-10 cm) with water flowing over rock surfaces, and a few species are found on smooth substrates in

deep water. Furthermore, intolerant macrozoobenthos, for example, *Hydropsyche* and *Cheumatopsyche*, are relatively sensitive to polluted water, and the presence of these animals will increase again downstream when the water quality improves ([Afkari, et al., 2014](#)).

The substrate in the small Masang river is rocky and muddy. According to [Wiedarti et al. 2014](#), Grastopoda is an organism that likes a wide range of distribution in rocky, sandy, or muddy substrates. However, these organisms prefer sand and slightly muddy bottom substrates. Previous research by [Izmiarti and Safitri \(2018\)](#) on the Macrozoobenthos Community as a Biological Indicator of Water Quality in the Masang Kecil River Receiving Palm Oil Industry Liquid Waste in Kinali Pasaman Barat, the results of the identification of macrozoobenthos obtained in the Masang Kecil River found 43 species consisting of Insects 33 species, four types of Oligochaeta, three types of Gastropods, two types of Hirudinae, one type of Arachnida and one type of Turbellaria. Insecta (71.89%) showed the highest number of individuals, followed by Hirudinea (25.1%) and other classes, not more than 3%. The highest density was at station III, and the lowest was at station I. The dominant species at the station I were *Stenelmis* sp. and *Psephenoides* sp.; stations II and III were *Erphobdella* sp. and *Hydropsycheelisoma*.

CONCLUSION

The results of identifying the types of Benthos organisms as a whole identified as many as 45 species. Most species are found in Class Insecta. The diversity value is categorized as high, namely H' in the upstream = 2.35, H' = 2.26 downstream after WWTP, and after the confluence of tributaries H' = 2.23. Benthic densities were 318.49 ind/m², 951.76 ind/m², and 155.54 ind/m², respectively. It can be concluded that benthic conditions are in good condition on a scale of 4. In the current study, the Diptera order as an indicator of polluted water was found the most among the orders of other insect classes, namely, ten species. However, there were nine species from the Order Ephemeroptera as an indicator of clean waters and six species for Trichoptera.

Author's declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of

results. The authors read and approved the final manuscript.

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Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

REFERENCES

- Afkar, Djufri, Ali, M, S. 2014. Asosiasi Makrozoobenthos Dengan Ekosistem Mangrove di Sungai Reuleng Leupung, Kabupaten Aceh Besar. *Jurnal EduBio Tropika*. 2 (2) : 187-250.
- Asra, R. 2009. Makrozoobentos sebagai Indikator Biologi dari Kualitas Air di Sungai Kumpeh dan Danau Arang-Arang Kabupaten Muaro Jambi, Jambi. *Biospecies*, 2 (1): 23-25.
- Brower, J.E. dan J.H. Zar. 1977. *Field and Laboratory Method of General Ecology*.
- Desmawati, I., Adany, A. dan Java C.A. 2019. Studi Awal Makrozoobentos di Kawasan Wisata Sungai Kalimas, Monumen Kapal Selam Surabaya. *Jurnal Sains Dan Seni ITS* Vol. 8, No. 2 (2019), 2337-3520 (2301-928X Print)
- Fachrul, M. F. (2007). *Metode Sampling Bioekologi*. Jakarta: Bumi Aksara
- Hutagalung, H. P. 1991. *Pencemaran laut oleh logam berat*. Oseana 5. P3O-LIPI. Jakarta.
- Indarmawan, T., & Manan, A. (2011). Pemantauan Lingkungan Estuaria Perancang Berdasarkan Sebaran Makrozoobenthos. *Jurnal Ilmiah Perikanan dan Kelautan*, 3(2), 215-220.
- Izmiarti dan V. Safitri. 2018. Komunitas Makrozoobentos sebagai Indikator Biologi Kualitas Air Sungai Masang Kecil yang Menerima Limbah Cair Industri Minyak Kelapa Sawit di Kinali Pasaman Barat. *Jurnal Biologi Universitas Andalas (J. Bio. UA.)* 6(1) : (ISSN : 2303-2162)
- Jailani dan M. Nur. 2012. Studi Biodiversiti Benthos di Krueng Daroy Kecamatan Darul Imarah Kabupaten Aceh Besar. *Jurnal Rona Lingkungan Hidup*, 5 (1) : 8 - 15.
- Jhonatan, F., Setyawati, T.R., Linda, R. 2016. Keanekaragaman Makrozoobentos di Aliran Sungai Rombok Banangar Kabupaten Landak Kalimantan Barat. *Protobiont* (2016) Vol. 5 (1) : 39-45.
- Michael, T. 1984. *Ecological Methods for Field and Laboratory Investigations*. USA. Tata McGraw-Hill Publishing.

- Nangin SR, Langoy ML, Katili DY. 2015. Makrozoobentos sebagai indikator biologis dalam menentukan kualitas air Sungai Suhuyon Sulawesi Utara. *Jurnal MIPA* 4(2): 165-168
- Nybakken, J. W. 1992. *Biologi Laut Suatu Pendekatan Ekologis*. PT. Gramedia. Jakarta
- Odum, E.P. 1993. *Dasar-dasar Ekologi*. Diterjemahkan dari *Fundamental of Ecology* oleh T. Samingan. Gadjah Mada University Press, Yogyakarta.
- Pelealu, G,G,E., Koneri R., Butarbutar , R.R., 2018. Kelimpahan Dan Keanekaragaman Makrozoobentos Di Sungai Air Terjun Tunan, Talawaan, Minahasa Utara, Sulawesi Utara. *Jurnal Ilmiah Sains* Vol. 18 No. 2, Oktober 2018.
- Putra, H., Izmiarti, Afrizal. 2014. Komunitas Makrozoobentos di Sungai Batang Ombilin Sumatera Barat. *Jurnal Biologi Universitas Andalas (J. Bio. UA.)* 3(3) – September 2014 : 175-182 (ISSN : 2303-2162).
- Rahmawaty. 2011. Indeks keanekaragaman makrozoobentos sebagai bioindikator tingkat pencemaran di Muara Sungai Jeneberang. *Bionature* 12 (2): 103-109.
- Resosoedarmo, S., K. Kartawinata dan A. Soegiarto. 1989. *Pengantar Ekologi*. Penerbit Ramadja Karya. Bandung.
- Ruswahyuni, 2010. Populasi dan Keanekaragaman Hewan Makrobenthos pada Perairan Tertutup dan Terbuka Di Teluk Awur, Jepara. *Jurnal Ilmiah Perikanan dan Kelautan*. 2(1) : 11-20
- Wardhani TS. 2007. Perbandingan Populasi Larva Odonata di Berbagai Sungai di Pulau Pinag dan Hubungannya dengan Pengaruh Habitat dan Kualiti Air. Thesis. Universiti Sains Malaysia.
- Wiedarti, S., Hardiyanti, D., Darda R.I. 2014. Keanekaragaman Makrozoobentos Di Sungai Ciliwung. *Ekologia*, Vol. 14 No.1 , April 2014: 13-20