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Fish diversity as bioindicator of downstream pollution in the Surabaya river and Jagir river

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ABSTRACT

Surabaya City is one of the major cities in Indonesia which has a large number of industries. The industry is suspected of pollution, one of which is water pollution in the city of Surabaya, more precisely downstream of the Kali Surabaya River and Kali Jagir River. The pollution has reduced the diversity of aquatic biota, one of which is fish, the decrease in diversity of fish can reduce the stability of river ecosystems and the loss of potential fish whose existence is not yet known but is lost due to pollution. This study aims to determine the number of fish species found, find out whether or not the differences in fish species found, the index value of fish species dominance, know the value of river pollution by bioindicators, know the stability profile of the two river ecosystems based on the value of fish diversity. This research was conducted in 2018 in March, June, September, and December. Fish sampling results were calculated and identified, then determined whether there were differences between fish species found at each location using similarity and dissimilarity indexes, determining the dominance index value (Simpson's diversity index) and fish diversity value (Shannon-Wiener), then the results were matched with the category of degree of pollution according to Lee and the stability profile of the ecosystem using the Odum. The results of this study are found as many as 19 species of fish in the Lower River Kali Surabaya and 16 species of fish in the Kali Jagir River. There are differences in fish species found downstream of the Kali Surabaya River and Kali Jagir River. The results of the dominance index value of fish species found downstream of the Kali Surabaya River and Kali Jagir River are included in the low dominance category. The results of the fish diversity index value are known that in the downstream of the Kali River in Surabaya, including mildly polluted and Kali Jagir River included in the category of medium polluted. Based on Odum the ecosystem profile of the two rivers is included in the category of moderate diversity, productivity is quite balanced, the ecological pressure and the stability of the ecosystem is moderate.

Key words: *Biodiversity, Bioindicator of pollution, Kali Surabaya River, Jagir River*

Introduction

The city of Surabaya is one of the major cities in Indonesia which has a large number of industries. This can be seen from the data of Irrigation Agency of East Java about the location of the industry monitored on the edge of the river irrigation area in Surabaya. Several types of industries stand around the river border Surabaya City, including 11 paper industries, 3 leather tanning industries, 3 textile industries, 1 oil industry, 1 nut and bolt industry, and 1 enamel industry (Muttaqin, 2013). The industry is

suspected of anthropogenic pollution. One of them, is river pollution in the city of Surabaya, more precisely downstream of the Kali Surabaya River and Kali Jagir River. Besides, both rivers experienced pollution problems in the form of anthropogenic pressure (Hayati *et al.*, 2017). This is a big problem because these two rivers play an important role in the daily life of people in Surabaya such as suppliers of clean water for the community, sources of raw materials for the PDAM (Regional Drinking Water Company), as a place of daily livelihood in fishing.

Based on those problems, the test is needed to show the degree of the pollutions and the effects. one of them is a bio-indicators test. Bio-indicators have several advantages. It can indicate a direct impact of pollution or the environment that is polluted and show the accumulated effects. The test is also able to portray the health of the waters for a relatively long period. Healthy waters are referred to have a high level of diversity and are not dominated by one species. One of the bio-indicators that can be used to describe the level of pollution in some waters, is the diversity of aquatic fauna, one of them is fish.

The diversity of fish species in river ecosystems can be used as an indicator of river water quality. High-level diversity indicates the state of the river is not polluted and vice versa. If the diversity of species in the ecosystem of the river is low, it indicates that the river has been polluted (Hayati *et al.*, 2017).

Based on the description above, it is necessary to do some research on the species diversity of fish in the Kali Surabaya and Kali Jagir river downstream. The research is intended to determine the level of pollution in the river through bio-indicators. This research is also aimed to determine the number of species of fish that are found in the downstream of Kali Surabaya and Kali Jagir river, the absence of differences and similarities of fish species that are found in both rivers, the level of dominance species of fish that are found in the river, knowing the profile stability of both river ecosystems that are based on fish diversity values.

Materials and Methods

The location of sampling in this study is downstream of Kali Surabaya and Kali Jagir river. At the downstream of the Kali River in Surabaya, 2 sampling points were conducted, namely Jrebeng - Karang Pilang (station 1), and Karang Pilang - Gunung Sari (station 2). At Kali Jagir River, there are 2 sampling points, the first sampling point is on the Stream Kali - Nginden (station 3) and the second sampling point at Nginden - Wonorejo (station 4). The location to identify samples of fish, as well as the preparation of the report, was done in the Laboratory of Ecology, Department of Biology Faculty of Science and Technology University of Airlangga.

The research is carried out in 2018 with 4 times replication. The replication is done every 3 months. It is in March, June, September, and December. The sampling both of the Kali Kali Jagir and Kali Surabaya downstream are carried out once in each month.

The materials used in the study of the diversity of fish are sampled fish that were obtained at the location of the sampling. The research tool used in the study is the tool of research for the diversity of fish. The tools of research for the diversity of fish were a fishnet, the guides of identification book, and camera. Fish sampling that was done in both Kali Jagir and Kali Surabaya Rivers downstream in the year 2018 is once in each March, June, September, and December. The fish samples that obtained at each station were counted and its kind was identified using a book of reference by Kottelat (2013). The results of identification will be used to find out if there are any differences of fish species that are found in the downstream of Kali Surabaya and Kali Jagir River descriptively. Also, the identified results can be used to determine the level of dominance species of fish in downstream of Kali Surabaya and Kali Jagir River by the formula as follows in Odum.

$$D = \Sigma [ni/N]^2 \quad .. (1) \quad \text{(Widiastuti, 2015)}$$

Where D is Dominance, n_i is number of individual species to –n, N is total number of individuals.

Based on the formula, according to Odum if $0 < D \leq 0, 5$ it is included in a genus dominates does not exist category, and if $0.5 < D < 1$ then there is a genus dominate (Fatimah *et al.*, 2018).

After the level of dominance is determined, it can be used to determine the value of the diversity of fish species by using a formula Index Diversity Shannon - Wiener:

$$H' = -\sum_{i=1}^{n} \left[\frac{n\,i}{N} ln \frac{n\,i}{N}\right] \quad .. (2) \quad \text{(Widiastuti, 2015)}$$

where H' is Shannon-Wiener diversity index. Once the value of the diversity of fish-based index of diversity Shannon-Wiener at each station sam-

pling is determined, then the result of the index of diversity Shannon-Wiener value is matched with the category of the degree of pollution according to Lee to determine the level of pollution of waters by bio-indicators. If the value of the index Shannon-Wiener is more than 2, then it is not polluted, If it's in between 1.6 to 2.0 then it is lightly polluted, if it's between 1.0-1.5 then it's medium polluted if it is smaller than 1.0 then it is heavily polluted (Widiastuti, 2015).

Based on the results of diversity values, it can also be known as the stability profile of the two river ecosystems based onOdumcriteria. Where the criterion is if the diversity value is greater than 3 then it can be said to be of high diversity, high productivity, high ecological stability, and resistant to ecological stress. If in the range 1 <H '<3 then the diversity is moderate, the productivity is quite balanced, the ecological pressure is moderate and the stability is moderate. If the range is less than low diversity, poor, very low productivity then it is an indication of heavy pressure, and the ecosystem is unstable (Fatimah *et al*., 2018).

Results

Based on the results of fish sampling that has been done (Table 1), 19 fish species are found in the Kali Surabaya River. Also, it is known that the number of fish species found in Jagir River is 17 fish species.

Based on the data from Table 1 diversity of fish species found in the Kali Surabaya River and Kali Jagir River above, there are differences in fish species found in the Kali Surabaya River and Kali Jagir River. The difference can be seen from the fish species found in the Kali Surabaya River but not found in the Kali Jagir River and vice versa. There are 5 species of fish found in Surabaya Kali River but not found in Surabaya Kali Jagir River, namely Papar fish (*Notopterus notopterus*), Sili fish (*Macrognathus aculeatus*), Eel (*Monopterusalbus*), Sepat Fish (*Trichogaster trichopterus*), and Sili fish (*Macrognathus aculeatus*), Eel (*Monopterusalbus*), Sepat Fish (*Trichogaster trichopterus*), and Tilapia (*Oreochromis niloticus*). There are 3 species of fish found in the Kali Jagir River but not found in the Kali River in

Table 1. Types of fish found in Surabaya Kali River and Kali Jagir River

No	Species of Fish	Average Number of Fish Species Found			
		Kali Surabaya River		Kali JagirRiver	
		Station 1	Station 2	Station 3	Station 4
1	*Pangasius humeralis*	0	0	7.5	6.25
2	*Trichogaster trichopterus*	1	1.25	0	0
3	*Oreochromis niloticus*	3.25	0	0	0
4	*Clarias gariepinus*	0	0	4	3.25
5	*Latescal califer*	0	0	0.5	0.5
6	*Channa striata*	2.5	3.75	0.75	0.5
7	*Oxyeleotris marmorata*	1.25	2.75	0	73.75
8	*Notopterus notopterus*	1.75	0.75	0	0
9	*Pseudolais micronemus*	5.25	7.75	82.5	73.75
10	*Macrognathus aculeatus*	2.25	2	0	0
11	*Hemibragus planiceps*	2.75	3	23	6.75
12	*Hampalamacrolepidota*	1.25	1.5	4.5	3.5
13	*Monopterus albus*	0	0.5	0	0
14	*Clarias batrachus*	0.75	0.25	13.75	14.5
15	*Liposarcus pardalis*	0.25	0.75	3	1.75
16	*Hemibragus nemurus*	0.25	0.75	6.75	7.75
17	*Oreochromis mossambicus*	2.75	6.5	4	3
18	*Barbonymus balleroides*	27.25	28.75	6	4
19	*Barbonymus gonionotus*	32.25	38.25	8.25	2.75
20	*Osteochillus hasseltii*	7.5	4.5	0.5	0.5
21	*Systomus rubripinnis*	1	1	1	0.75
22	*Anabas testudineus*	3	1.75	0.75	0.5
The average total of fish obtained at each sampling point		96.25	105.75	166.75	203.75

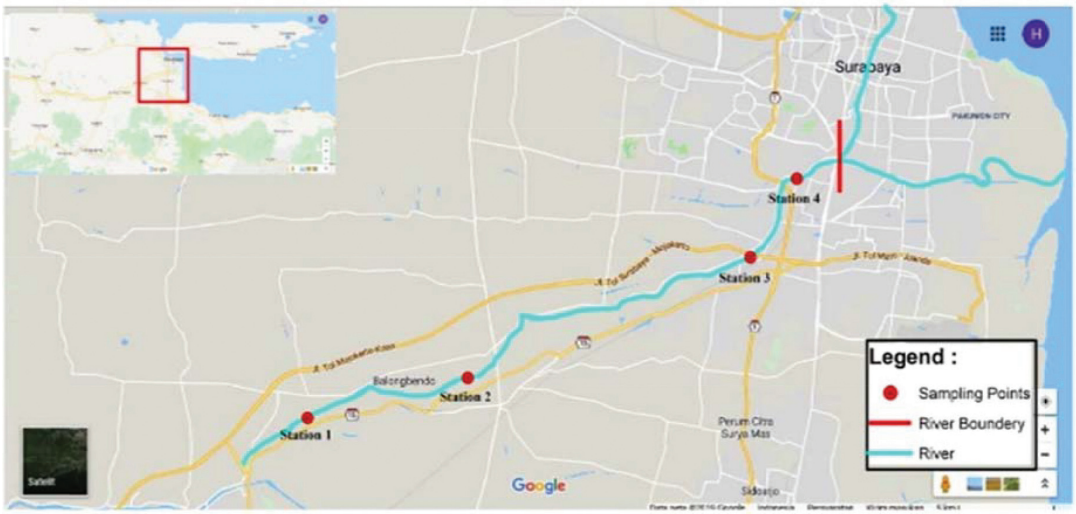

Fig. 1. Sampling station: Jrebeng - Karang Pilang (station 1); KarangPilang - Gunung Sari (station 2); Streen Kali - Nginden (station 3); Nginden - Wonorejo (station 4).

Surabaya, namely Patin (*Pangasius humeralis*), Dumbo Catfish (*Clarias gariepinus*), and Cukil fish (*Latescal califer*).

Based on the dominance index, the highest dominance index is at station 4 of 0.350875 and the lowest dominance index is at station 1 of 0.22435 (Fig 2A). Based on the results of the average Shannon-Wiener diversity index value (Fig. 2B) obtained, it is known that the Kali Surabaya River has a higher diversity value compared to Kali Jagir River.

At Kali Surabaya River, it is known that Station 1 has the highest Shannon-Wiener diversity index value, which is an average of 1.8118 with a standard deviation value of 0.079271, while at Station 2 the Shannon-Wiener diversity index value is 1.7854. with a standard deviation of 0.03523. At Kali Jagir, it is known that at station 3 the highest Shannon-Wiener diversity index value is 1.696375 with a standard deviation of 0.053102, while at station 4 it has an average Shannon-Wiener diversity index value of 1, 5733 with a standard deviation value of 0.08702.

Based on the results of the average Shannon-Wiener diversity index value (Fig. 2B) obtained, it is known that the Kali Surabaya River has a higher diversity value compared to Kali Jagir River. At Kali Surabaya River, it is known that Station 1 has the highest Shannon-Wiener diversity index value, which is an average of 1.8118 with a standard deviation value of 0.079271, while at Station 2 the Shannon-Wiener diversity index value is 1.7854. with a standard deviation of 0.03523. At Kali Jagir, it is known that at station 3 the highest Shannon-Wiener diversity index value is 1.696375 with a standard

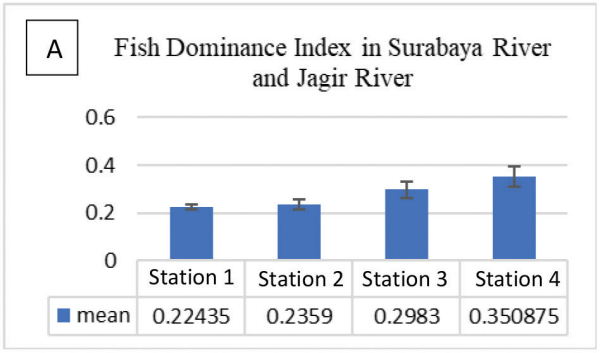

Fig. 2. Fish Dominance Index in Kali Surabaya Surabaya River and Kali Jagir River

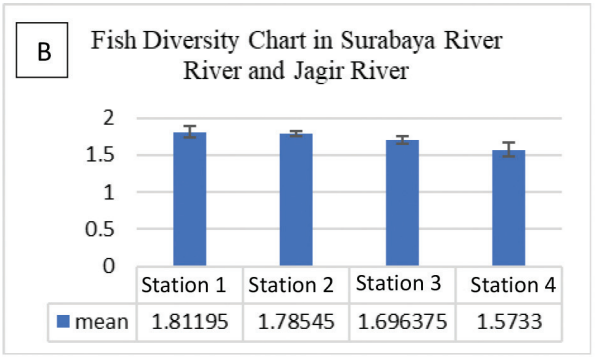

Fig. 3. Fish Diversity in the Kali Surabaya Surabaya River and Kali Jagir River

Fig. 2. (A) Dominance and **(B)** diversity indexes of fish community in Surabaya and Kali Jagir River

deviation of 0.053102, while at station 4 it has an average Shannon-Wiener diversity index value of 1, 5733 with a standard deviation value of 0.087023.B

Discussion

Based on Table 1 that has been described above, it can be seen that from the total average of each fish species from March, June, September, and December found downstream of the Kali Surabaya River at Station 1, the most commonly found in the white Bader (*Barbonymus gonionotus*) with an average of 32.25, while the least found fish species are brooms (*Liposarcus pardalis*) and cracks (*Hemibragus nemurus*) with an average of 0.25. At station 2, the fish species most commonly found were white Baders (*Barbonymus gonionotus*) with an average of 38.25, while the least found fish species was river catfish (*Clariasbatrachus*) with an average of 0.25.

The average total of each fish species found in the downstream of Kali Jagir River at Station 3 is the most common is jendil (*Pseudolais micronemus*) with an average of 82.5, while the least found fish species are montho (*Osteochillus hasseltii*) and cukil (*Latescalcalifer*) with an average of 0.5. At station 4, the most common were jendil (*Pseudolais micronemus*) with an average of 73.75, while the smallest species of fish found were montho (*Osteochillus hasseltii*), bethik (*Anabas testudineus*), kuthuk (*Channastriata*), and cukil (*Latescalcalifer*) with an average of 0,5.

Based on the average fish sampling results downstream of the Kali Surabaya River, it is known that the fish species most commonly found is the white bader (*Barbonymus gonionotus*) which is a fish from the Cyprinidae family. A large number of Cyprinidae family members found, due to this family is the largest family of freshwater fish in every place in the world, except Australia, Madagascar, New Zealand, and South America (Kottelat, 2013). According to Roesma *et al*. (2016) fish from the Cyprinidae family is known as the largest group of true freshwater fish. This is the same as a study conducted by Hayati *et al.* (2017) in 2016 where the species most commonly found was *Barbonymus gonionotus*. Kali Jagir River is downstream from Kali Brantas River and Kali Surabaya River, according to Mccabe (2011) on wide-sized or downstream rivers (order> 6) dominated by Collector invertebrates and usually dominated by Catfishes (Siluriformes) and fish species of Planktivorous species (plankton eaters), this is the reason why Siluriformes fish species (*Pseudolais micronemus, Hemibragus planiceps, Clariasbatrachus, Liposarcuspardalis, Hemibragus nemurus*) are found in many downstream of Kali Jagir River.

Fish species found in Surabaya River but not found in Jagir River, there are 6 species, namely *Oxyeleotris marmorata, Notepterus notepterus, Macrognathus aculeatus, Monopterusalbus, Tricogastertrichopterus, and Oreochromis niloticus*. Bloso (*Oxyeleotris marmorat*a), papar (*Notepterus notepterus*), eel (*Monopterus albus*), and sili (*Macrognathus aculeatus*) species are not found in Kali Jagir River because these fish species are generally in the benthic ecosystem of the Kali Surabaya whichcannot flow into the River Sungai Kali Jagir due to adam (Muttaqin, 2013), besides that the Kali Jagir River is a river that is directly related to the Surabaya East Coast River estuary so that there is an input of seawater which makes an increase in water salinity so that the fish cannot survive (Arisandi, 2013), in addition to a large amount of organic waste pollution originating from residents' homes that stand along the boundaries of the Kali Jagir River can also affect the absence of these fish species

Table 2. Percentage of dissimilarity index and percentage of similarity index between stations.

Station	A	B	C	%IS	%ID
Station 1 with station 2	18	19	18	97.3	2.7
Station 4 with station 3	16	16	16	100	0
Station 1 with station 4	18	16	13	76.5	23.5
Station 1 with station 3	18	16	13	76.5	23.5
Station 2 with station 4	19	16	13	74.3	25.7
Station 2 with station 3	19	16	13	74.3	25.7

*Information:
A= Number of types in the first community; B= Number of types in the second community; C= Number of species in two communities; IS= Index of similarity (similarity); ID= Dissimilarity index type (dissimilarities)

in Kali Jagir (Rasyad, 2017).

In this study, to determine the percentage of differences in fish species found at each sampling point by Table 1, first determine the percentage of species similarity using the Sorensen similarity index. Sorensen's similarity index formula:

IS = (2 C / A + B) X 100% .. (3) (Fatimah *et al*., 2018)

where A is number of first community types, B is number of species in the second community, C is number of species in the two communities.

After obtaining the percentage value of the type of similarity index, then determined the percentage value of the type of inequality index or dissimilarity index, the percentage value of the type of inequality index (dissimilarity index) used the following formula:

% ID = 100% -% IS (4) (Fatimah *et al*., 2018)

where % ID is percentage of dissimilarity index, % IS is percentage index similarity. Based on the calculation results in Table 2 it is known that the highest similarity index is at the location of station 4 with station 3 by 100%, while the lowest is at the location of station 2 with station 4 and station 2 with station 3 by 74.3 %. The highest species inequality index (dissimilarity index) is between the location of station 2 and station 4 and station 2 with station 3 at 25.7%, while the lowest is between the location of station 4 and station 3 at 0%. Based on this it can be concluded that the location of station 1 with station 4, station 1 with station 3, station 2 with station 4, and station 2 with station 3 have a similarity index (similarity) > 90%, so it can be said to be a different community so the value of dissimilarity index tends to be high.

Based on the calculation results in Table 2 it is known that the highest similarity index is at the location of station 4 with station 3 by 100%, while the lowest is at the location of station 2 with station 4 and station 2 with station 3 by 74.3%. The highest species inequality index (desimilarity index) is between the location of station 2 and station 4 and station 2 with station 3 at 25.7%, while the lowest is between the location of station 4 and station 3 at 0%. Based on this it can be concluded that the location of Station 1 to Station 4, stasiun1 to station 3, station 2 to station 4 and station 2 to station 3 has an index of equality of (similarity) > 90%, so it can be said to represent the different communities that value desimilarity index tends to be high.

Based on the dominance index (Fig. 1), the highest dominance index at station 4 is 0.350875 and the lowest dominance index at station 1 is 0.22435. Then based on these results according to Odum including the range if $0 < D \leq 0.5$ then included in the category no genus dominates. This is reinforced by Gusmaweti (2018) if the value of dominance approaches the value of 1 means that in the community there is a genus that dominates other genera, conversely if approaching the value of 0 means that in the community structure there is no genus that is extremely dominating the genus the other.

Based on the results of the average Shannon-Wiener diversity index value obtained (Fig. 2), it is known that the Kali Surabaya River has a higher diversity value compared to Kali Jagir River. At Kali Surabaya River, it is known that Station 1 has the highest Shannon-Wiener diversity index value, which is an average of 1.8118 with a standard deviation value of 0.079271, while at Station 2 the Shannon-Wiener diversity index value is 1.7854. with a standard deviation of 0.03523. At Kali Jagir, it is known that at station 3 the highest Shannon-Wiener diversity index value is 1.696375 with a standard deviation of 0.053102, while at station 4 it has an average Shannon-Wiener diversity index value of 1, 5733 with a standard deviation value of 0.087023.

After knowing the diversity value of fish based on Shannon-Wiener diversity index at each sampling station, then to find out the level of water pollution in bioindicator through the value of fish diversity, the results of the Shannon-Wiener diversity index value are matched with the category of degree of pollution according to Lee (Widiastuti, 2015). Based on the pollution degree category it can be seen that the Shannon-Wiener diversity index values in the Kali Surabaya River and Kali Jagir River at all sampling points except station 4 are included in the mildly polluted category with Shannon-Wiener diversity index values in the range 1.6 - 2, 0 At station 4 it is more inclined to the medium polluted category.

In this study it is known that the Kali Surabaya River has a high diversity compared to Kali Jagir River, this is because the number of fish species found in the Kali Surabaya River is more than the Kali Jagir River. Also, based on the Simpsons dominance index value, the Kali Surabaya River has a smaller dominance value than the Kali Jagir River. At Kali Jagir river, especially at station 4, it has a

higher pollution pressure than the other three stations where the diversity index results are more moderately polluted than mildly polluted, where the diversity index value does not reach 1.6 which is the mildly polluted category.

At least fish species found in the Kali Jagir River due to a large amount of organic waste pollution entering the Kali Jagir River, more than six thousand buildings are standing along the boundaries of the Kali Jagir River (Arisandi, 2013). Besides, the decline in the quality of the waters of the Kali Jagir River is also caused by a large amount of sedimentation in this river, where sedimentation contains a lot of garbage which interferes with fish breeding.

Based on the results of diversity values, it can also be known as the stability profile of the two river ecosystems based on Odumcriteria (Fatimah *et al*., 2018). So based on the Odum criteria, the Kali Surabaya River and Kali Jagir River fall into the criteria in the range of 1 <H '<3, namely moderate diversity, moderately balanced productivity, moderate ecological pressure, and moderate stability. These criteria also support the results of the category of pollution degrees according to Lee (Widiastuti, 2015) which based on these criteria cover a range of light and moderate degrees of pollution categories, so that it can be known that the Kali Surabaya River and Kali Jagir River have moderate ecological pressure and moderate stability, wherein the Kali Jagir River the pressure is greater and the stability is lower than in the Kali Surabaya River. This is because in the Kali Jagir River the diversity value is lower than the Kali Surabaya River.

Conclusion

The conclusion of this research is found as many as 19 species of fish in the River Downstream of Kali Surabaya and 16 species of fish in the Kali Jagir River. There are differences in fish species found downstream of the Kali Surabaya River and Kali Jagir River. Based on the dominance index value of fish species found downstream of the Kali Surabaya River and Kali Jagir River are included in the category of low dominance. Based on the fish diversity index value, it is known that downstream of the Kali Surabaya River is mildly polluted and Kali Jagir River is included in the medium polluted category. Based on Odum's criteria (Fatimah *et al*., 2018) the ecosystem profile of the two rivers is included in the category of moderate diversity, productivity is quite balanced, the ecological pressure is moderate, and the stability of the ecosystem is moderate.

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