

The Epilithic Diatom Community as a Bioindicator of Water Quality Brangkal Subwatershed in the Mojokerto Area

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Abstract. *Diatoms are widely used as bioindicators of water quality because of their short life cycle and sensitivity to changes of environmental conditions in waters. One type of diatom that is used as a bioindicator is an epilithic diatom. Epilithic diatoms are one of the diatom microalgae communities attached to rock, so they are difficult to be carried away by currents. This study aimed to determine the type, composition, abundance, diversity, and dominance of epilithic diatoms found in the waters of the Brangkal subwatershed, and to determine the quality of water in the Brangkal subwatershed based on the epilithic diatom trophic index. Epilithic diatom samples were taken from 4 stations in the Brangkal subwatershed, Mojokerto Regency at the beginning of the dry season (July-August). The analysis carried out includes abundance, diversity index, dominance index, and Diatom Trophic Index (TDI). Based on the results of the study, 17 genera of epilithic diatoms were found, with the highest abundance of epilithic diatoms, including Navicula, Cocconeis, Nitzschia, and Gomphonema. The diversity index of all stations was in the medium category, with a value between 1.206 to 1.882. The lowest dominance index at station 1 was 0.167 and the highest was at station 4 with 0.373. In addition, the observed water quality is based on the Diatom Trophic Index (TDI), stations 1 to 3 are in a good category, and stations 4 are in a bad category.*

Keywords: *bioindicators, Brangkal subwatershed, epilithic diatoms, water quality*

Citation

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INTRODUCTION

River conditions will never be separated from various human activities so they have the potential to experience pollution loads in river bodies due to negative behavior carried out by the community such as disposing of domestic and non-domestic waste (Halder and Islam, 2015). The Brantas river basin, Mojokerto Regency, plays an impor-

tant role in various sectors of community life which include environmental, economic and social. The Brangkal subwatershed is part of the Brantas river basin located in the Mojokerto Regency, originating from the Anjasmoro and Welirang mountains, and flows through agricultural land, plantations, and residential areas and then empties into the main Brantas river. Its territory passes through the Districts of Pacet, Gondang, Jatirejo, Sooko and Jetis.

The increasing number of community activities around the Brangkal subwatershed area, including agricultural activities, housing, and industrial activities can affect water quality (Sulomo, 2015).

Pollution that occurs in river ecosystems will have an impact on changes in biotic and abiotic elements in the river. One of the organisms that can be used to describe conditions in river waters is diatoms. In addition to making an important contribution to primary productivity that supports the food web cycle in waters (Fehling et al., 2012). Diatoms are widely used as bioindicators of water quality because of their short life cycle and sensitivity to changes in environmental conditions in waters (Madhavi et al., 2014). Diatoms have varied responses to water quality conditions ranging from sensitive to tolerant. The response shown by diatoms when there is a change in the quality of the aquatic environment includes species abundance and community structure found (Friedrich et al., 1992). This condition is one of the characteristics of diatoms that are used as bioindicators of the quality of the aquatic environment. The increase in the number and activity of the population, as well as the use of land in the Brangkal sub-watershed, can later lead to an increase in the input of organic matter into the river which has the potential to affect water quality so that it will affect the diversity of diatoms. In addition, the species abundance and the diatom community structure found can also be used for the Diatom Tropic Index (TDI) analysis. Through the TDI analysis, an overview of the presence of diatom species that can tolerate pollution and monitor changes in the quality of the aquatic environment will be obtained (Kelly & Whittton, 1995). Epilithic diatoms are one of the diatom microalgae communities attached to rock substrates found in aquatic ecosystems (Megawati, 2017). Furthermore, McGowan

et al. (2018) also stated that the characteristic of epilithic diatoms is that they live attached to rock substrates, so they are difficult to be carried away by currents. Increasing anthropogenic activity around river waters will have an impact on changes in the characteristics of epilithic diatoms which have varied responses to water conditions. However, using these epilithic diatoms to assess the quality of river waters is still infrequent.

Therefore, it is necessary to study the diversity of epilithic diatoms and water conditions in the Brangkal subwatershed to eventually describe the condition of the waters of the Brangkal subwatershed. The results of this study are expected to provide information on the quality of the waters in the Brangkal subwatershed, in order to help plan sustainable management. Based on these, this study aimed to determine the type and composition of epilithic diatoms, determine the abundance, diversity, and dominance of epilithic diatoms, and know the water quality of the Brangkal subwatershed (Brantas River) based on the TDI analysis.

MATERIALS AND METHODS

This research is a quantitative descriptive research and was conducted during the dry season, from July to October 2020. The method used was the exploration method. Parameters observed were composition, abundance (N), Shannon Wiener Index (H'), Simpson Index (C), and Trophic Diatoms Index (TDI).

Study Area

Sampling was carried out in 4 stations (Figure 1). Each station was divided into three sub-stations. Locations were determined using the purposive sampling method (selected), based on land use and human activities in the

Bangkal subwatershed (Table 1), in accordance with Segura et al. (2012) and Salomoni et al. (2011). In addition, location consider-

ations were based on data on environmental conditions and the use of rivers and water sources (BSN, 2004).

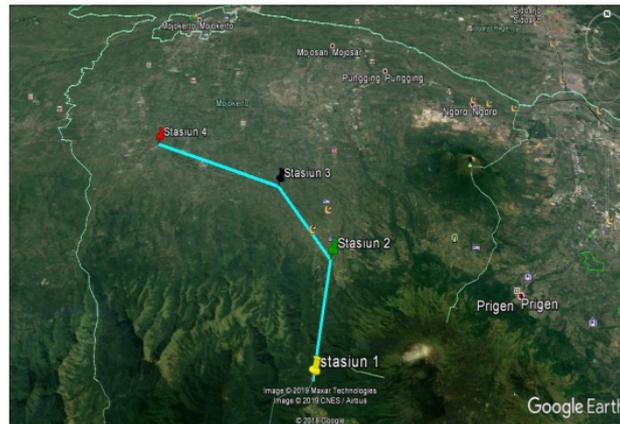


Figure 1. Sampling station location map (Google Earth, 2020)

Table 1. Description of the research station

Station	Station Description	Coordinate Location		Above Sea Level (meter)
		East Longitude	South Latitude	
1	The station is located in a protected forest area, in the Tahura R. Soerjo area which is a water catchment area. The station is located in the Pacet District, Mojokerto Regency	112°31'48.07"E	7°44'4.02"S	1248
2	The station is used for ecotourism. There are very few settlements around the river area. The station is located in Pacet Village, Pacet District, Mojokerto Regency.	112°32'18.95"E	7°40'40.81"S	712
3	This station is located in an agricultural area where waste has the potential to enter the surrounding river waters. This station is located in Padi Village, Gondang District, Mojokerto Regency.	112°30'37.10"E	7°37'56.59"S	338
4	The station is located in a fairly densely populated residential area and the buildings are located around the river body, there are also mining activities and the sand industry. The station is located in Padangasri Village, Jatirejo District, Mojokerto Regency.	112°26'11.96"E	7°35'57.47"S	92

Sampling

Epilithic diatom samples were taken in the morning from rock substrates submerged in water shallow (Reavie & John, 1998), and less than 20 cm deep (Salomoni et al., 2011). Muddy and plant-based rocks were avoided to prevent the entry of epipellic and epiphyte di-

atoms into the sample (Reavie & John, 1998). Samples were taken from the surface of the stone by scraping using a toothbrush, the area of the stone scraped referred to the literature from Lobo et al. (2010), Segura et al. (2012), and Castilejo et al. (2018) which 10-30 cm in size.

The results were washed with distilled water and then put into a 20 ml sample bottle, with an exact volume of 20 mL. The sample was then preserved with 1% Lugol iodine, and stored in a coolbox at a temperature of around 4 °C. Preservation with Lugol iodine referred to Paul et al. (2016) and Reavie & John (1998). Lugol's preservation is also recommended for the calculation of diatom samples, because Lugol's iodine can inhibit samples to move during observation and causing inaccurate results (Hotzel & Roger, 1999). In the sample were then analyzed in the laboratory.

Data Analysis

The identification of epilithic diatoms was based on the morphology of the frustules, according to Tomas (1997). Identification was also based on the presence of raphe, valve shape, apex, and stria (Taylor et al., 2007). Diatoms were identified using the identification books by Bellinger & David (2010), Taylor et al. (2007), Roy & Karthick (2019).

The composition of diatoms was used to determine the presence of a type of diatom in certain waters. The composition and abundance value of epilithic diatoms can be determined by the following formula (APHA, 2005):

$$N = n \times \frac{Vt}{Vcg} \times \frac{Acg}{Aa} \times \frac{1}{As}$$

N: Abundance (ind/cm²)

n: The number of observed diatoms i (cells) on average

Vt: Volume of sample bottle (20 ml)

Vcg: Volume on haemocytometer (0.0001 ml)

Acg: Area of hemocytometer (9 mm²)

Aa: Observation area (0.1 mm²)

As: Area of the scraped substrate (cm²) 10x10 = 100 cm² x 3 substrate = 300 cm²

The value of diversity can be determined through the Shannon-Wiener index, with the analysis of H' < 1 = Low diversity; 1 < H' < 3 = Moderate diversity; and H' > 3 = High diversity (Fachrul, 2008). Meanwhile, for the dominance analysis, it can be determined through the Simpson Dominance Index, with a value between 0-1. If it is closer to 0 then there is no dominance of a species and the condition of the community structure is stable (Odum, 1993).

TDI (Trophic Diatom Index) is used to monitor eutrophication or pollution in river waters. The formula for TDI as follow (Kelly, 1998):

$$TDI = (WMS \times 25) - 25$$

$$WMS = \frac{\sum a_j \cdot v_j \cdot s_j}{\sum a_j \cdot v_j}$$

a_j: Abundance of diatom j found in sample

s_j: The sensitivity value of diatom j to organic matter pollution

v_j: Taxa indicator value j

The categories of values and status of TDI pollution are:

0 - 35 : not polluted

35 - 50 : low polluted

50 - 60: moderately polluted

60 - 75: highly polluted

75-100: very highly polluted

RESULTS AND DISCUSSION

The Composition and Abundance of Epilithic Diatoms

Epilithic diatoms found in the Brangkal subwatershed, Mojokerto Regency, East Java consist of 17 genera with a total abundance of 904,000 ind/cm². The type of each diatom found is presented in figure 2. The average abundance value for each station is as follows: station 1 with 79,333 ind/cm², station 2 with 88,000 ind/cm², station 3 with 64,000 ind/cm² and station 4 with 70,000 ind/cm². The highest abundance value was at station 2 and the lowest was at station 3 (figure 3). The highest

abundance values found in the genera *Navicula*, *Cocconeis*, *Nitzschia*, and *Gomphonema* by 204000 ind/cm²; 174000 ind/cm²; 124000 ind/cm² and 104000 ind/cm², respectively. Meanwhile, the lowest genus was *Encyonema* with 4000 ind/cm². The abundance value of each genus can be seen in figure 4. Some types of epilithic diatoms were only found at one station and not found at other stations, this resulted in low abundance values.

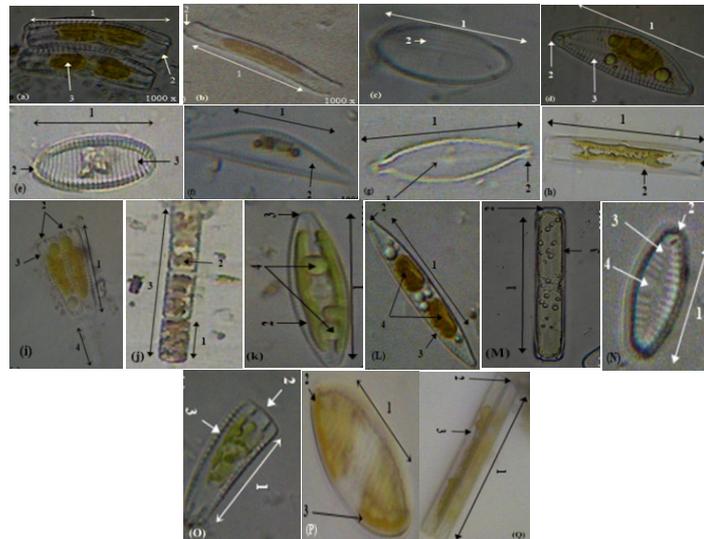


Figure 2. Genus of *Achnanthes* (a), *Achnantheidium* (b), *Cocconeis* (c), *Cymbella* (d), *Diatoma* (d), *Encyonema* (f), *Encyonopsis* (g), *Fragilaria* (h), *Gomphonema* (i), *Melosira* (j), *Navicula* (k), *Nitzschia* (l), *Pinnularia* (m), *Planothidium* (n), *Rhoicosphenia* (o), *Tryblionella* (p), and *Ulnaria* (q). 1000x magnification. (Information: 1. Curved rectangular valve, 2. Apex rounded, 3. Chloroplast)

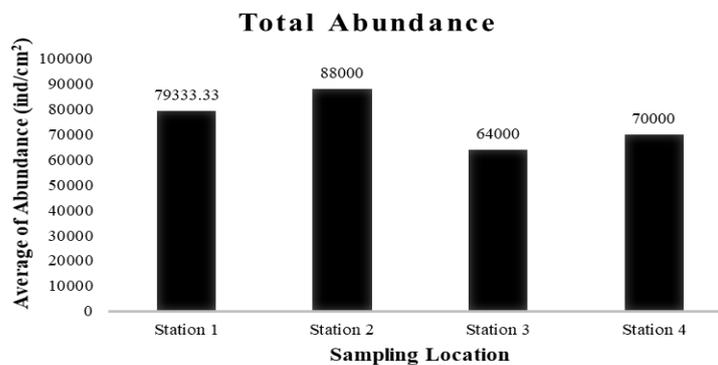


Figure 3. Average abundance of epilithic diatoms in the Brangkal Subwatershed Mojokerto

Abundance of each Genera of Epilithic Diatom (ind/cm²)

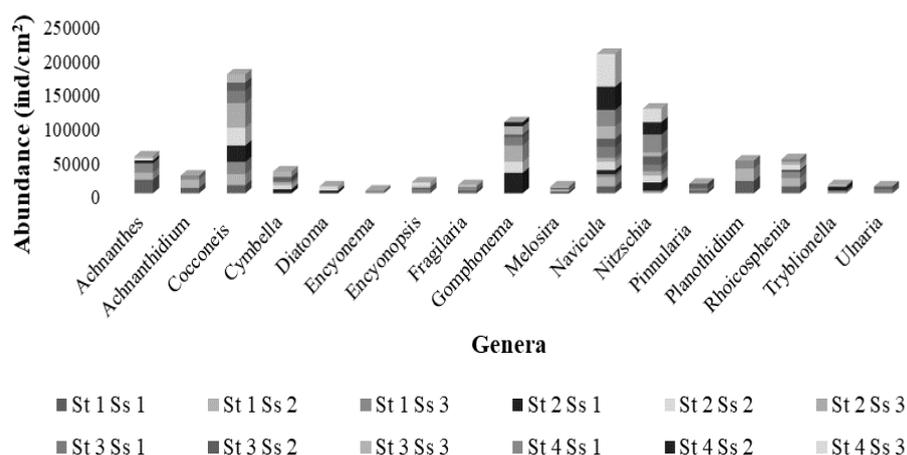


Figure 4. Abundance of each genus of epilithic diatoms in the Brangkal Subwatershed, Mojokerto (St= Station; Ss= substation)

Each station has a different genus composition and total abundance of epilithic diatoms. This is influenced by the tolerance properties of each epilithic diatom species found. In addition, river conditions also affect the total abundance of epilithic diatoms found. Stations 3 and 4 had a lower total abundance of epilithic diatoms compared to stations 1 and 2. River conditions at stations 3 and 4 have a basic substrate dominated by sand and clay, thus rocks, where epilithic diatoms live and attach naturally, were rarely found (McGowan et al., 2018). In addition, at station 3 and station 4, community activities such as agricultural and housing activities are higher than other stations. This situation has the potential to cause disturbances such as waste that pollutes river in the area.

The composition and abundance of epilithic diatoms found to be different at each research station. The genus found in almost all research stations were *Navicula* and *Nitzschia*, while *Encyonema* only existed in one station and had the lowest relative frequency value. According to Srivastava et al. (2016) diatoms have different tolerances for water quality, so each type has specific water Prahardika & Setyawan

chemistry requirements. In addition, Pasingi (2014) stated that diatoms in response to their environmental conditions are quite varied, some are sensitive and tolerant to conditions in the surrounding aquatic environment. Types of diatoms that have a high tolerance for water conditions include *Nitzschia* and *Navicula* which are found in almost all observation stations on the Cileungsi river (Pasingi, 2014). According to Onyema (2013), *Nitzschia* sp. is a diatom with a high degree of adaptation and tolerance to organic matter contamination or nutrient-rich waters. So that the diatoms can be found in all observation locations. Some types of epilithic diatoms were only found at one station and were not found at other stations, this resulted in low abundance values.

The Diversity Index of Epilithic Diatom

The diversity index value decreased from stations 1 to 4 (figure 5), and most significant decrease was at station 4 ($H' = 1.206$). Different environmental characteristics of each station caused differences in the diversity index value. The diversity values for all research station are in the same category, which is moderate ($1 \leq H' \leq 3$).

The Shannon-Wiener Diversity Index shows the comparison between variations in the number of species and the number of individuals of each species. Soegianto (1994) stated that a community has a high diversity if it is composed of many species and an even abundance of species. According to Fachrul (2008), the criteria for the Shannon-Wiener diversity index value are if $H' < 1$ then the diversity is low, if the value is $1 < H' < 3$ then the species diversity is moderate, and if the value is $H' > 3$ then the diversity is high. The highest diversity value was found at station 1 with a value of 1.882 and the lowest was at station 4 with a value of 1.206. The diversity index

value decreased from stations 1 to 4 (figure 5). The most significant decrease was at station 4. The different environmental characteristics of each station caused differences in the diversity index value. According to Leksiono (2007), species diversity is influenced by environmental factors or abiotic factors, if there is a disturbance in the ecosystem such as pollution, tolerant species will increase, and otherwise sensitive species will decrease. The Shannon-Wiener (H') diversity index value for each station was different but not too significant. However, all stations were in the same category of moderate diversity.

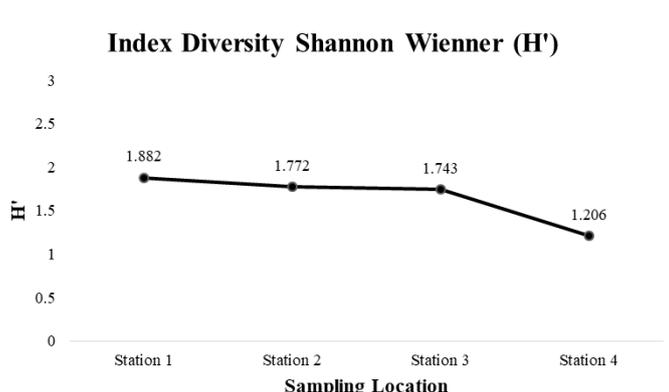


Figure 5. Epilithic diatom diversity index value in Brangkal Subwatershed Mojokerto

The Dominance Index of Epilithic Diatom

The dominance index describes the dominance of a particular species in a community (Odum, 1993). Based on the results of observations of epilithic diatoms in the Brangkal subwatershed, Mojokerto Regency, East Java, the dominance index value of each station varies as shown in figure 6). The lowest dominance index value was at station 1 with 0.167 and the highest was at station 4 with 0.373. The value of the Simpson dominance index is between 0-1. Odum (1993) stated that the smaller the value of the dominance index, no dominance of a particular species, on the contrary, the higher the index value, a particular

species dominates in a community. Station 1 has the lowest dominance index value because the abundance of each genus found is almost the same and no genus dominates the other genera. While station 4 has the highest dominance index value (C), because the genus *Navicula* and *Nitzschia* has a higher abundance than the other genera. Overall, the dominance index value is low. This shows that the condition of epilithic diatom species in the Brangkal subwatershed, Mojokerto Regency, East Java, has a fairly even population distribution so that there is no dominant genus. Except for the high abundance of the genus *Nitzschia* and *Navicula* at station 4, it is suspected that

this genus is quite tolerant to polluted water conditions. According to Pasingi (2014), the types of diatoms that have a high tolerance for water conditions are *Nitzschia* and *Navicula*. This condition indicates that station 4 has water conditions that are less favorable for the

life of other diatom genera so the genera *Navicula* and *Nitzschia* found in high abundance. In addition, the two genera can also be used as bioindicators because of their high abundance at the observation station.

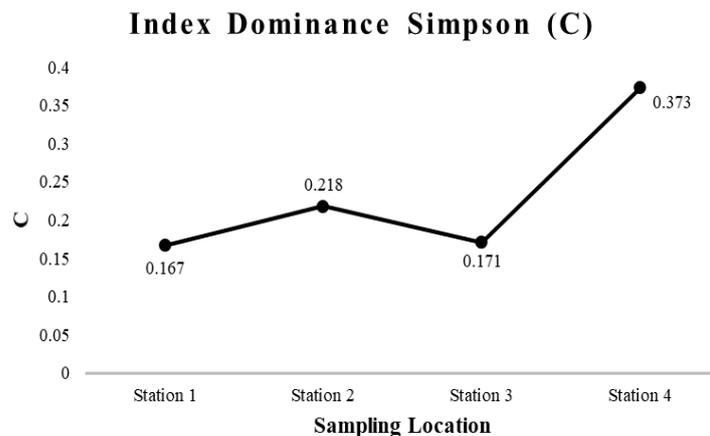


Figure 6. Epilithic diatom dominance index in Brangkal subwatershed Mojokerto

Trophic Diatoms Index (TDI) of Epilithic Diatom

TDI values ranged from 37-70 (Figure 7). The higher the TDI value, the more polluted it is. The water quality category for stations 1, 2, and 3 are included in the good category and the trophic status is oligotrophic to mesotrophic. Station 4 which has the highest TDI value is included in the bad category and its trophic status is eutrophic. Based on the TDI value, the waters of the Brangkal subwatershed are in good to bad condition (Table 2).

Diatoms as aquatic bioindicators have been widely developed in several European countries, America, and Canada (Hering et al., 2006; Kalyoncu et al., 2009; Lavoie et al., 2009), and have even been commonly used almost all over the world to assess the condition of river waters. Diatoms will respond to water conditions in the form of abundance, a number of species, and colonization of certain

taxa based on various inputs of organic matter. According to Kelly & Whitton (1995) the Diatom Trophic Index (TDI) is used to monitor water quality and pollution in river waters. TDI calculations are based on the presence of diatoms, such as the abundance and composition of diatom taxa, and also require tolerance data from diatom taxa in waters. Each diatom has a sensitivity value (s) and an indicator value (v) respectively, which are published in Kelly & Whitton (1995) and Kelly (1998). TDI was first developed in rivers located in subtropical areas, but TDI has been widely used in assessing the quality and pollution of river water in the tropics. This is because of the cosmopolitan distribution of diatoms throughout the world, so the application of the Diatom Trophic Index can be used worldwide (Bellinger et al., 2006). One of the diatom studies that has used the diatom trophic index is Pasingi (2014) who conducted research in the Cileungsi River, Bogor Regency.

Based on the results of TDI stations 2 and 3 have values that are not much different and are still in the same category. This is presumably due to the presence of low levels of pollutants in the area. Station 1 is located in a conservation forest area with rare human activities, while Station 2 is located in an ecotourism area and a small agricultural land. Station 2 is suspected of potentially getting an enter pollutant materials from tourism activities and runoff of organic matter from agricultural land. Land use at station 3 is dominated by agricultural land and few settlements so the presence of pollutant compounds can come

from domestic waste and agricultural activities. The condition of station 4 which is in the bad category and eutrophication is thought to be due to high levels of pollutants originating from activities in the watershed, as it is located in an area with more complex human activities. The population density in the area of station 4 which is included in the Jatirejo subdistrict is the highest compared to other stations. According to this condition, station 4 can potentially get water contamination from household domestic waste such as wastewater, garbage, or feces which will later affect abiotic factors in the water.

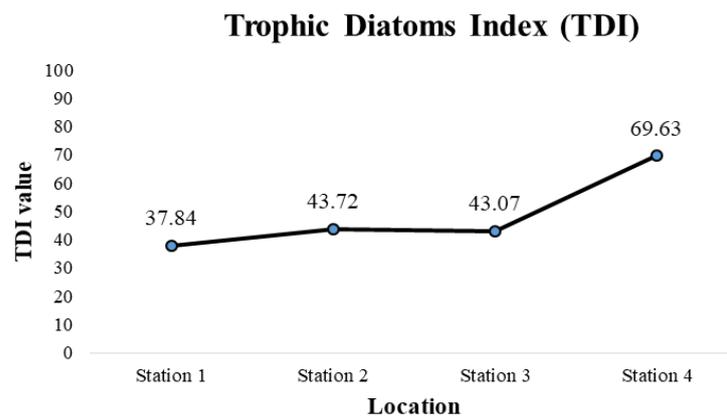


Figure 7. Trophic diatoms index of epilithic diatom in Brangkal Subwatershed Mojokerto

Table 2. Categories of TDI values

Station	TDI value	Ecological Status	Tropical Status (Kelly, 1998)
1	37.59	Good	Oligotrophic/ Mesotrophic
2	43.72	Good	Oligotrophic/ Mesotrophic
3	43.07	Good	Oligotrophic/ Mesotrophic
4	70.46	Bad	Eutrophic

CONCLUSION

Based on the result of this study, the diatom community has the potential as an indicator of water quality. Further research is still needed by observing the diversity of epilithic diatoms in the Brangkal sub-watershed during the rainy season, this aims to obtain data in various seasonal conditions. In addition, ob-

servations on further watersheds covering upstream to downstream also need to be carried out to monitor sustainable water quality.

AUTHOR CONTRIBUTION

B.A.P. designed and supervised all the research and also wrote the manuscript, W.M.LD.S. collected samples from stations

and analysis in the laboratory.

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CONFLICT OF INTEREST

We do not have any conflict of interest. In accordance with that, we as an author have disclosed those interests fully to the journal, and I have in place an approved plan for managing any potential conflicts arising from (that involvement).

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