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Epipelic Diatoms to Determine Ecological Status Based on Diatom Index in Mangrove Ecosystem of Morosari Village, Indonesia

Dian Aghnaita Hasrini[1,2], Tri Retnaningsih Soeprobowati[1,2,3*], Jumari Jumari[1,2]

[1] Departement of Biology, Faculty of Science and Mathematics, Diponegoro University, 50275, Semarang, Indonesia
[2] Cluster for Paleolimnology (Cpalim), Diponegoro University, 50241, Semarang, Indonesia
[3] School of Postgraduate Studies, Diponegoro University, 50275, Semarang, Indonesia
* Corresponding author's e-mail: trsoeprobowati@live.undip.ac.id

ABSTRACT

The mangrove ecosystem of Morosari Village, located in Sayung District, Demak Regency, Central Java, Indonesia, frequent experienced water pollution problems such as tidal flooding, abrasion and pollution due to anthropogenic activities. These problems can lead to further deterioration of water quality. This study aims to use epipelic diatoms to determine the ecological status of waters based on the diatom index in the coastal waters of Morosari Village, Central Java, Indonesia. Sampling was conducted at 3 sampling locations in July-December 2022. Samples from three stations were analyzed based on the diatom index using OMNIDIA software version 6.1.5 and RStudio Software for water quality. Four diatom water quality indices (IBD, IPS, IDG, and TDI index) were obtained percentage value of more than 70% of diatom species. The results of the analysis showed varied ecological status and water quality. Station 1 ranges from 10.9 to 5.2 which is categorized meso-eutrophic to eutrophic in terms of diatom species that dominate *Fallacia pygmaea* and *Nitzschia clausii*, Station 2 ranges from 14.3 to 6.9 which is categorized mesotrophic to eutrophic in terms of species *Diatoma vulgaris* and *Thalassiosira pseudonana*, and Station 3 ranges from 13.9 to 3.5 with diatom species dominating *Cocconeis placentula* and *Nitzschia palea*.

Keywords: Morosari Village, ecological status, epipelic diatoms, diatom index, OMNIDIA.

INTRODUCTION

Indonesia is geographically known as an archipelago rich in biodiversity. Biodiversity in the form of land, freshwater, marine and coastal. Coastal ecosystems such as coral reefs, seagrasses and mangroves, but these ecosystems are threatened due to degradation, around 40% of mangroves are lost, 71% of coral reefs are in poor condition, pollution, and rising sea surface temperatures [Suyadi et al., 2021]. Morosari Village, Demak Regency, Indonesia is a coastal area that has become a mangrove ecotourism area. The existence of mangroves along the waters of Morosari Village greatly supports ecological functions and other coastal ecosystems [Hutami et al., 2018]. Coastal areas have various potential problems such as abrasion, tidal flooding and land subsidence which causes some areas to be below sea level and causes land change mangrove abrasion due to tides [Mulya et al., 2021]. Another cause of abrasion is due to port development activities so that there are changes in current patterns that cause sedimentation, abrasion and mangrove damage in the Morosari mangrove ecosystem area. The coast of Morosari Village has lost some land area and the coastline has regressed due to tidal floods that damage public facilities, houses, and schools that residential areas are close to the sea and the quality of water in the environment is decreasing [Siringoringo et al., 2018]. Water quality can detected by using biological indicators [Arifanti et al., 2022]. One component of the aquatic ecosystem used in monitoring water quality is diatoms. Diatoms

(*Bacillariophyceae*) include unicellular organisms that live in all aquatic environments and are very abundant [Wong et al., 2021]. Epipelic diatoms can respond quickly to environmental changes and can be indicated of pollution caused by human activities [Bere, 2017]. The purpose of this study is to examine the use of epipelic diatoms to determine the ecological status of waters using the diatom index in the coastal waters of Morosari Village, Indonesia.

MATERIAL AND METHOD

Study area

The research was conducted in the waters of the mangrove ecosystem of Morosari Village, Demak Regency, Central Java, Indonesia in June-December 2022. There are 3 sampling stations that have different characteristics with the Purposive Sampling method and the sampling location has activities that have the potential to affect water conditions and diatom distribution. The three sampling stations are: station 1 (M1) (110º 29’2.4 “E; 6º55’30 “S) is a station close to the sea, station 2 (M2) (110°29’5.581 “E; 6°55’33.6 “S) is a station located in the middle of the mangrove ecosystem, and station 3 (M3) (110°29’6.179 “E; 6°55’37.2 “S) station located close to residential areas. Research stations and sampling locations are shown in Figure 1 and Figure 2.

Diatom data collection

Diatom sediments were collected using the Dissection corer method at station 1 (M1), station 2 (M2), and station 3 (M3). Sediments were transferred to a pipe and covered with plastic wrap. Digestion was carried out by heating the sediment for 3 hours using 10% H_2O_2 and 10% HCL to separate the diatoms from the sediment. Then the diatom sample was washed with distilled water until it was not acidic [Nurimanysah et al., 2015]. Diatom samples were prepared using Naprax glue on a glass plate and observed under a microscope with 1000x magnification. Identification of diatoms using references [Krammer and Lange-Bertalot, 2004a, 2004b, 2004c, 2004d], [Gell and Sonneman, 1999], [Sonneman et al., 2000] and the *AlgaBase.org* website.

DATA ANALYSIS

Analysis of water quality based on diatom index using OMNIDIA software version 6.1.5

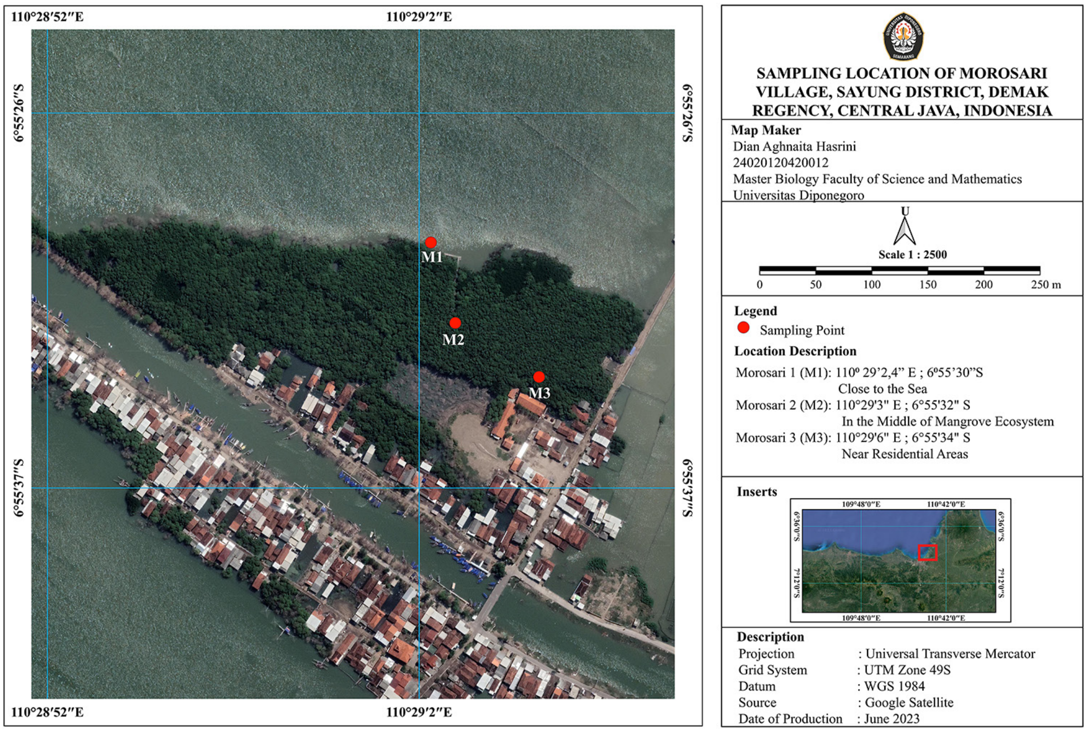

Figure 1. Research station map

Table 1. The index scores and trophic status of diatoms

Index score	Class	Trophy
>17	High	Oligotrophy
15–17	Good	Oligo-mesotrophy
12–15	Moderate	Mesotrophy
9–12	Poor	Meso-eutrophy
<9	Bad	Eutrophy

and RStudio software. The OMNIDIA index can indicate the ecological status of waters and the pollution of organic matter contained in waters. The general ecological status can be rated from 0 to 20. In OMNIDIA, ecological status can be seen based on index scores and trophic status of diatoms (Table 1):

RESULTS AND DISCUSSION

Diatom assemblage

The results of diatom identification obtained as many as 137 species and 46 genus found in 3 research stations: *Achnanthes, Amphipleura, Amphora, Aulacoseira, Bacillaria, Caloneis, Cocconeis, Craticular, Cyclostephanos, Cyclotella, Cymatopleura, Denticula, Diatoma, Diploneis, Discostella, Encyonopsis, Fallacia, Fragilaria, Gyrosigma, Luticola, Mayamaea, Melosira, Navicula, Nitzschia, Pinnularia, Pleurosigma, Simonsenia, Stauroneis, Planothidium, Eolimna, Lemnicola, Staurosira, Surirella, Encyonema, Stephanodiscus, Campylodiscus, Tabularia, Frustulia, Gomphonema, Hantzschia, Cymbella, Tabellaria, Thalassiosira, Asterionella, Tryblionella, Eunotia*.

Diatom biological index

The results of diatom analysis there are 18 diatom indices in OMNIDIA, only 4 indices with a total percentage of more than 70% can reveal diatom species, such as the IBD, IDG, IPS and TDI indices. The use of this diatom has carried out in the Dieng area, Central Java, Indonesia [Sari et al., 2021]. The diatom species found in the index explain the ecological status of the waters. Changes in diatom composition at three stations indicate changes in water quality. Changes that occur based on depth, from the bottom of the depth towards the top of the surface according to the time span of sediment formation.

Figure 2. Sampling stations are: (a) M1 – close to the sea, (b) M2 – in the middle of the mangrove ecosystem, (c) M3 – close to residential areas

The IBD index of Station 1 at a depth of 100–90 cm shows meso-eutrophic ecological status with values ranging from 9.3 to 9.1, but changes at a depth of 80–10 cm to eutrophic with values ranging from 7.9 to 8, the same as shown in the IPS index at a depth of 100–10 cm has eutrophic waters with values ranging from 8.8 to 8.1 while at a depth of 100–20 cm eutrophic waters whose values range from 10 to 9.2 become meso-eutrophic with a value of 8.9 at a depth of 10 cm in the IDG index (Fig. 3). Based on the species found *Cyclotella meneghiniana* and *Nitzschia clausii*. *Cyclotella meneghiniana* is a common aquatic bioindicator species found in the world and is found in brackish and freshwater

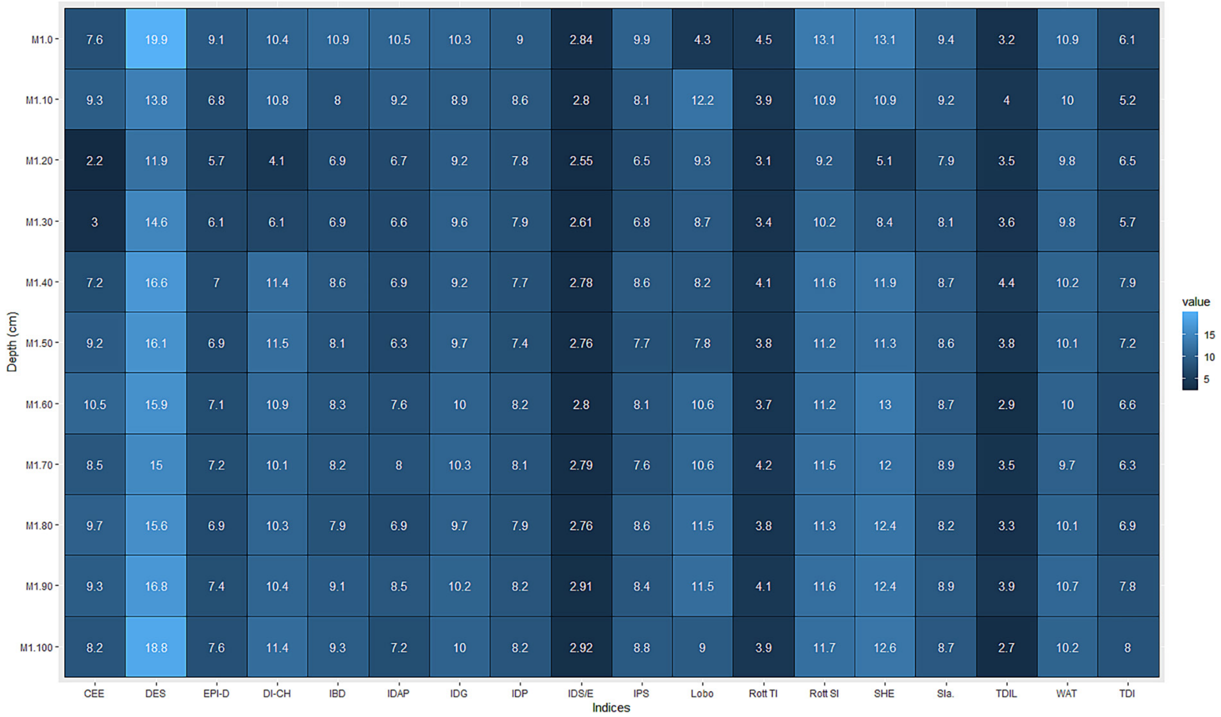

Figure 3. Diatom index at station 1 in mangrove ecosystem of Morosari Village

Figure 4. Percentage of species (%) at station 1 in mangrove ecosystem of Morosari Village

waters with mesosaprobic to polysaprobic ecological status [Hidayat et al., 2019]. The presence of *Nitzschia clausii* species may indicate that the species has tolerance to α-mesosaprobic to eutrophic (heavily polluted) conditions and can live in water depths that have high electrolyte content [Zobi, 2022]. In the IBD index has a value of 10.9, the IPS index with a value of 9.9, and the IDG index with a value of 10.3 in surface waters indicates a meso-eutrophic ecological status. The IDG index gives a species percentage value of 100% for all depths (Fig. 4). Judging from the species found, *Nitzschia irremissa* is a species that is able to adapt and tolerate organic matter or nutrient-rich waters and is found in water conditions that experience moderate to high eutrophication that these diatoms are found on the surface [Saxena et al., 2021]. This criteria indicates that the species is tolerant of the eutrophication that occurs. Eutrophication at the surface occurs due to industrial waste and domestic waste polluting the study site. In accordance with the TDI index at all depths 0–100 cm is categorized as eutrophic with values ranging from 6.1 to 8.

The species found at these depths is *Fallacia monoculata* which is a species that has tolerance to poor waters and tolerant of organic pollution [Juggins, 2003]. Based on the results of OMNIDIA software analysis, it can be seen that there is organic pollution and organic matter content in the waters. High organic pollution occurs at a depth of 70 cm with a value of 53.5 characterized by the species *Fallacia pygmaea* and *Cyclotella meneghiniana*. According to Krammer [1988] *Cyclotella meneghiniana* is s species found in various habitats with tolerance to organic pollution and eutrophication. The occurrence of *Fallacia pygmaea* indicated polluted water conditions [Şahin et al., 2020]. OMNIDIA also analyzes the acidity level at station 1 is alkaline (pH 7.3–7.9) and oxygen demand is classified as moderate (saturation 83–91%). The saprobic status of waters according to [Carayon *et al.*, 2019] is β-mesosaprobic (BOD 1.56-2.14 mg/L) and the level of nitrate nutrients is eunitrophilous (NO_3 13.91–17.84) inicated by species *Diploneis elliptica* and *Fallacia pygmaea*. *Diploneis elliptica* included in oligohalobous-mesohalobous diatoms which are distributed at depth in brackish waters in the mangrove ecosystem in Morosari village [Sugianto et al., 2017]. The halophilic taxon Fallacia pygmaea is representative of relatively heavily polluted urban rivers in China with relatively higher sediment salinity [Chen et al., 2019]. This analysis shows that the quality of water and soil nutrients is strongly influenced by seasons and extreme weather such as heavy rains, which can make water conditions change frequently due to tides [Febriarta, 2020]. Sea tides occur because the station 1 research location is a mangrove ecosystem habitat adjacent to the open sea so that water conditions are classified as meso-eutrophic to eutrophic.

The IBD results of station 2 at 170–150 cm depth had eutrophic water conditions with values ranging from 10.5 to 11.3 and changed at 140 cm depth to mesotrophic with a value of 12.6. However, the water conditions shifted at a depth of 130–110 cm to eutrophic with values ranging from 11.6 to 11.9 and mesotrophic, which is 12.6 at a depth of 100 cm (Fig. 5). This is due to the characteristics of the habitat in the middle of the mangrove ecosystem and there is a mangrove track as a mangrove ecotourism that makes the source of pollution into the waters. At 90-50 cm depth, eutrophic water conditions with values ranging from 12 to 10.7 became mesotrophic which ranged from 12.9 to 14.3 at 40–10 cm depth. This is similar to the IDG index results at a depth of 170–30 cm having eutrophic conditions ranging from 11.1 to 11.8 and changing at a depth of 20–10 cm to mesotrophic with values ranging from 12.4 to 12.5, can be seen from the appearance of species *Thalassiosira pseudonana, Eunotia formica* and *Gyrosigma parkerii. Thalassiosira* diatoms found at all depths are a type of diatom that is widespread in the sea and can live in oligrotrophic, mesotrophic and eutrophic areas [Hutami et al., 2018]. Station 2 is in the middle of a mangrove ecosystem that has a slow flow of sea water. *Eunotia formica* species have been found, these species can survive in wetlands and slow waters such as mesotrophic to oligotrophic water areas with a water pH of 5.6–7.4 [Nardelli et al., 2021; Sari et al., 2018]. Meso-eutrophic or mesotrophic waters are waters that have a moderate level of fertility. Periphytic diatom species *Eunotia formica* can tolerate acidic conditions but most can live in neutral to slightly alkaline conditions [Sari et al., 2021]. Station 2 is a mangrove ecosystem area that has muddy substrate soil with high nutrient content that it is categorized as mesotrophic. At this station *Gyrosigma parkerii* has

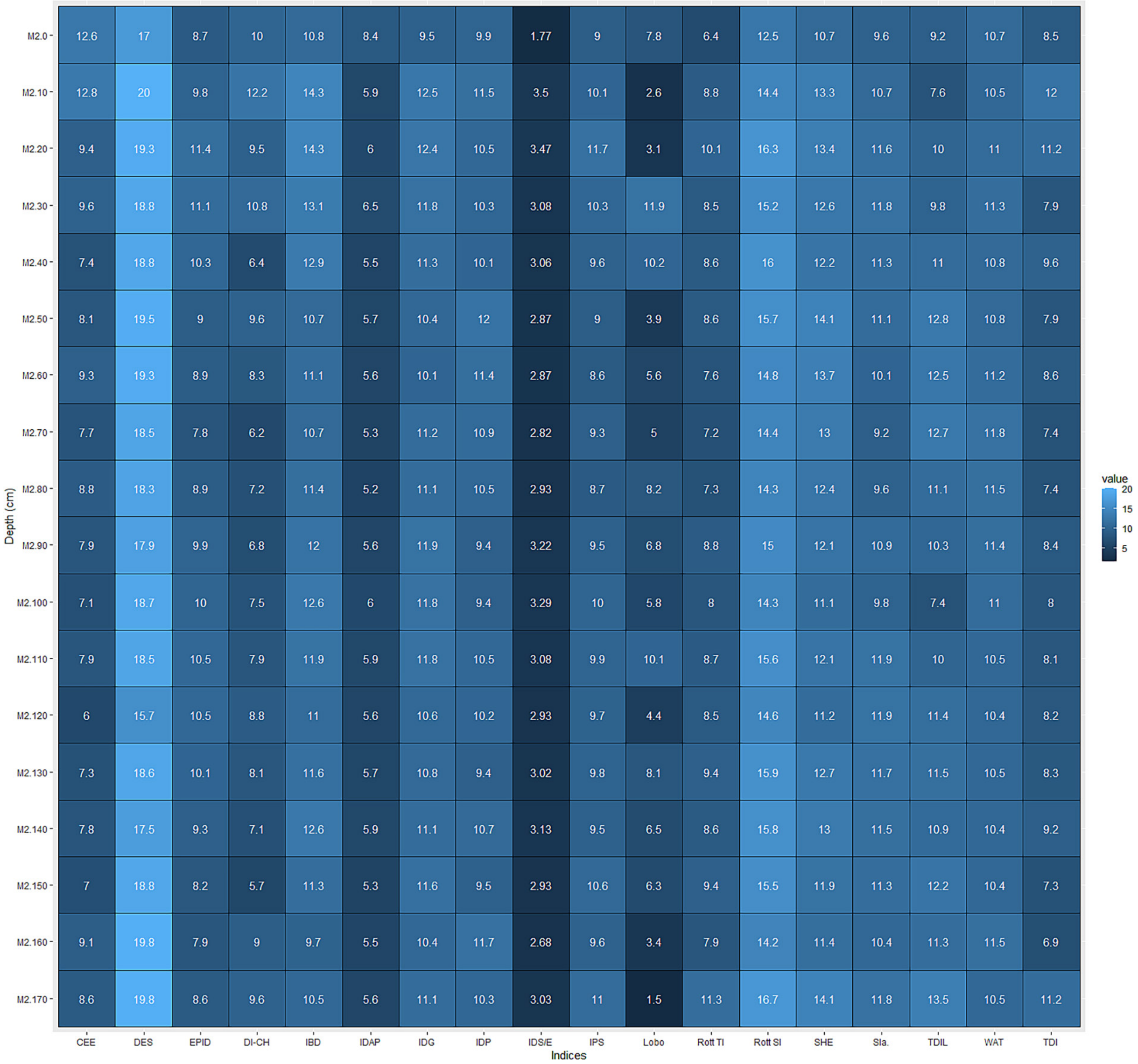

Figure 5. Diatom index at station 2 in mangrove ecosystem of Morosari Village

been found, which is a diatom species capable of inhabiting freshwater and seawater habitats. *Gyrosigma parkerii* is also able to live in mesotrophic waters [Suyadi et al., 2021]. The characteristics of station 2 have oligo-mesonitrophilous to mesonitrophilous nitrate content from the mixing of river water and groundwater from residential areas around the research site as part of the supply of nutrients and mud.

The depth of 160 cm has a high organic pollution of characterized *Diatoma vulgaris*. The emergence of pollution-sensitive *Diatoma vulgaris* in moderately polluted areas and can tolerate mesotrophic to eutrophic waters [Park et al., 2020]. *Diatoma vulgaris* is a cosmopolitan diatom that has been used in diatom pollution indices in Europe and America. Based on the acidity level at station 2, it is in alkaline condition (pH 7.3–7.9). Oxygen demand was high at 170–120 cm depth (91–96% saturation) then changed to medium at 110–10 cm depth (83–91% saturation) and high again at the surface. The level of saprobic status at all depths to the surface has mesosaprobous conditions (BOD 1.14–1.56) and nitrate nutrient content at 170–120 cm depth is in oligo-mesonitrophilous conditions (NO_3 6.10–10.64) to mesonitrophilous (NO_3 10.64–13.91) at 110–100 cm depth then changes back to oligo-mesonitrophilous conditions (NO_3 6.10–10.64) at 90 cm depth to the surface. Characterized by the presence of *Gyrosigma parkerii, Navicula cincta,* and *Fallacia monoculata*. *Gyrosigma parkerii* and *Navicula cincta* indicates that the water has eutrophic status conditions [GÜMÜŞ, 2018].

The discovery of *Fallacia monoculata* at station 1 and station 2 tend to be eutrophic based on organic pollution data with a value of 53.5. *Fallacia monoculata* can also be found in benthic habitats in marine and brackish waters and form communities in estuarine and intertidal areas [Juggins, 2003]. The TDI index at a depth of 170 cm has an ecological status of meso-eutrophic waters with a value of 11.2 to eutrophic with values ranging from 6.9 to 7.3 at a depth of 160–150 cm and changes back to meso-eutrophic with a value of 9.2 at a depth of 140 cm, then changes to eutrophic which ranges from 8.3 to 7.9 at a depth of 130–50 cm. This has similarities with the IPS index at a depth of 170–90 cm which has eutrophic water conditions with values ranging from 11 to 9.5 to meso-eutrophic with a value of 8.7 at a depth of 80 cm. Changes again occur at a depth of 70 cm to eutrophic with a value of 9.3 to meso-eutrophic with a value of 8.6 at a depth of 60 cm. Shown with species *Fragilaria nanana* and *Cyclostephanos dubius*. *Fragilaria nanana* can live in nutrient enriched waters derived from mangrove litter. The presence of *Fragilaria nanana* indicates eutrophic water conditions [Siringoringo *et al.*, 2018]. *Cyclostephanos dubius* was also found at a depth of 110 cm which is a planktonic diatom with a centric shape and lives in high alkalinity waters so it is considered an indicator of eutrophic water conditions [Schroeder et al., 2016].

The TDI value at a depth of 40 cm has meso-eutrophic water conditions with a value of 9.6 to eutrophic with a value of 7.9 at a depth of 30 cm and changes again at a depth of 20–10 cm to meso-eutrophic with values ranging from

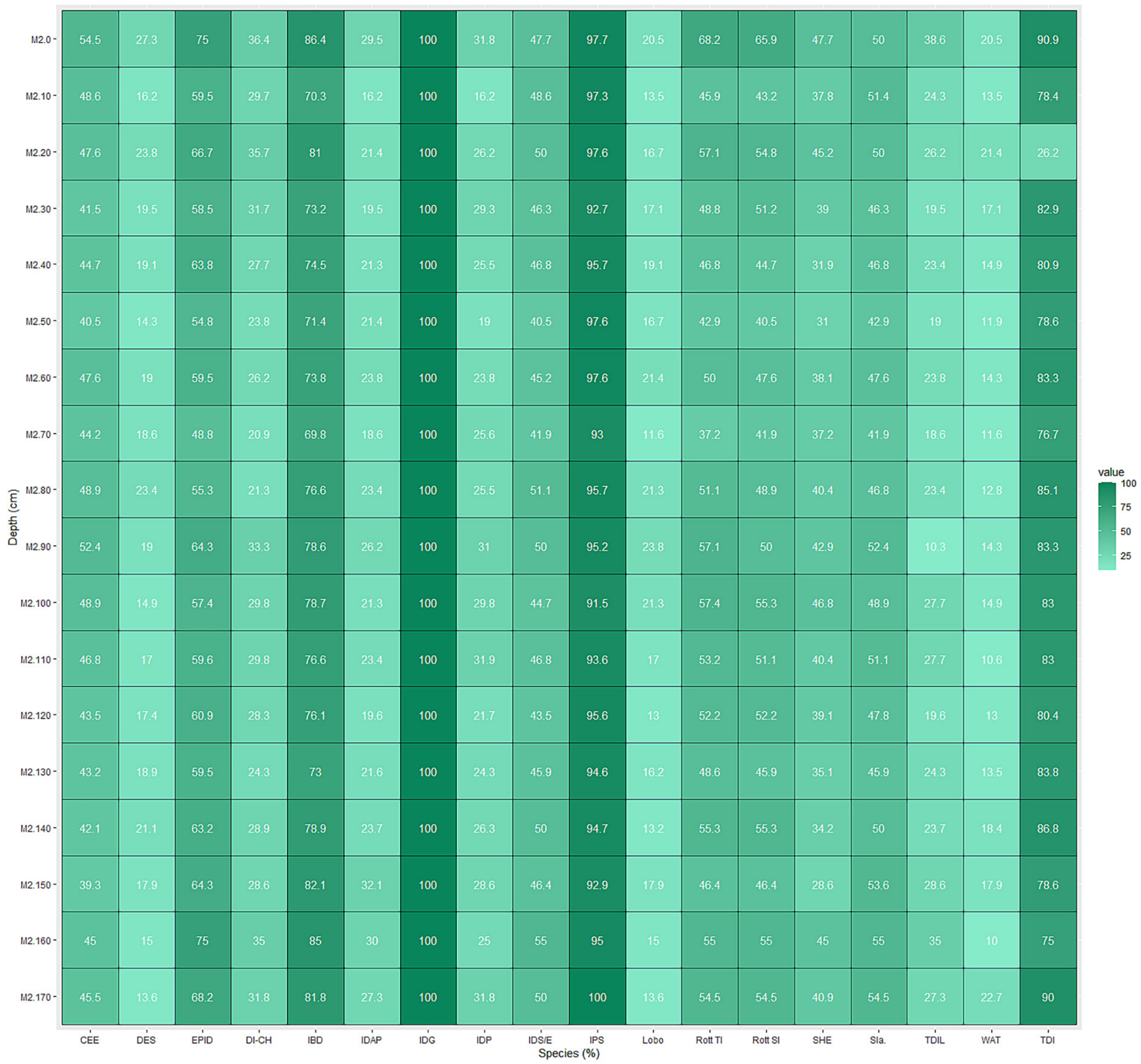

Figure 6. Percentage of species (%) at station 2 in mangrove ecosystem of Morosari Village

11.2 to 12. While the IPS value at a depth of 50 cm to the surface is eutrophic with a value of 9. The diatom species that are able to live in β-mesosaprobic trophic water conditions is *Planothidium engelbrechtii* which can tolerate high concentrations of nutrients and pollutants that show eutrophication and saprobication of water [Mulya et al., 2021].

The surface area shifted to eutrophic based on IBD index with a value of 10.8, the IDG index with a value of 9.5 and TDI index with a value of 8.5. Due to the presence of *Tabularia fasciculata*. The IDG index shows a species value of 100% at a depth of 0–100 cm (Fig. 6). *Tabularia fasciculata* is a seawater diatom that can survive in water conditions with high organic matter content so that it has a high degree of eutrophication [Frederika et al., 2021]. The occurrence of organic pollution in this area is due to the presence of mangrove tourism objects with high tourist activity. The results of the IBD index at station 3 at a depth of 0–160 cm (Fig. 7) have a meso-eutrophic ecological status with a value of 12 to 11.3, because station 3 has the characteristics of a mangrove ecosystem adjacent to residential areas so that there are nutrients due to domestic and industrial waste disposal and aquaculture activities (ponds) that enter the waters indicated by the emergence of species that dominate *Simonsenia delognei* and *Cocconeis placentula*. *Simonsenia delognei* can exist in mesotrophic and eutrophic conditions as a result of weathering erosion of phosphate-containing waters [Li et al., 2019]. While *Cocconeis placentula* species can be found in moderate hydraulic water content [Solak et al., 2019]. *Cocconeis placentula* can

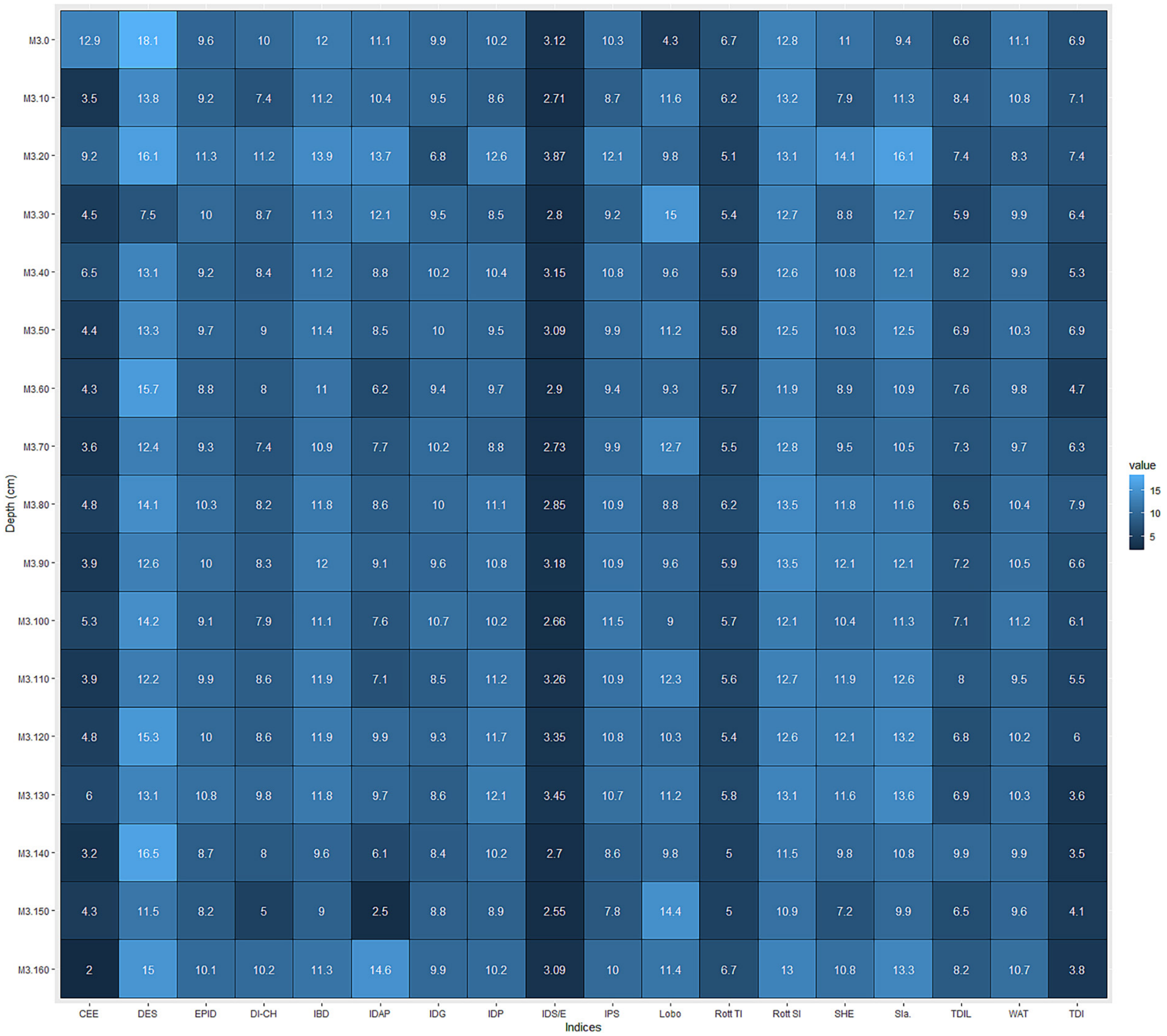

Figure 7. Diatom indexs at station 3 in mangrove ecosystem of Morosari Village

tolerate mesotrophic to eutrophic waters with high nutrient and salinity water conditions.

The IDG index shows 100% species value at all depths (Fig. 8). The ecological status of the IDG index at 160 cm depth showed meso-eutrophic waters with a value of 9.9, but changed at 150–130 cm depth to eutrophic with values ranging from 8.8 to 8.6, indicated by *Fallacia tenera*, a species classified as living in waters with high eutrophication [Panarelli et al., 2021]. The occurrence of changes at this depth is due to anthropogenic factors by human activities resulting in organic pollution and the entry of nutrients into the waters that settle on the previous sediments.

The level of acidity at station 3 is in alkaline conditions (pH 7.3–7.9). At a depth of 150 cm has a high level of organic pollution around 30.7 which is characterized by the presence of *Navicula antonii, Nitzschia palea,* and *Cocconeis placentula*. The appearance of *Navicula antonii* is considered more tolerant of trophic and saprobic conditions [Nugroho, 2019] that occur in these waters. *Cocconeis placentula* and *Nitzschia palea* can be found in waters that have mesotrophic to eutrophic characteristics. According to [Tokatli, 2013] *Cocconeis placentula* and *Cyclotella* species were found to be quite dominant in Porsuk Dam Lake. There is *Nitzschia palea* which is quite dominant in Porsuk Dam Lake which has eutrophic characteristics and highly polluted waters.

High oxygen demand is found at a depth of 160 cm (saturation 91–96%) then becomes moderate (saturation 83–91%) at a depth of 150 cm, changes to high at a depth of 140–30 cm (saturation 91–96%) until it changes to moderate (saturation 83–91%) at a depth of

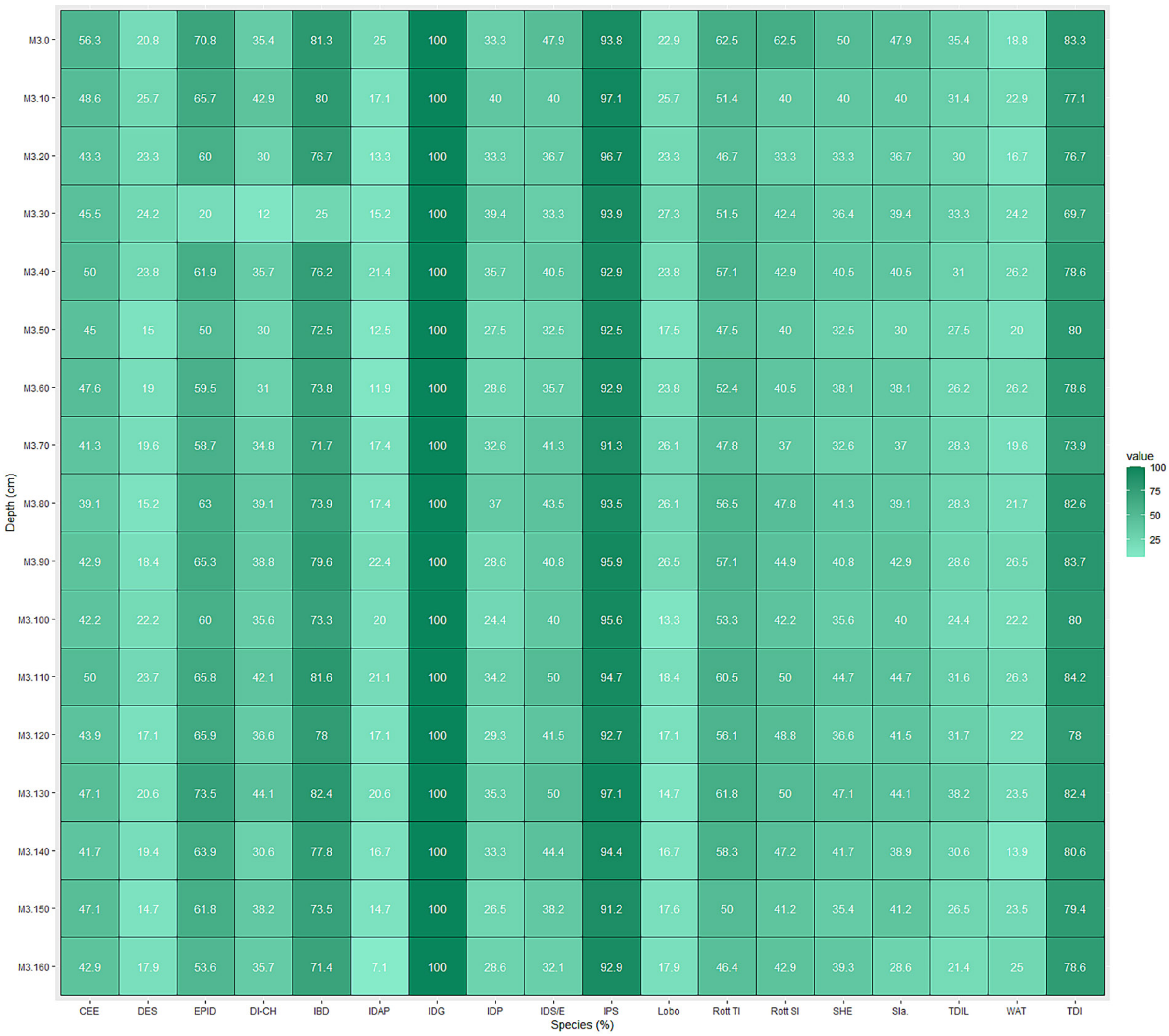

Figure 8. Percentage of species (%) at station 3 in mangrove ecosystem of Morosari Village

30–20 cm and returns to high in the surface area. In these water conditions *Diploneis elliptica* species were found. *Diploneis elliptica* belongs to oligohalobous-mesohalobous diatoms that are distributed at depth in brackish waters [Nugroho, 2019]. The level of saprobic status at all depths to the surface has mesosaprobous conditions (BOD 1.14–1.56) and nitrate nutrient content at a depth of 160 cm is in meso-nitrophilous conditions (NO_3 10.64–13.91) to eunitrophilous (NO_3 13.91–17.84) at a depth of 150–140 cm then changes back to mesonitrophilous conditions (NO_3 10, 64–13.91) at a depth of 130–100 cm, eunitrophilous (NO_3 13.91–17.84) at a depth of 90–80 cm and became mesonitrophilous (NO_3 10.64–13.91) from a depth of 70 to the surface, indicated by the presence *Nitzschia palea* and *Nitzschia clausii*. The high levels of nutrients entering the waters at the site had induced *Nitzschia clausii* which is able to live in poor water quality by organic matter, nutrients and mineral salts. Similar to the emergence of the dominating species *Nitzschia palea*, which is considered tolerant of eutrophication and organic pollution [Zhang et al., 2011, Wang et al., 2019].

The influence of pollution such as the presence of plastic waste carried by ocean currents and trapped in the roots of mangrove plants resulting in mangrove root growth is stressed so that mangrove plants can not protect the coastal area to the maximum, plastic waste can be trapped in the root. The depth of 120–110 cm based on the IDG index there is a change in ecological status from eutrophic to meso-eutrophic with values ranging from 9.3 to 8.5 indicated by *Nitzschia heufleriana*. The *Nitzschia* can move to nutrient-rich areas and live in lotic systems in fine sedimentation [Hanif et al., 2023], which in general fine sediments are at the bottom of the water. There was a change in the IDG index at a depth of 100-30 cm to meso-eutrophic with values ranging from 10.7 to 9.5, indicated by the presence of diatom *Fragilaria ungeriana. Fragilaria ungeriana* species are indicated to be resistant and associated with slightly alkaline environmental conditions. This species is commonly found in temperate mesotrophic waters [Aykut et al., 2021]. This is in accordance with research conducted by [Basmi, 1999] that *Fragilaria* diatoms in Cilalay Pond with a trophic index of around 40–61 which is categorized as mesotrophic to eutrophic.

The IDG index results in surface sediments up to 10 cm have a meso-eutrophic ecological status with values ranging from 9.9 to 9.5 but change at a depth of 20 cm to eutrophic with a value of 6.8 because there is a dominating species such as *Craticula accomodiformis*. The *Craticula* is epipelic and lives in freshwater and brackish water. This diatom thrives in eutrophic habitats and is resistant to organic pollutants with waters that have high electrolyte content [Atici et al., 2018]. Based on its ecological status, through the IPS index at a depth of 160 cm that meso-eutrophic conditions with a value of 10 have changed to eutrophic with values ranging from 7.8 to 8.6 at a depth of 150–140 cm due to the presence of *Denticula creticola* species. The dominant diatom species at this bottom depth is a brackish water species that prefers one type of microhabitat (epilithon) [Nurkhasanah et al., 2019].

The diatom community indicated mesotrophic waters with an abundance of *Denticula* diatoms indicating suitable conditions for their growth so that changes in their relative abundance were used as an indication of past changes in macrophyte abundance [Aykut et al., 2021]. Then shifting to a depth of 20 cm has mesotrophic water conditions with a value of 12.1 and then changes at a depth of 130–30 cm categorized as meso-eutrophic waters with values ranging from 10.7 to 9.2, at a depth of 10 cm to the surface changes from meso-eutrophic to eutrophic with values ranging from 8.7 to 10.3, this is due to the appearance of *Diploneis smithii*. *Diploneis smithii* a polyhalobous diatom which is seawater diatom associated with brackish water diatoms is quite dominant at that depth [Nugroho, 2019]. This coastal area is under pressure from community activities such as industrial activities that cause pollution, abrasion, domestic waste and marine transportation activities at Semarang port which have a negative impact. These activities can pollute the aquatic ecosystem [Ima, 2021]. Based on the TDI index obtained at all depths (0–160 cm) indicated eutrophic waters with values ranging from 6.9 to 3.8. Characterized by the diatom species *Nitzschia palea. Nitzschia palea* is a species tolerant of eutrophication and organic pollution and can show an alkaliphilous environment [Shen et al., 2018; Wang et al., 2019]. According to Krammer [1988] *Nitzschia palea* has tolerance to organic pollution and mesosaprobic to polisaprobic conditions with highly polluted ecological conditions. One of the causes of eutrophication is the input of nutrients, especially phosphorus, which is related to deforestation that occurs at the research site. Based on the condition of the waters at station 3, the waters are in mesotrophic to eutrophic conditions. The increase in trophic status occurs due to the presence of organic waste from mangrove litter and household waste from residential areas. These activities make the waters highly polluted [Utami et al., 2021].

There are variation diatom species that dominate at the depth of each station has variations. *Nitzschia clausii* species found at the bottom of the depth can indicate that the species has a tolerance of meso-eutrophic to eutrophic waters. The presence of *Fallacia pygmaea* and *Cyclotella meneghiniana* that dominate station 1 shows that eutrophication waters and tolerate polluted waters. Station 1 changes in ecological status (IBD, IDG, IPS and TDI indices) that occur from the bottom of the depth towards the top of the surface (100–0 cm) with values ranging from 10.9 to 5.2 on Table 1 which indicate station 1 is meso-eutrophic to eutrophic waters. *Fallacia pygmaea* can be associated in mangrove environments that have many nutrients on the Coast of Hungary. *Cyclotella meneghiniana* identified in rivers to be indicators for mesotrophic waters with water temperature, pH, conductivity, phosphate and nitrate values higher and lower dissolved oxygen due to industrial pollution occurring in Tohma Stream (Malatya, Turkey) [Oliveira et al., 2022, Yildirim et al., 2019].

The presence of *Diatoma vulgaris* indicates organic polluted waters at station 2. *Diatoma vulgaris* is a species that describes the conductivity and high salinity found in nutrient-rich waters with poor oxygen downstream of the Tuntang River, Central Java [Al-Falah, 2023]. The discovery of *Thalassiosira pseudonana* and *Gyrosigma parkerii* that dominate from the bottom to the surface (170–0 cm) with values (IBD, IDG, IPS and TDI indices) ranging from 14.3 to 6.9 which indicates station 2 in mesotrophic to eutrophic waters. *Thalassiosira pseudonana* is indicated to be able to survive in poor aquatic conditions such as high salinity and low trophic conditions in Hungary and *Gyrosigma parkerii* is affected by higher conductivity and is affected by high nutrient concentration levels (N and P) and low DO as a result of anthropogenic disturbances in the Myristica Swamp in the Western Ghats, India [B-Béres et al., 2022; Thacker, 2022]. The ecological status at station 3 is not much different based on the analysis of OMNIDIA diatom water quality with values (IBD, IDG, IPS and TDI indexes) ranging from 13.9 to 3.5 showing mesotrophic to eutrophic waters at bottom to surface depths (160–0 cm) indicating dominating species such as *Cocconeis placentula* and *Nitzschia palea* which indicate waters polluted with organic matter. *Cocconeis placentula* species is positively correlated with NO_3 can survive in waters with high nutrient concentrations in the Coastal Area of Port Dickson, in Negeri Sembilan, Malaysia, and the *Nitzschia palea* was the most common species found in inland waters and abundant in nutrient salt rich and poor oxygen in Mersin Rivers, Turkey [Everest, 2016; Sas, 2022].

Table 2. Trophic status of three stations of mangrove ecosystem water in Morosari Village

Stations	Trophic status
Station 1	Meso-eutrophic to eutrophic
Station 2	Mesotrophic to eutrophic
Station 3	Mesotrophic to eutrophic

The results of ecological status at the three stations of the mangrove ecosystem in Morosari Village can be seen in the Table 2. This study may provide evidence that diatom assemblages reflect the environmental conditions and ecological status of soil and water degradation by natural factors in the tropics and human activities especially organic pollution and eutrophication.

CONCLUSIONS

Based on the results of the analysis conducted at 3 sampling locations in the waters of the mangrove ecosystem in Morosari Village. It has been found 137 species of diatoms and 46 genera. The results of the OMNIDIA analysis based on the diatom index produced four indices (IBD, IPS, IDG, and TDI index) which can give rise to diatom species with more than 70% species. The condition of ecological status based on the diatom index at station 1 ranges from 10.9 to 5.2 with the category of meso-eutrophic to eutrophic can be seen from the diatom species that dominate *Fallacia pygmaea, Cyclotella meneghiniana* and *Nitzschia* *clausii.* Station 2 ranges from 14.3 to 6.9 with the mesotrophic to eutrophic category can be seen from the diatom species that dominate *Diatoma vulgaris, Thalassiosira pseudonana* and *Gyrosigma parkerii.* Station 3 ranging from 13.9 to 3.5 shows the mesotrophic to eutrophic category can be seen from the diatom species that dominate *Cocconeis placentula* and *Nitzschia palea.* Pollution that occurs is caused by several factors such as tides, high organic matter in waters and due to anthropogenic activities.

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REFERENCES

1. Al Falah M.H., Soeprobowati T.R., Hadiyanto. 2023. Epipelic Diatom Assemblages to Determine Water Quality in The Tuntang River Downstream, Demak, Central Java. IOP Conf. Ser. Earth Environ. Sci., 1137(1).
2. Arifanti V.B., Sidik F., Mulyanto B., Susilowati A., Wahyuni T., et al. 2022. Challenges and Strategies for Sustainable Mangrove Management in Indonesia: A Review. Forests, 13(5), 1–18.
3. Atici T., Tokatli C., Cicek A. 2018. Diatoms of Seydisuyu Stream Basin (Turkey) and Assessment of Water Quality by Statistical and Biological Approaches. Sigma J. Eng. Nat. Sci., 36(1), 271–88.
4. Aykut T.O., Balkis-Ozdelice N., Durmus T., Solak C.N. 2021. Evaluation of The Relationship Between Epiphytic Diatoms and Water Quality Parameters in The Büyükçekmece Reservoir. Eur. J. Biol., 80(1), 54–68.
5. B-Béres V., Stenger-Kovács C., Buczkó K., Padisák J., Selmeczy G.B., et al. 2022. Ecosystem Services Provided by Freshwater and Marine Diatoms. Hydrobiologia.
6. Basmi J. 1999. Planktonologi : Biologi Plankton Algae
7. Bere T. 2017. Challenges of Diatom Based Biological Monitoring and Assessment on Stream in Developing Countries. Environmental Sci Polutt Res.
8. Carayon D., Tison-Rosebery J.D.F. 2019. Defining a New Autoecological Trait Matrix for French Stream Benthic Diatoms. Ecol. Indic., 103, 650.
9. Chen S., Zhang W., Zhang J., Jeppesen E., Liu Z., et al. 2019. Local Habitat Heterogeneity Determines The Differences in Benthic Diatom Metacommunities Between Different Urban River Types. Sci. Total Environ., 669, 711–20.
10. Everest A., Aslan D.C. 2016. Seasonal Diatom Density Investigation of The Mersin Rivers. World J. Res. Rev., 2(5), 21–30.
11. Febriarta E. 2020. Kajian Kualitas Air Tanah Dampak Intrusi di Sebagian Pesisir Kabupaten Tuban. J. Geogr. Media Inf. Pengemb. dan Profesi Kegeografian, 17(2), 39–48.
12. Frederika Y.C., Ihsan Y.N., Riyantini I. 2021. Nutrient Profile and Mangrove Vegetation Composition in. J. Ilmu Kelaut. SPERMONDE, 7(1), 42–51.
13. Gell, P.A., Sonneman J.A. IMA& SJA. 1999. An Illustrated Key to Common Diatom Genera from Southern Australis. Cooperative Research Centre for Freshwaater Ecology Identification Guide, 26, Albury.
14. Gümüş F. 2018. Epilithic Diatom-Based Ecological Assessment in Taşmanli Pond (Sinop, Turkey). Trak. Univ. J. Nat. Sci., 19(1), 71–76.
15. Hanif M., Falah A., Soeprobowati T.R., Rahim A., Noor B.M., Permatasari N. 2023. Diatom Stratigraphy as a Flood Record in the Lower Tuntang River, Demak, Central Java, 10(1), 272–82.
16. Hidayat S., Husnia F., Rohmah E., Mukhlishoh S. 2019. Study on Diversity of Dragonfly (Odonata) as A Bioindicator of Water Quality in Mount Muria Area, Central Java. J. Nat. Sci. Math. Res., 5(2), 53–61.
17. Hutami G.H., Muskananfola M.R., Sulardiono B. 2018. Analisis Kualitas Perairan Pada Ekosistem Mangrove Berdasarkan Kelimpahan Fitoplankton dan Nitrat Fosfat di Desa Bedono Demak. Manag. Aquat. Resour. J., 6(3), 239–46.
18. Ima Nurmalia Permatasari. 2021. Kajian Resiko, Dampak, Kerentanan dan Mitigasi Bencana Abrasi di Beberapa Pesisir Indonesia. J. Ris. Kelaut. Trop. (Journal Trop. Mar. Res., 3(1), 56.
19. Juggins S. 2003. User Guide C2. Software For Ecological And Palaeontological Data Analysis And Visualisation. User Guide Version, 1.6.
20. Krammer K., Lange-Bertalot H. 1988. Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. In: Sußwasserora von ¨ Mitteleuropa, Bd. 2/2. H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer (eds.): 1-596. Gustav Fischer Verlag, Stuttgart.
21. Krammer K., Lange-Bertalot H. 2004. Subwasserflora Von Mitteleuropa, Bd. 02/1: Bacillariophyceae: Teil 1: Naviculaceae. Spectrum. Berlin.
22. Krammer K., Lange-Bertalot H. 2004. Subwasserflora Von Mitteleuropa, Bd. 02/2: Bacillariophyceae: Teil 2: Bacillariphyceae, Epithemiaceae, Surirellaceae. Spectrum.
23. 23.Krammer K., Lange-Bertalot H. 2004. Subwasserflora Von Mitteleuropa, Bd. 02/3:

Bacillariophyceae: Teil3: Centrales, Fragillariaceae, Eunotiaceae. Spectrum, Berlin. Berlin.
24. Krammer K., Lange-Bertalot H. 2004. Subwasserflora Von Mitteleuropa, Bd. 02/4: Bacillariophyceae: Teil 4: Achanthes S.I., Navicula Sstr. Spectrum,. Berlin
25. Li W., El-Askary H., Qurban M.A., Li J., Mani-Kandan K.P., Piechota T. 2019. Using Multi-Indices Approach to Quantify Mangrove Changes Over The Western Arabian Gulf Along Saudi Arabia Coast. Ecol. Indic., 102, 734–45.
26. Mulya H., Santosa Y., Hilwan I. 2021. Comparison of Four Species Diversity Indices in Mangrove Community. Biodiversitas, 22(9), 3648–55.
27. Nardelli M.S., Bicudo D.C., Sampaio S.C., Cordovil C.M.D.S. 2021. Structure and Species Composition of Diatom Community during The Wet Season in Three Floodplain Lakes of Brazilian Pantanal. PLoS One, 16(5 May), 1–22.
28. Nugroho septriono hari. 2019. Karakteristik Umum Diatom dan Aplikasinya Pada Bidang Geosains Oleh Septriono Hari Nugroho 1). J. Oseana., XLIV, 70–87.
29. Nurimansyah E., Soeprobowati T.R., Murningsih. 2015. Distribusi Vertikal Diatom Epipelik di Muara Sungai Banjir Kanal Timur Semarang. J. Akad. Biol., 4(4), 1–7.
30. Nurkhasanah D., Ambariyanto, Suprijanto J., Yulianto B., Sunaryo, Pusparini N. 2019. Accumulation of Heavy Metals Pb, Cu, Zn in the Water and Sediment in Cirebon and Demak. IOP Conf. Ser. Earth Environ. Sci., 246(1).
31. Oliveira F.R., Cardozo A.Y.V., Gomes D.F. 2022. Ecological Assessment of Recent Anthropogenic Impacts on an Estuarine Ecosystem Based on Benthic Diatom Assemblages. Reg. Stud. Mar. Sci., 52, 102294.
32. Panarelli E.A., Nielsen D.L., Holland A. 2021. Cladocera Resting Egg Banks in Temporary and Permanent Wetlands. J. Limnol., 80(1).
33. Park J., Lee J., Lee H., Park J. 2020. Study on Timber Yield Regulation Method using Probability Density Function., 109(4), 504–11.
34. Şahin B., Akar B., Barinova S. 2020. Bioindication of Water Quality by Diatom Algae in High Mountain Lakes of the Natural Park of Artabel Lakes, (Gümüşhane, Turkey). Transylvanian Rev. Syst. Ecol. Res., 22(1), 1–28.
35. Sari K., Hidayat J.W., Soeprobowati T.R. 2018. Community Structure and Species Diversity of Diatom in Area Between Telaga Warna and Telaga Pengilon Pengilon, Indonesia, 7(11), 1–6.
36. Sari K., Soeprobowati T.R. 2021. Impact of Water Quality Detorioration in Mangrove Forest in Semarang Coastal Area. Indones. J. Limnol., 2(2), 37–48.
37. Sari K., Soeprobowati T.R., Jumari J., Hariyati R., Miller J.R. 2021. Trace Metals and Diatom Stratigraphy Along The Sill Between Lakes Telaga Warna and Telaga Pengilon, Dieng, Central Java, Indonesia. Sustain, 13(7).
38. Sas A.A., Suriyanti S.N.P., Das S.K., Cob Z.C. 2022. Effect of Seawater and Surface-Sediment Variables on Epipelic Diatom Diversity and Abundance in the Coastal Area of Negeri Sembilan, Malaysia. Water (Switzerland), 14(19).
39. Saxena A., Tiwari A., Kaushik R., Iqbal H.M.N., Parra-Saldívar R. 2021. Diatoms Recovery From Wastewater: Overview from an Ecological and Economic Perspective. J. Water Process Eng., 39 (September 2020), 101705
40. Schroeder L.A., Martin S.C., Kerns G.J., McLean C.E. 2016. Diatom Assemblages in a Reservoir Sediment Core Track Land-Use Changes in The Watershed. J. Paleolimnol., 55(1), 17–33.
41. Shen R., Ren H., Yu P., You Q., Pang W., Wang Q. 2018. Benthic Diatoms of The Ying River (Huaihe River Basin, China) and Their Application in Water Trophic Status Assessment. Water (Switzerland), 10(8).
42. Siringoringo H.H., Narendra B.H., Salim A.G. 2018. Water Quality of Mangrove at Ciasem, Pamanukan, Subang District, West Java. J. Pengelolaan Sumberd. Alam dan Lingkung. (Journal Nat. Resour. Environ. Manag., 8(3), 301–7.
43. Soeprobowati T.R., Anggoro S., Puryono S., Purnaweni H., Sularto R.B., Mersyah R. 2022. Species Composition and Distribution in the Mangrove Ecosystem in the City of Bengkulu, Indonesia. Water (Switzerland), 14(21).
44. Solak C.N., Alakananda B., Kulikovskiy M., Blanco S., Kaleli A., Yilmaz E. 2019. Distribution of Nitzschioid Diatoms in Kütahya Waters. Oceanol. Hydrobiol. Stud., 48(2), 140–64.
45. Sonneman J.A., Sincock A., Fluin J., Reid M., Newall P., Tibby J., And Gell P. 2000. An Illustrated Guide To Common Stream Diatom Species From Temperate Australia. Cooperative Research Centre For Freshwater Ecology, Identification Guide No. 33. NSW.
46. Sugianto D.N., Widada S., Wirasatriya A., Ismanto A., Darari A., Suripin. 2017. Modelling of Suspended Sediment Transport in Coastal Demak Indonesia by Using Currents Analyzing. ARPN J. Eng. Appl. Sci., 12(16), 4666–78.
47. Suyadi, Nugroho D.A., Irawan A., Pelasula D., Ruli F., et al. 2021. Biodiversity in The Coastal Ecosystems of Small Islands and its Conservation Status. IOP Conf. Ser. Earth Environ. Sci., 762(1).
48. Thacker M., Karthick B. 2022. Response of Diatoms to the Changing Water Quality in the Myristica Swamps of the Western Ghats, India. Diversity, 14(3), 1–21.
49. Tokatli C. 2013. Evaulation of Water Quality by Using Trophic Diatom Index: Exaple of Porsuk Dam Lake. J. Appl. Biol. Sci., 7(1), 1–4.

50. Utami W., Wibowo Y.A., Hadi A.H., Permadi F.B. 2021. The Impact of Mangrove Damage on Tidal Flooding in The Subdistrict of Tugu, Semarang, Central Java. J. Degrad. Min. Lands Manag., 9(1), 3093–3105
51. Wang J., Liu Q., Zhao X., Borthwick A.G.L., Liu Y., et al. 2019. Molecular Biogeography of Planktonic and Benthic Diatoms in The Yangtze River. Microbiome, 7(1), 1–15.
52. Wong W.Y., Al-Ani A.K.I., Hasikin K., Khairuddin A.S.M., Razak S.A., et al. 2021. Water, Soil and Air Pollutants' Interaction on Mangrove Ecosystem and Corresponding Artificial Intelligence Techniques Used in Decision Support Systems - A Review. IEEE Access, 9, 105532–63.
53. Yildirim V., Baran N. 2019. the Relationship Between Epilithic Diatom Communities and Water Quality Variations Across Tohma Stream (Malatya-Turkey).
54. Zhang N., Fan Y., Liu Y. 2011. Relationship Between Diatom Communities and Environmental Conditions at Honghe Wetland, China. African J. Biotechnol., 10(76), 17506–18.
55. Zobi F. 2022. Diatom Biosilica in Targeted Drug Delivery and Biosensing Applications: Recent Studies. Micro., 2(2), 342–60.