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Research Article

Phytoplankton Diversity as a Bioindicator of Water Quality Mangrove Ecosystems in Clungup Mangrove Conservation, Kondang Merak and Sempu Island, Malang Regency

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ABSTRACT
Local community groups have handled damage to the mangrove ecosystem on the coast of South Malang by carrying out restoration. The purpose of this study was to evaluate water quality in the restoration mangrove ecosystem based on phytoplankton diversity as bioindicators. A water and phytoplankton sampling was repeated three times with a depth of about 10-15 cm (below the surface water) at each location consisting of 4 restored mangrove ecosystems in Clungup Mangrove Conservation (CMC) and Kondang Merak as well as one natural mangrove ecosystem in Teluk Semut, Sempu Island, Malang Regency. Water quality parameters include water temperature, air temperature, conductivity, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), nitrate, and orthophosphate content. The biotic index includes the Trophic Diatom Index (TDI) as an indicator of water nutrient content and Percentage Pollution Tolerance Value (%PTV) as an indicator of organic pollution. The water quality in the five mangrove ecosystems of CMC, Kondang Merak, and Teluk Semut has met the water quality standard for marine biota except for DO, nitrate, and orthophosphate content in several locations. Water quality in five mangrove ecosystems CMC, Kondang Merak, and Teluk Semut based on phytoplankton indicators did not show any contamination with toxic materials (H'). Based on TDI, it is categorized as eutrophic – hypereutrophic, except at the reference site of Teluk Semut mangrove; based on PTV polluted with moderate to high organic matter except at the reference site locations, namely Teluk Semut, and CMC 2. Thus, a location that has good phytoplankton bioindicators is Teluk Semut.

INTRODUCTION
Mangrove vegetation combines coastal and lowland plant communities in tidal or brackish areas (Serosero et al. 2020). Mangrove vegetation is the most productive ecosystem and has high economic value as building materials, medicines, industrial raw materials, and food ingredients (Giri et al. 2008; Khairnar et al. 2013). Mangrove ecosystems also have an ecological function to protect the coast from abrasion, a source of germplasm, prevent seawater intrusion, and provide a place to live for aquatic, land, and air biota (Asuk et al. 2018; Saputra et al. 2020). Howev-

er, rampant human disturbances in the mangrove ecosystem, such as exploitation of biota, logging, industry, shrimp ponds, and agriculture, have reduced most of the mangrove forest area (Malik et al. 2015; Nichols et al. 2019; Bao et al. 2020).

Mangrove forest covered 18,253,871 hectares in East Java in 2013 (Saputro et al. 2009). 344 hectares located on the southern shore of Malang Regency (Imaduddien & Krisnadi 2020). Mangrove forests of south Malang are scattered on Kondang Merak, Balekambang, Clungup Mangrove Conservation (CMC), Sendang Biru, and Sempu Island. From 1998 to 2010, the mangrove forests that suffered the worst damage were in the Kondang Merak Beach, Sendang Biru, and Clungup Mangrove Conservation areas. The damage was caused by land conversions, such as forest fires, tourist attractions, plantations, and agriculture (Ridhoi et al. 2020; Rudianto et al. 2020). Continuous damage to mangrove ecosystem will cause a decrease in ecosystem services. The decline in ecosystem services reduces the biophysical quality of mangrove forest ecosystems and the surrounding environment, such as loss of habitat for biota, coastal abrasion, flooding, and decreased water productivity (Rahmania et al. 2019). Restoration is one of the best solutions to this problem (Amalia et al. 2018). Restoration is a program of planting or rearranging damaged ecosystems back to their original functions, such as ecosystems at the reference site (López-Portillo et al. 2017). One example of a beach implementing a mangrove restoration program is CMC Beach and Kondang Merak Beach. CMC Beach restoration began in 2005, while at Kondang Merak Beach, it began in 2008 (Hakim et al. 2017; Ridhoi et al. 2020). To find out whether the quality of the mangrove ecosystem is good or bad, an unspoiled comparison location is used, namely Teluk Semut mangrove ecosystem in Sempu Island. Sempu Island is an area that has a natural mangrove ecosystem and is a protected area as a Nature Reserve (Hakim et al. 2017). The success of mangrove ecosystem restoration can be evaluated by monitoring mangrove ecosystem services, one of which is using the assessment of supporting services. The assessment may include measurement of the water physicochemical, whereas the biological quality can be assessed using community structure and phytoplankton diversity as bioindicators.

Phytoplankton is microorganisms that live passively floating in the waters. Phytoplankton in aquatic ecosystems plays a role as the primary source of producers, regulating nutrient cycles, stabilizing marine sediments, and utilizing organic matter (Effendi et al. 2016; Hilmi et al. 2020; Inyang & Wang 2020). Phytoplankton can be a bioindicator because it has a short life cycle and can respond quickly to environmental changes (Hilmi et al. 2020; Febriansyah & Retnaningdyah 2021). Phytoplankton survival is supported by good and measurable physicochemical quality of water, including pH, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), conductivity, temperature, and turbidity (Singh et al. 2017). Therefore, it is necessary to evaluate the mangrove ecosystem's water quality based on the phytoplankton community's structure as a bioindicator in Clungup Mangrove Conservation, Kondang Merak, and Sempu Island, Malang Regency, East Java.

MATERIALS AND METHODS

Study area

The research was carried out from September to December 2021. The location of water and phytoplankton sampling was carried out in the mangrove ecosystem at Clungup Mangrove Conservation (CMC), Kondang Merak Beach, and Sempu Island, Malang Regency, East Java

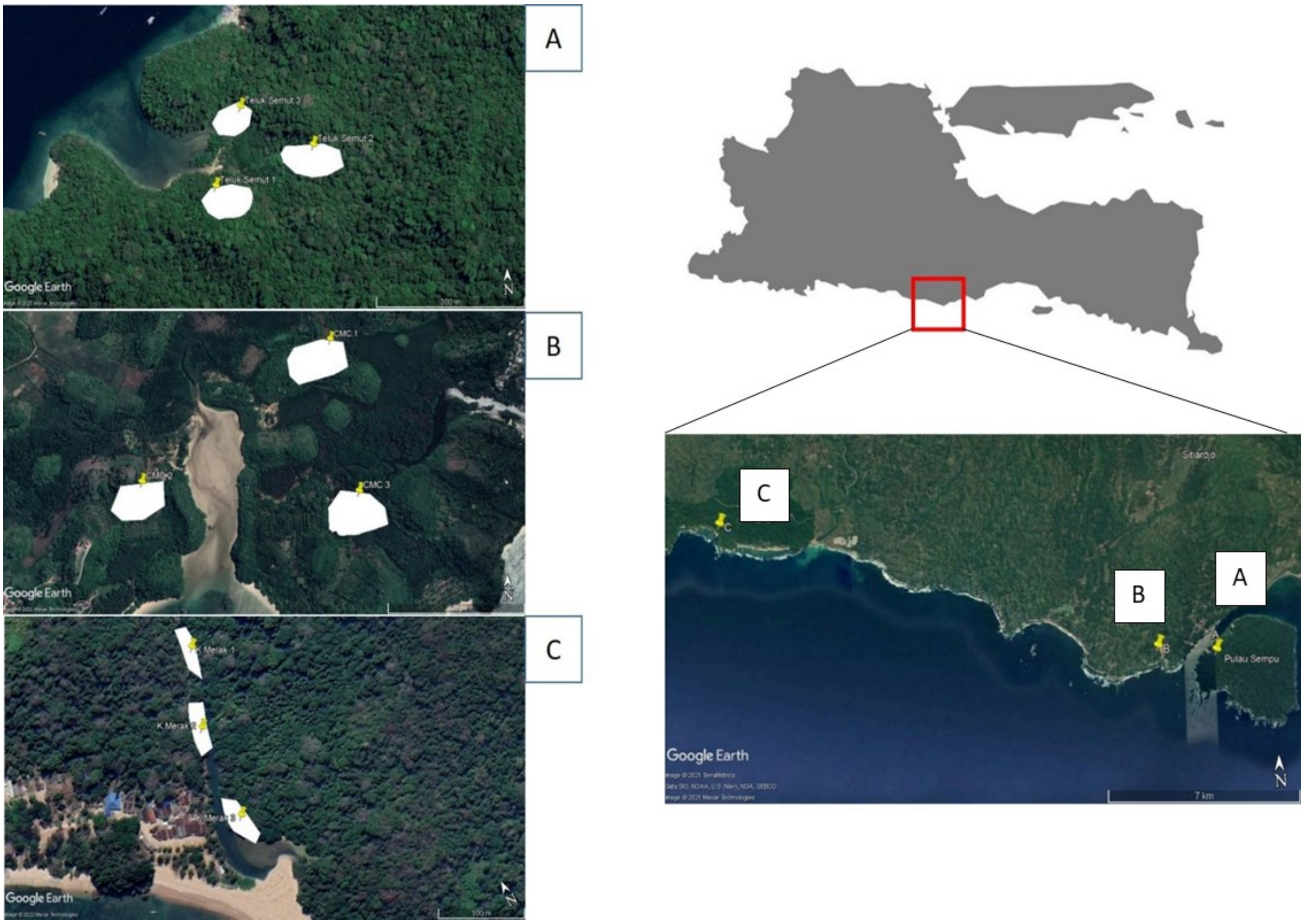

Figure 1. Sampling location at the coast of South Malang. (Note: A = Teluk Semut (Sempu Island); B = Clungup Mangrove Conservation; C = Kondang Merak).

(Figure 1). Phytoplankton identification was conducted at the Laboratory of Ecology, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, East Java.

Sampling locations at the Clungup Mangrove Conservation (CMC) area was carried out at three different stations, namely CMC1 (the results of the restoration in 2015), CMC2 (the mangrove ecosystem remaining from the 2008 fires, which were restored periodically), and CMC3 (the natural mangrove ecosystem). The research location at Kondang Merak Beach consists of only one site, namely the mangrove ecosystem which was rehabilitated in 2019. A sampling at the Sempu Island mangrove ecosystem was carried out at Teluk Semut. Teluk Semut is the Reference site in this study because it has a natural mangrove ecosystem and is protected as a Natural Reserve. The water and phytoplankton samplings were carried out in triplicates at each location.

Phytoplankton Sampling, Identification, and Counting

Phytoplankton samples were taken by filtering 4 liters of water at a depth of ± 15 cm (below the water surface) using a plankton net. The phytoplankton sample was transferred to a sample bottle, then 1 mL of 4% formalin and 0.5 mL of $CuSO_4$ were added. Phytoplankton observations were done by dropping 1 mL of sample water into the Sedgewick-Rafter cell counting chamber. Next, the sample was observed under a light microscope with a magnification of ×200 (APHA 2005). Identification of phytoplankton by comparing the species observed with the images in the identification manual (Gell et al. 1999; Du Buf & Bayer 2002; Van

Vuuren et al. 2006; Bellinger & Sigee 2010). Phytoplankton samples were observed in 500 boxes in the Sedgewick Rafter Chamber which were counted at each station. Cell density was calculated according to the equation (Effendi et al. 2016):

$$K = \frac{1}{A} \times \frac{B}{C} \times \frac{V}{v} \times n$$

Notes:
K : phytoplankton abundance (ind/L);
A : volume of filtered water sample (L);
B : total area/container area of Sedgwick-Rafter Counting Cell (mm^2);
C : observation area (mm^2);
V : volume of filtered water (mL);
v : concentrate volume of Sedgwick Rafter Counting Cell (mL);
n : number of observed phytoplankton

Water Sampling and Measurement of Water Physicochemical's Parameters

Water physicochemical's parameters were measured at each specified location. 1.5 L of water samples were taken using a water sampler at a depth of ± 15 cm (below the water surface). The depth is only around the water surface because the water depth at each location is shallow. The parameters measured consisted of physical and chemical properties of water, namely water temperature, air temperature, pH, conductivity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), nitrate, and orthophosphate content (Table 1).

Table 1. Physicochemical parameters of water with its measurement method.

Parameter	Unit	Tool/Method
Water temperature	°C	Thermometer
Air temperature	°C	Thermometer
pH	-	pH meter
Conductivity	Siemens/meter	Conductivity meter
DO	mg/L	DO meter
BOD	mg/L	Winkler Method
Nitrate	mg/L	Colorimetric
Orthophosphate	mg/L	Colorimetric

Data Analysis

Analysis of the profile of community structure and phytoplankton diversity included The Importance Value Index (IVI), Shannon-Wiener Diversity Index (H'), Dominance Index (Id) and Evenness Index (E) were done based on the formula from Wu et al. (2014). Analysis of physical, chemical, and biological parameter data at each location was carried out using descriptive analysis (minimum & maximum values). In addition, to determine the correlation between the physicochemical properties of water and the biotic index, a biplot analysis was performed using PAST 16.0 software.

Analysis related to community structure and phytoplankton diversity calculated, among others, Importance Value Index (IVI), Simpson Dominance Index (Id), Evenness Index (E), Shannon-Wiener Index and Diversity (H'). Analysis of phytoplankton data related to the level of pollution of organic matter in the waters uses the biotic index of phytoplankton, namely the Trophic Diatom Index (TDI), and % Pollution Tolerant Value (% PTV). Trophic Diatom Index (TDI) is an index to determine the level of nutrients in the waters. Species counted in TDI analysis, i.e. species included in diatoms only based on Kelly & Whitton (1995).

The equation used to determine the TDI value index (Wu et al. 2014):

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

Where, WMS is the weighted average sensitivity and can be obtained from the following formula:

$$WMS = \sum_{i=1}^{n}(ai \times si \times vi) / \sum_{i=1}^{n}(ai \times vi)$$

Notes:
WMS: weighted mean sensitivity
a_i : proportion of all individuals in a sample that belong to species i
s_i : pollution sensitivity (1-5) of species i
v_i : indicator values (1-3) of species i
n : total number of species in a sample (based on Kelly & Whitton 1995)

PTV is an index to determine the level of organic matter pollution in the waters. The equation used to determine the PTV value index (Kelly & Whitton 1995):

$$\%PTV = \frac{Abundance\ of\ tolerant\ taxa}{total\ taxa\ abundance}$$

The %PTV value was calculated based on comparing the abundance of tolerant diatoms (*Gomphonema* sp., *Navicula* spp., *Sellaphora* spp., and *Nitzschia* spp.) with the number of diatoms obtained (Kelly & Whitton 1995).

RESULTS AND DISCUSSION

Water Quality Profile Based on Water Physicochemical Parameters in CMC Mangrove, Kondang Merak, and Teluk Semut

Measurement of water physicochemical's parameters in mangrove CMC, Kondang Merak, and Teluk Semut included of water temperature (°C), air temperature (°C), pH, conductivity (S/m), DO (mg/L), BOD (mg/L), nitrate (mg/L), and orthophosphate content (mg/L) (Table 2). Our results showed that the water temperature and air temperature at the 5 locations of sampling were met the water quality standards for marine biota in mangrove based on government rules (PP NO.22/MENLH/2021), namely 28-32°C. According to Pourafrasyabi & Ramezanpour (2012), the optimal temperature that can affect plankton growth ranges from 25 -30° C.

Table 2. The profile of physicochemical water quality in CMC, Kondang Merak, and Teluk Semut.

Location	Physicochemical Parameters (min-max)							
	WT (°C)	AT (°C)	pH	Cond (S/m)	DO (mg/L)	BOD (mg/L)	NL (mg/L)	OL (mg/L)
CMC 1	25-27	27-29	7.07-7.36	5.4-5.64	3.23-3.87	6.16-8.44	0.023-0.181	0-0.0101
CMC 2	25-26	27-29	7.6-7.67	2.27-4.24	3.6-4.6	3.72-6.08	0.128-0.137	0-0.0101
CMC 3	27-29	30-30	7.57-7.63	4.8-4.86	4.32-4.75	2.84-4.72	0.02-0.104	0.009-0.024
Kondang Merak	25-27	26-28	7.72-7.9	0.19-0.25	3.88-4.03	3.16-4.74	0.43-0.76	0.01-0.03
Teluk Semut	26-27	27-29	7.21-7.59	4.67-4.94	4.28-4.67	2.52-5.6	0.02-0.072	0.01-0.0115
Water Quality Standart (Indonesia Ministry of Environment Regulation No 22/2021)	**26-32**		**7-8.5**	**-**	**>5**	**20**	**0.008**	**0.015**

Notes: WT: Water Temperature; AT: Air Temperature; Cond: Conductivity; NL: Nitrate Content; OL: Orthophosphat Content.

The pH values showed no significant difference between the 5 locations (Table 2). Based on the water quality standard for marine biota in mangroves based on government rules (PP NO.22/MENLH/2021), the pH value still meets the optimal limit of 7-8.5. A good pH value to support the sustainability of aquatic life ranges from 6.5-8 (Wassie & Melese 2017). Changes in the degree of acidity of the water are also influenced by the metabolic activity of phytoplankton that utilizes organic matter content and light intensity (Gao & Zheng 2010).

The conductivity values obtained indicate a significant difference between locations (Table 2). The highest conductivity value was found in the mangrove CMC 1, which ranges from 5.4-5.64 S/m, while the lowest conductivity value was located in the Kondang Merak mangrove, which ranges from 0.19 to 0.25 S/m. In addition, the conductivity values of the 4 locations were compared with those in Teluk Semut, and the Kondang Merak mangrove location has a value that is much different from the Reference site. It is because the waters in the Kondang Merak mangrove are freshwater that comes from the seashore of the Kondang Merak river and are not connected to seawater. Water conductivity fluctuations are influenced by the content of inorganic materials, salts, pollutants, currents, and water turbidity (Hatzikos et al. 2008).

Based on the data in Table 2, the DO values obtained ranged from 3.23-4.75 mg/L. The highest DO value 4.75 mg/L was found in mangrove CMC 3, while the lowest DO value 3.23 mg/L was found in mangrove CMC 1 (Table 2). Based on the water quality standard for marine biota in mangrove based on government rules (PP NO.22/MENLH/2021), the DO value from 5 locations did not meet the quality standard value > 5 mg/L. However, the optimal DO value for aquatic microorganisms ranges from 4-6.5 mg/L (Onyema 2013). According to Pour et al. (2014), DO plays a vital role in reduction and oxidation of organic and inorganic materials. DO levels that are too low in aquatic ecosystems can interfere with the life of aquatic organisms, such as affecting cell respiration (Wirabumi 2017).

Our results showed that BOD values ranged from 2.52-8.44 mg/L (Table 2). The highest BOD value 8.44 mg/L was found in mangrove CMC 1, while the lowest BOD value 2.52 mg/L was found in Teluk Semut mangrove. Based on the water quality standard for marine biota in mangroves based on government rules (PP NO.22/MENLH/2021), the BOD value at five mangrove locations met the 20 mg/L standards. According to Anyanwu & Solomon (2015), BOD is the total dissolved oxygen consumed by microorganisms to degrade organic matter such as food waste and the remains of other living things, where the higher the BOD indicates a higher amount of DO reduction in the waters.

The nitrate levels obtained in CMC, Kondang Merak, and Teluk Semut mangroves ranged from 0.02-0.76 mg/L (Table 2). The highest nitrate level was found in the Kondang Merak mangrove at a the concentration of 0.76 mg/L, while the lowest nitrate level was found in the Teluk Semut mangrove at the concentration of 0.02 mg/L. Based on the water quality standard for marine biota in mangrove based on government rules (PP NO.22/MENLH/2021), the value of nitrate levels at 5 locations did not meet the optimal standard of 0.008 mg/L. It is because around the location, there are human activities that contribute to the in littering organic matter (Eddy et al. 2021). Remaining waste originating from agricultural, plantation and livestock activities will be carried by runoff water from rivers and accumulates in coastal and sea areas (Rohila et al. 2017).

The orthophosphate levels in CMC, Kondang Merak, and Teluk Semut mangroves ranged from 0 to 0.0235 mg/L (Table 2). The highest value of orthophosphate content was found in mangrove CMC 3 at the concentration of 0.024 mg/L, while the lowest value of orthophosphate content was found in mangroves CMC 1 and CMC 2 at the concentration of 0 mg/L. Based on the water quality standard for marine biota in mangrove based on government rules (PP NO.22/MENLH/2021), the value of orthophosphate content met the standard (0.015 mg/L) in all mangrove locations except in CMC 3 was 0.024 mg/L. According to Saifullah et al. (2016), nitrate and phosphate are potential elements that affect the fertility of waters and the abundance of phytoplankton. Based on the measurement results, the physical and chemical parameters of the observed water all meet the quality standards except DO. From the water physicochemical data above, the growth of phytoplankton can be influenced by water quality conditions in an environment (Yuliana et al. 2012; Zhang et al. 2021).

Profile of Community Structure and Phytoplankton Diversity in CMC Mangroves, Kondang Merak, and Teluk Semut

Assessment of the success of mangrove ecosystem restoration is based on biological water quality parameters, including community structure and phytoplankton diversity. Diatoms are part of phytoplankton with limited mobility and are more sensitive to changes in water quality so they can be bioindicators (Suther & David 2009). Analysis related to the community structure of the phytoplankton diversity calculated, among others, The Importance Value Index (IVI), Simpson Dominance Index (Id), Evenness Index (E), Shannon-Wiener Diversity Index (H'), the phytoplankton biotic index Trophic Diatom Index (TDI), and %Pollution Tolerant Value (%PTV) (Figure 2-5 and Table 3). Based on the results of mangrove identification and data analysis, it was found that different species compositions at each location (CMC 1, CMC 2, CMC 3, Kondang Merak, and Teluk Semut) were found to be 13, 13, 11, 12, and 15 species, respectively.

The results of the IVI showed that phytoplankton species dominate at each location (Figure 2). At the mangrove locations in CMC 1, CMC 3, and Kondang Merak two codominant species were found., namely *Nitzschia* sp. dan *Navicula* sp. with IVI values of CMC 1 (35.09%,

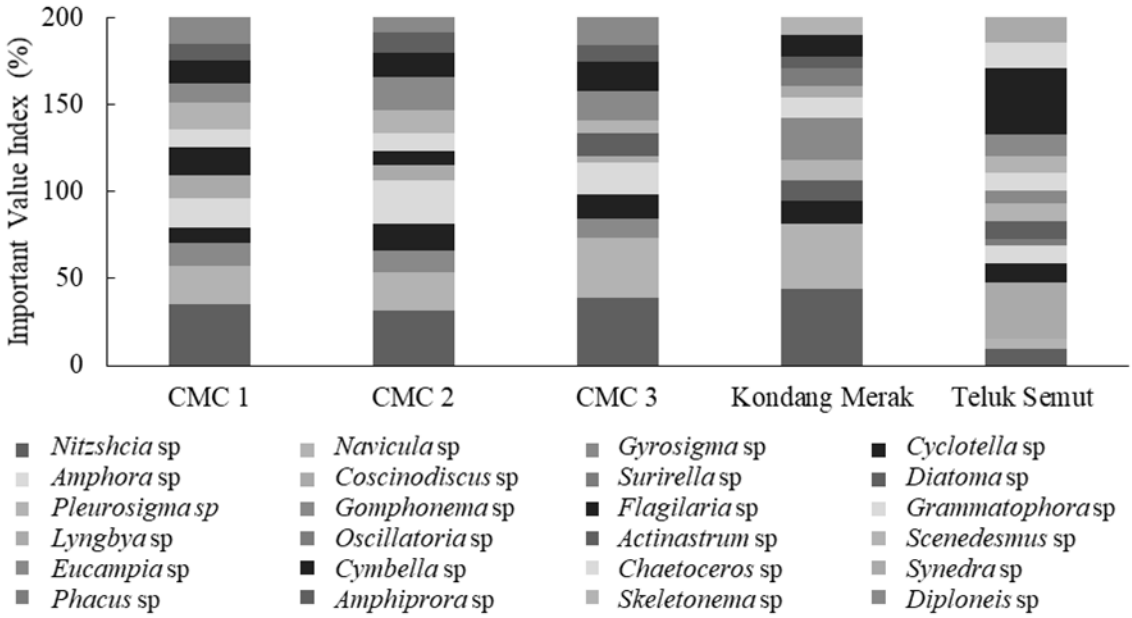

Figure 2. Spatial variation of IVI values in Clungup Mangrove Conservation (CMC), Kondang Merak, and Teluk Semut.

21.98%); CMC 3 (38.73%, 34.37%); and Kondang Merak (43.5%, 37.17%) respectively (Figure 3B and 3D). At the CMC 2 location, the dominant species was found *Nitzshia* sp., with IVI values of 31.32% (Figure 3D). At the Teluk Semut location, two codominant species were found, namely *Tabellaria* sp. and *Coscinodiscus* sp., with IVI values of 37.83% and 32.57%, respectively (Figure 3A and 3C). Dominant species found in an aquatic ecosystem indicate instability that causes the water quality to be categorized as poor (Inyang & Wang 2020). According to Onyema (2013), *Nitzschia sp.* is a diatom with a high level of adaptation and tolerance to organic matter pollution or in high nutrients water. It can be said that CMC 1, CMC 2, CMC 3 and Kondang Merak locations were exposed to organic matter pollution. According to Taylor et al. (2007), *Tabellaria* sp. is a phytoplankton species that can live in oligotrophic conditions and is sensitive to high organic matter. In addition, *Coscinodiscus* sp. is a cosmopolitan and phytoplankton species that usually lives in brackish and marine waters.

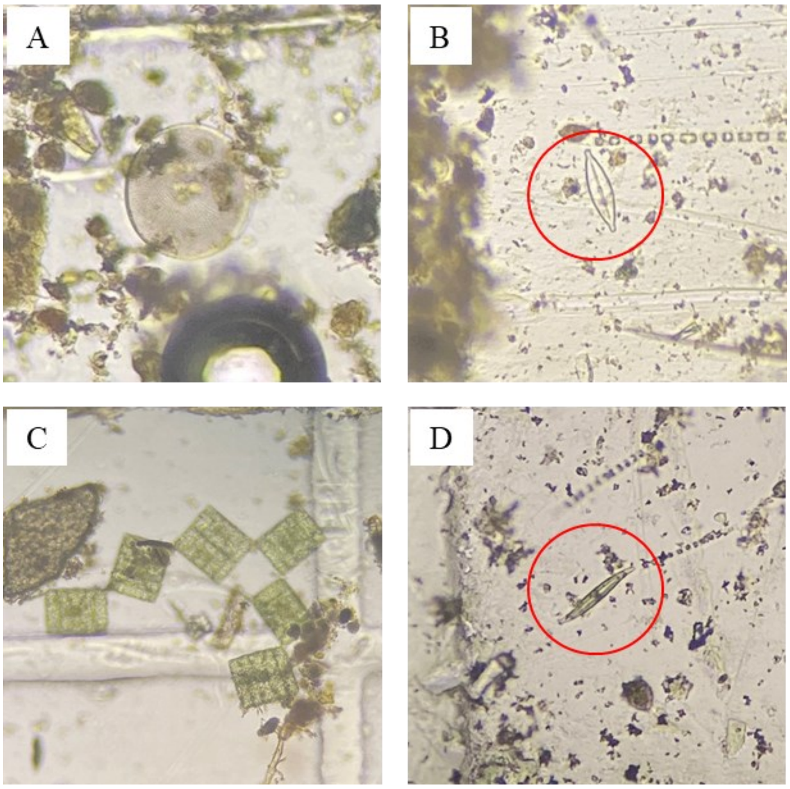

Figure 3. Images of the phytoplanktons found in Clungup Mangrove Conservation (CMC), Kondang Merak, and Teluk Semut. Notes: A. *Coscinodiscus* sp.; B. *Navicula* sp.; C. *Tabellaria* sp.; and D. *Nitzschia* sp. with a magnification of ×200.

Our results showed that the biotic index analysis, the Shannon-Wiener diversity index (H'), evenness index (E), and Simpson dominance index (Id) differ between locations (Table 3). The calculation results of H' show values ranging from 2.48 to 3.10, which means the five research sites were not contaminated with toxic substances. According to Wu et al. (2014) and Junaidi & Azhar (2018), the range of waters contaminated with toxic materials based on the Shannon-Wiener diversity index is divided into two categories, namely lightly polluted (2 < H' < 3), and moderately polluted (1 < H < 2).

The Simpson dominance index obtained at five mangrove forest locations ranged from 0.10 - 0.23, which means low partial dominance (Table 3). According to Febriansyah & Retnaningdyah (2021), the range of Id values ranges from 0-1. If the value < 0.4 includes low partial dominance, 0.4-0.6 includes moderate partial dominance and > 0.6 includes high partial dominance. The Evenness index (E) values obtained at five mangrove locations ranged from 0.7 to 0.84 (Table 3). Based on the value of E obtained, it showed that the five mangrove forest locations was classified as evenly distributed with the E value > 0.6, including species evenly distributed (Wu et al. 2014). It is positively correlated with the results of the Importance Value Index, where it was assumed that each location did not have a dominant species, but rather species codominance.

Table 3. Spatial variation of phytoplankton diversity index in Clungup Mangrove Conservation (CMC), Kondang Merak, and Teluk Semut.

Location	Restoration Time	Biotic Index		
		E	Id	H'
CMC	CMC 1	0.70	0.11	2.61
	CMC 2	0.79	0.18	3.10
	CMC 3	0.72	0.20	2.48
Kondang Merak	Rehabilitated in 2019	0.72	0.23	2.57
Teluk Semut	Natural	0.84	0.10	3.07

Notes: Evenness Index (E); Simpson Dominance Index (Id); Shannon-Wiener Diversity Index (H').

The Trophic Diatom Index is a biotic index developed for monitoring the level of eutrophication by organic pollution from diatom groups (Kelly & Whitton 1995). According to Wu et al. (2014), the level of eutrophication is divided into four levels. Those are oligo-eutrophic (TDI < 24), which means the waters have low nutrients and primary productivity, meso-eutrophic (25 < TDI < 49), which means the waters have medium nutrients and primary productivity, eutrophic (50 < TDI < 74), which means the waters have high nutrient content and primary productivity, and hyper-eutrophic (75 < TDI < 100), which means the waters have very high nutrient content and primary productivity.

The TDI index results obtained from the five mangrove forest locations ranged from 26.25 – 76.07% (Figure 4). The location of the Kondang Merak mangrove was classified as poor (hyper-eutrophic) with a TDI value of 76.07%. This result was positively correlated with high nitrate levels in Kondang Merak mangroves. The existence of active anthropogenic activities causes the accumulation of organic matter such as nitrate and phosphate (Çulha et al. 2022). Moreover, the CMC 1, CMC 2, and CMC 3 mangrove locations were classified as moderate (eutrophic) with TDI values of 64.5%, 53.9%, and 70.03%, respectively. The location of the Teluk Semut mangrove was categorized as a meso-eutrophic location with a TDI value of 26.25%. It was because the mangrove location is within the Sempu Island Nature Reserve, which is conserved and minimally anthropogenic. The main cause of eutrophication is the presence of phytoplankton that can utilize organic matter as nutrients for metabolism (Bellinger & Sigee 2010). According to Adesuyi et al. (2015), the high content of nitrate and phosphate cause an increase in the abundance of diatoms. In addition, the accumulation of organic matter is caused by the environmental carrying capacity that exceeded the limit so that it cannot be absorbed and remediated (Zhang et al. 2021).

The %PTV index describes the level of organic pollution by comparing the abundance of tolerant diatoms (*Gomphonema* sp., *Navicula* spp., *Sellaphora* spp., and *Nitzschia* spp.) with the total number of diatoms obtained (Wu et al. 2014). Our results showed that the %PTV values at the five locations of mangrove forests ranged from 6.4 to 71.2 % (Figure 5). The Teluk Semut and CMC 2 mangroves obtained %PTV values of 6.4%

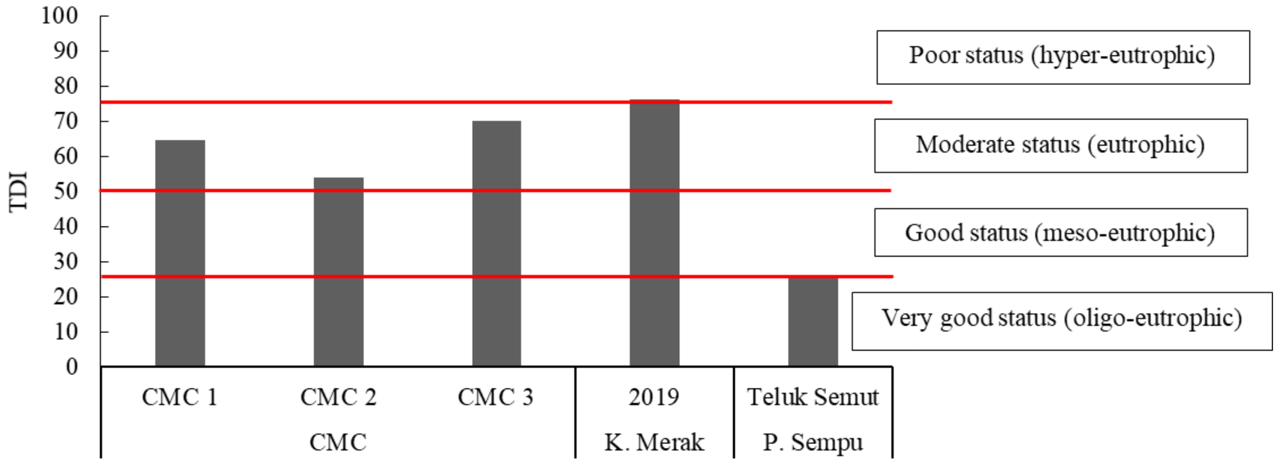

Figure 4. Spatial variation of Trophic Diatom Index values in Clungup Mangrove Conservation (CMC), Kondang Merak, and Teluk Semut. (Note: ▬ = Value limit between categories)

and 17.9%, respectively, indicating that they were not polluted with organic matter. The location of CMC 1 obtained a %PTV value of 53.6%, classified as moderate organic pollution, which can contribute significantly to eutrophication. The location with the highest %PTV value was in the mangrove CMC 3 and Kondang Merak with 65.1% and 71.2%, respectively, indicating heavy organic matter pollution. These results showed a positive correlation with the TDI value, if the level of organic pollution is high, the level of eutrophication is also high. The influence of organic matter from anthropogenic activities is evidenced by the many types of diatoms found as indicators of organic matter pollution, such as *Nitzschia* sp. and *Navicula* sp. (Ferreira-Marinho et al. 2014; Han et al. 2016).

Correlation between water quality and plankton community structure in CMC, Kondang Merak, and Teluk Semut

The correlation between the physicochemical water parameters, the diverse community structure, and the plankton biotic index were shown in the principal component analysis (PCA) diagram in Figure 6. Mangrove ecosystems CMC 1 and CMC 2 have similar water quality, characterized by high E and H', and also low DO and orthophosphate content. Teluk Semut (Sempu Island) mangrove location was characterized by low TDI and %PTV values and high DO. The location of CMC 3 and Kondang

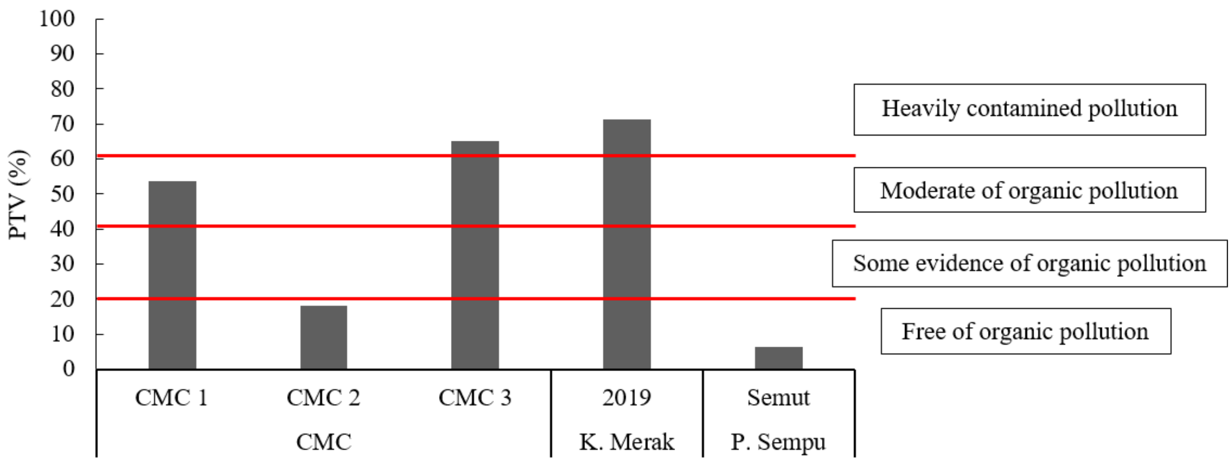

Figure 5. Spatial Variation of Pollution Tolerance Values in Clungup Mangrove Conservation (CMC), Kondang Merak, and Teluk Semut. (Note: ▬ = Value limit between categories)

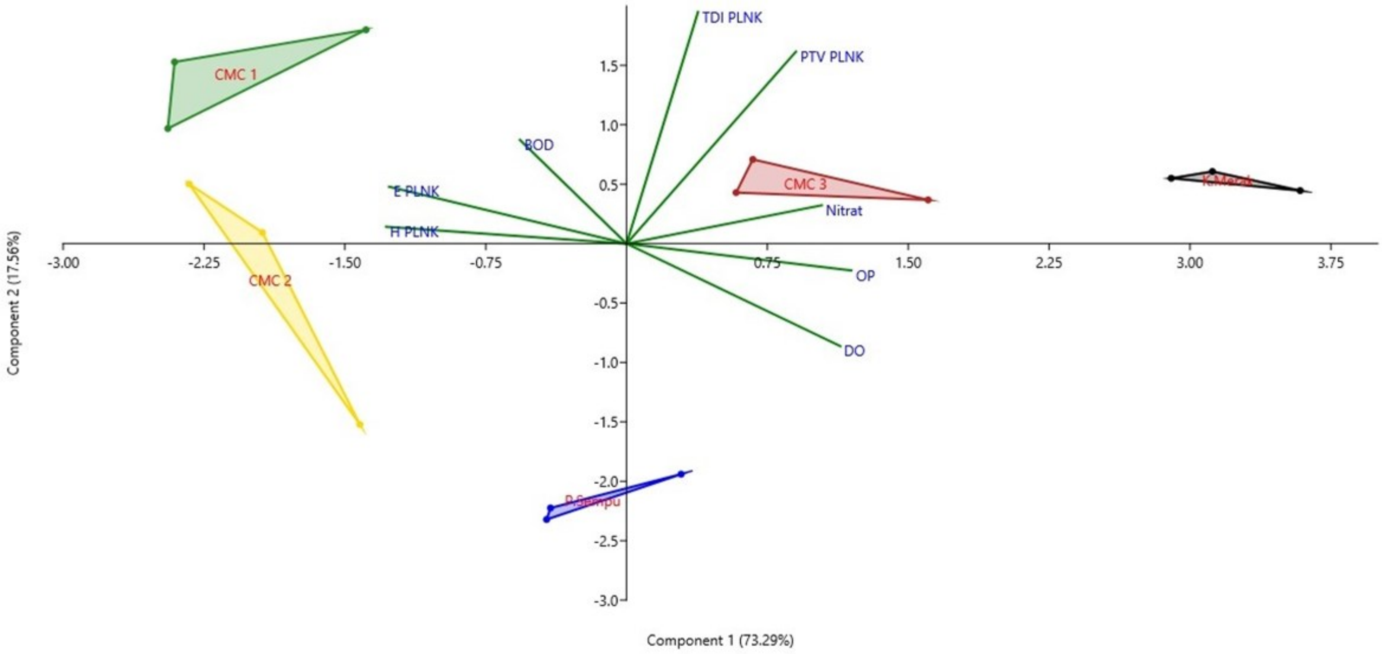

Figure 6. Correlation between water quality and phytoplankton community structure in Clungup Mangrove Conservation (CMC), Kondang Merak, and Teluk Semut using Biplot analysis. Notes: OP: Orthophospate, TDI PLNK: TDI Plankton; PTV PLNK: PTV Plankton; E PLNK: E Plankton; H PLNK: H' Plankton; Component 1 & 2 = variety of computational data.

Merak are characterized by high TDI, %PTV, nitrate, orthophosphate, and DO values. So, it can be concluded that the places that have successful mangrove restoration, which showed promising results, were the location of CMC 1 and CMC 2 because the water quality parameters were almost similar to those at Teluk Semut (Sempu Island). The location of CMC 3 and Kondang Merak is very different from Teluk Semut because there are still excessive human activities such as tourism, and settlements, beside the Kondang Merak mangrove adjacent to agricultural and plantation areas.

CONCLUSION

Water quality of the five mangrove ecosystems of CMC (2015, 2008, and natural), Kondang Merak, and Teluk Semut has met some of the water quality standards for marine biota. Water quality in five mangrove ecosystems Clungup Mangrove Conservation, Kondang Merak, and Teluk Semut based on phytoplankton indicators not contaminated with toxic materials (H'); based on TDI, it is categorized as eutrophic – hypereutrophic, except at the reference site of Teluk Semut mangrove; based on PTV polluted with moderate to high organic matter except at the reference site locations, namely Teluk Semut, and CMC 2. The conclusion is that the location with good water quality based on the diversity of phytoplankton is Teluk Semut.

AUTHORS CONTRIBUTION

All authors have contributed to completing this research. The contributions of each author were as follows, F; collecting data, analyzing data, compiling and writing manuscripts. R and H; compiling main conceptual ideas and critical revision of articles. S; granting research permits for mangrove locations and as a guide for research locations. All authors discussed the results and contributed to the final manuscript.

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CONFLICT OF INTEREST

The author confirms that there are no known conflicts of interest regarding this publication and there is no financial support for this work yet, which can affect the results.

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