

Regional Case Study

Phytoplankton Diversity as Bioindicator of Water Quality in Mangrove Area of Surabaya East Coast

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Abstract

Mangrove forests in Surabaya's estuaries and coastal areas are designated by the government as protected areas. However, in the last decade, water pollution in the estuary and coastal areas of Surabaya has increased. This is due to rivers and tributaries that lead to the estuary carrying garbage and waste, as a result the waters in the mangrove area began to be polluted. The purpose of this study was to map water pollution in the Mangrove area, using the plankton diversity index. This diversity is based on the sensitivity of plankton, so it is used as a bioindicator of water pollution. This study, conducted in the estuary and along the East Coast of Surabaya. The results showed 70% of phytoplankton abundance in Wonorejo Mangrove is influenced by the value of COD, TSS, salinity, and phosphate. The estuary and coastal Mangrove Gunung Anyar 92% is influenced by the parameter values of temperature, COD, current strength, and salinity. *Bacillariophyceae* and *Coscinodiscophyceae* were the dominant phytoplankton in the Wonorejo and Gunung Anyar mangrove areas, respectively. The dominance of these two plankton, which were able to survive, indicates that the water quality in the Wonorejo and Gunung Anyar estuaries is polluted.

Keywords: Phytoplankton; bioindicator; pollution; mangrove area

1. Introduction

Population growth and increased human activity in many areas of life put pressure on the environment, particularly the waters. Pollutants that enter water bodies have the potential to endanger river, coastal, and marine water biota and, more specifically, can disrupt the development of organisms in these waters. The coastal areas of Surabaya's East Coast will receive estuarine pollution from upstream tributaries and major rivers. Alluvial substrates, sea tides, temperature, waves, and ecosystem structure and function all have an impact on this ecosystem (Suyarso, 2019). Nutrient-rich mangrove coastal areas can promote phytoplankton diversity. When it comes to high water temperature, salinity, low nutrient concentrations, and high turbidity, coastal ecosystems have a significant impact on the abundance of phytoplankton (Hashmi et al., 2013). Turbidity also causes diatoms to disappear from the phytoplankton community. For changes in the biological quality of water, phytoplankton is used as a marker. Its presence has a significant impact on the primary productivity of estuarine and coastal waters, and it is tolerant of changes in water quality and reacts differently to them (Latuconsina, 2018). The biological approach is used because it can continuously monitor pollution levels and provides a simple framework for doing so. It may be possible to tell if an ecosystem cannot be used as a good example by its poor water quality and dominance of a particular phytoplankton species (Anestiana, et al., 2017).

To determine the impact of water quality on the phytoplankton population, this study will identify phytoplankton as a biological pollutant index, which will then be correlated with physicochemical parameters. The biological approach is used because it allows for continuous monitoring

and serves as a simple manual for reviewing instances of pollution (Hendrasarie et al., 2020). If there is a change in the ecosystem in their habitat, phytoplankton are the first vulnerable organisms to be impacted (Thakur et al., 2013; Brito et al., 2017; Putra, 2022). Phytoplankton composition not only indicates the particular condition of the waters but also the previous state of the aquatic ecosystem. Phytoplankton influence water quality through changes in community composition, distribution and proportion of sensitive species (Gharib et al., 2011).

The waters on the East Coast of Surabaya, is one of the areas with dense settlement activities and pond activities. This causes more and more waste to enter the waters of the East Coast of Surabaya. This increase in waste is feared to damage the quality of Surabaya's East Coast waters. To determine the impact of water quality on phytoplankton population, this study will identify phytoplankton as an index of biological pollutants, which will then be correlated with physic-chemical parameters. The physic-chemical parameters studied include COD, TSS, DO, pH, salinity, brightness, current speed, nitrate, phosphate.

2. Methods

The study area included Surabaya's East Coast (sampling points 1 through 4) and the area from the Gunung Anyar River to the coast next to the Gunung Anyar mangroves (sampling points 5 through 8). According to estimates of pond outlets, urban water flows, and estuary areas, the distance between sampling points ranges from 0.8 km to 2 km (Cunha & Calijuri, 2011). The sampling period was 11.00 - 13.30 WIB, with three repetitions, taking into account the tides, the incubation period of light intensity according to the activity of phytoplankton (Dwi, et al. (2014), and the absence of rain.

Phytoplankton samples were collected with square mouthed bolting silk plankton net of 100 nm mesh size sunk beneath the surface of the reservoir and towed for a distance of one meter for each sampling operation. Samples were immediately preserved with Lugol's solution and then stored for subsequent examination. Species identification was done using keys in Needham & Needham (1975). Numerical estimations of the both phytoplankton was done using the drop method described by Margalef (1974).

The relative abundance of the various taxa was calculated for each sample using the equation (1):

$$N = [a/b] n \dots\dots\dots (1)$$

Where: N= estimated number of genus per sample,

a = volume of water sample in ml,

b = volume of sub sample in ml,

n = number of organisms in sub sample

Using Shanon-Weaver diversity index (H'), the phytoplankton population and biotic index are calculated. Shannon-Weaver & Weaver (1949) diversity index (H) and species evenness was used to determine the phytoplankton species composition and abundance in equation (2) (Shanon & Weaver, 1949).

$$\text{Shannon Index (H)} = -\sum(\text{pi ln pi}) \dots\dots\dots (2)$$

Where H = the Shannon-Weaver` index of diversity,

pi = the proportion of the nth species in the sample i.e (Number of Individual Species/Total Number of Individuals in Sample)

E = Eveness = H/Hmax

Where Hmax =Maximum diversity possible

The physical and chemical parameters that were analyzed included pH, temperature, dissolved oxygen (APHA 5220 C, Ed 23, 2017), salinity, nitrate, phosphate, suspended solids, brightness, and current speed. Data on temporal and spatial distribution patterns of physico-chemical parameters and phytoplankton composition were analyzed



Figure 1 Sampling point location

3. Result and Discussion

3.1. East Coast Region of Surabaya's Phytoplankton Biotic Index

The value of the biotic index at each sampling point is determined by sampling at each sampling point once a week and is shown in Table 1 below. With an evenness index of 0.84 and a dominant index of 0.13, Sampling point 1's diversity index has an average value of 2.3515. According to sampling point 2, the diversity index is 1.8, the evenness index is 0.63, and the dominance index on average is 0.281. At sampling point 3, the average values for the diversity, train, and dominance indices are 2.178, 0.73, and 0.189, respectively. With an evenness index of 0.65, a dominance index of 2.028, and a diversity index of 2.028 as a whole, sampling point 4 has an average diversity score.

Table 1. Biotic index value for each sampling point in the Wonorejo Mangrove estuary and coast

Sampling Point	Week	H (diversity Index)	D (evenness Index)	N (dominant index)	(ind/L)
1 st Sampling point	1	2.214	0.766	0.151	240
	2	2.3105	0.833	0.135	704
	3	2.530	0.912	0.104	445
2 nd Sampling point	1	1.970	0.682	0.321	264
	2	1.699	0.588	0.259	2294
	3	1.733	0.625	0.264	1675
3 rd Sampling point	1	2.112	0.705	0.197	582
	2	2.2173	0.7401	0.1884	1003
	3	2.206	0.736	0.183	844
3 rd Sampling point	1	1.896	0.633	0.220	2254
	2	2.228	0.701	0.167	1178
	3	2.403	0.756	0.153	1533

According to Table 1, high abundance can be found at sampling points 2 and 4 every week. Sampling points 1 to 4 per week are still stable community structures based on the value of the diversity index. The greater the H' value, the more diverse the life in these waters, indicating that this condition is a better place to live. The evenness index ranges from 0.588 to 0.912 at each sampling point per week. This indicates that population dominance by one or more specific species does not occur in the phytoplankton community. Dominance values ranged from 0.104-0.264 at each sampling point. This demonstrates that the species at the sample point locations do not compete with one another. The research sampling points located in Gunung Anyar's Estuary and Coastal Mangrove, namely sampling points 5 to 8, cover the estuary and coastal areas.

Table 2. Biotic index value for each sampling point in the Gunung Anyar Mangrove estuary and coast

Sampling Point	Week	H (diversity Index)	(evenness Index)	D (dominant index)	N (ind/L)
5 th Sampling point	1	1.571	0.566	0.323	1279
	2	1.581	0.570	0.339	1044
	3	1.620	0.584	0.287	1722
6 th Sampling point	1	1.844	0.626	0.216	2466
	2	1.971	0.598	0.292	1725
	3	1.884	0.639	0.207	2886
7 th Sampling point	1	1.925	0.598	0.236	1530
	2	1.741	0.541	0.203	1289
	3	2.001	0.632	0.217	1967
8 th Sampling point	1	2.197	0.659	0.180	2775
	2	1.916	0.603	0.228	2067
	3	2.175	0.653	0.165	4610

According to Table 2, the second week had the lowest abundance because of rain before sampling. Sampling points 5 to 8 per week are still stable based on diversity index values. The evenness index (J) at each sampling point ranges from 0.541 to 0.659 per week. This demonstrates that the population distribution/evenness of the phytoplankton community is moderate, with no dominance by one or more specific species. Odum (1996) states in (Haninuna et al., 2015) that the individual evenness of biota is 0-0.5, indicating that the individual wealth of the phytoplankton species is very different and the individual evenness is relatively uniform in the community, and the value of 0.6-1 indicates that evenness individuals exist in each phytoplankton community.

Dominance values ranged from 0.165 to 0.339 at each sampling point. This demonstrates that the species at the sample point locations do not compete with one another. According to Basmi (2000) in Hutabarat (2014), if the dominance value is close to one, it means that there are species in the community that dominate other species. The abundance, diversity index, dominance index, and distribution index of phytoplankton indicate that the East Coast of Surabaya is light to moderately polluted.

3.2. Phytoplankton domination on the Wonorejo Coast, Surabaya, Indonesia

Every week, 7 classes of phytoplankton are found in the estuary and coastal waters of the Estuary and Mangrove Wonorejo Coast: *Bacillariophyceae*, *Cyanophyceae*, *Fragilariophyceae*, *Pyramimonadophyceae*, *Chlorophyceae*, *Coscinodiscophyceae*, and *Euglenoid*. Furthermore, there are several classes, namely Dinophyceae, that live in the estuaries and coastal areas of the Wonorejo Mangrove. *Bacillariophyceae* is a phytoplankton family that is abundant in the Wonorejo Mangrove's estuaries and coastal areas.

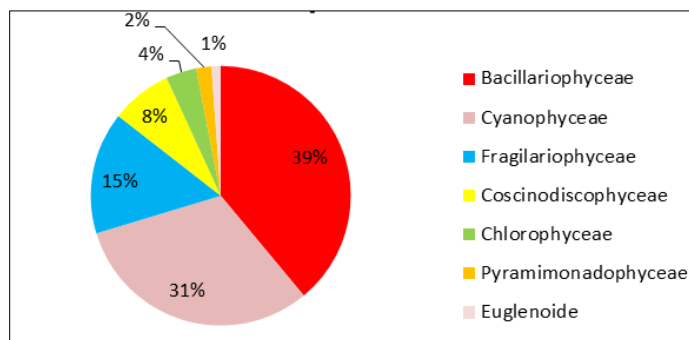


Figure 2. Class percentage of phytoplankton in the estuary and coastal Mangrove Wonorejo

Melosiraceae, *Bascillariaceae*, and *Thalassionemataceae* were the *Bacillariophyceae* families with the highest abundance at each sampling point. The *Bacillariophyceae* class, according to Nybakken (1992) in Ayuningsih (2014), can grow quickly even in low light and nutrient conditions. This type of phytoplankton can adapt well, allowing it to regenerate and reproduce in greater numbers than other types of phytoplankton. The *Bacillariophyceae* class is also the most resistant to environmental changes caused by tides, and it is most abundant in sampling points 2, 3, and 4. Sampling points 2 and 3 have the second-highest abundance of phytoplankton in the *Cyanophyceae* class, with the most *Microsystaceae*, *Nostocaceae*, and *Oscillatoriaceae* families.

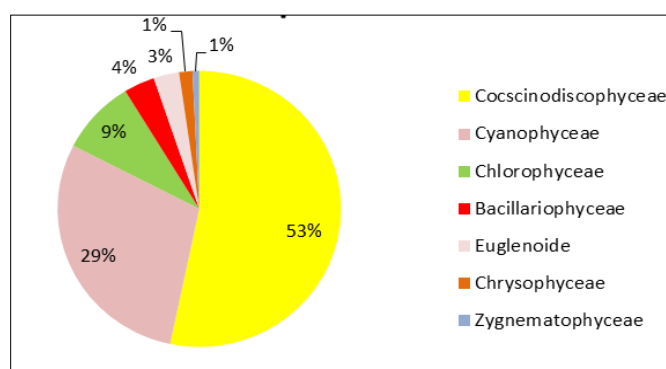


Figure 3. Class percentage of phytoplankton in estuaries and mangrove coasts of Gunung Anyar

Every week, phytoplankton from the *Coscinodiscophyceae*, *Cyanophyceae*, *Chlorophyceae*, *Bacillariophyceae*, *Euglenoide*, *Chrysophyceae*, and *Zygnematophyceae* families are found at each sampling point. Furthermore, there are several classes, including *Dinophyceae*, that live in the estuaries and coastal areas of the Gunung Anyar Mangrove. *Coscinodiscophyceae* is a phytoplankton family that is abundant in Gunung Anyar Mangrove's estuaries and coastal areas.

Melosiraceae, *Stephanodiscaceae*, *Chaetocerotaceae*, and *Tabellariaceae* were the *Coscinodiscophyceae* families with the highest abundance at each sampling point. Burhanuddin (2019) claims that the *Coscinodiscophyceae* family is the most abundant group of diatom phytoplankton in the environment. This class only lives in shallow waters and can reproduce quickly to produce a large number of diatoms. It is also the most resistant to environmental changes caused by tidal influences. *Coscinodiscophyceae* were the most abundant at sampling points 6, 7, and 8. The *Cyanophyceae* class had the second highest abundance of phytoplankton (29%), with the most families being *Microsystaceae* and *Oscillatoriaceae*, which were mostly found at sampling points 6, 7, and 8, and *Nostocaceae*, which were mostly found at sampling point 5.

3.3. Physical and Chemical Parameters of the East Coast of Surabaya

Water quality is determined by measuring physical and chemical parameters. There are two standards in use: Surabaya Regional Regulation No. 02 of 2004 and Ministerial Decree No. 51 of 2004. Table 3 shows the physical and chemical parameters of the research results after three weeks.

Table 3. Physical and chemical parameters of research results for 3 weeks

Parameters	Sampling Point				Week	Standard of water	
	5	6	7	8		Surabaya Regional Regulation No. 02 of 2004	Ministerial Decree No. 51 of 2004
Temperature (°C)	27.75	27.5	28	28.5	1	-	28-32°C
	28.5	28.75	28.75	29	2		
	29	29	29.5	30	3		
Brightness (cm)	31.5	21.5	31.5	49	1	-	-
	31.5	21	31.5	28.5	2		
	41.5	41	35	31.5	3		
Current speed (m/s)	0.048	0.056	0.091	0.206	1	-	-
	0.038	0.037	0.136	0.257	2		
	0.036	0.045	0.159	0.286	3		
TSS (mg/L)	200	390	180	350	1	400	80 (3 rd class)
	136	84	80	124	2		
	80	76	68	96	3		
pH	7.45	7.6	7.5	7.85	1	6 – 9	7 – 8.5
	7.3	7.5	7.5	7.7	2		
	7.6	7.7	7.6	7.8	3		
DO (mg/L)	3.5	3.4	2.6	2.1	1	3	>5
	4.7	4.6	3.7	1.7	2		
	3.8	3.9	3.1	2.0	3		
COD (mg/L)	126.154	101.538	110.769	1538.462	1	50	-
	110.222	106.667	110.222	1244.444	2		
	80.734	77.064	95.413	917.431	3		
Nitrate (mg/L)	0.24	0.22	0.25	0.21	1	20	0.008
	0.149	0.155	0.15	0.156	2		
	0.124	0.134	0.134	0.145	3		
Phosphorus (mg/L)	2.030	1.170	1.240	0.920	1	1	0.015
	2.460	2.830	1.800	1.010	2		
	1.540	1.210	0.940	0.780	3		
Salinity (‰)	0.433	1.274	2.128	11.807	1	-	s/d 34
	0.478	0.904	2.294	10.186	2		
	0.488	1.122	2.299	11.415	3		

According to Table 3, Sampling point 1 and 5 have the lowest pH because they receive the first signals from upstream of the river for settlement and urban activities. An increase in pH can increase the diversity index, whereas a decrease in pH can result in a decrease in the diversity index value. According to Rajkumar's (2014) & Hendrasarie, Januar (2019) research, the decrease in pH value is thought to be due to CO₂ as a byproduct of aquatic organism respiration, which causes high water pH values to be reduced

by the photosynthetic process of aquatic plants and phytoplankton. Photosynthesis causes bicarbonate, a carbon source, to degrade (Rajkumar, 2014). Because of salinity and pond water accumulation, the pH value and diversity index value increased at sampling points 3, 4, 7, and 8.

Even though the result of phytoplankton photosynthesis is oxygen, the presence of eutrophication causes a decrease in DO values. Sampling point 8 had the greatest decrease in DO values and the greatest increase in diversity index values. Because pond inputs were accumulated with the urban river upstream, DO values at sampling points located at pond outlets, specifically sampling point 2, were below the quality standard, causing the dominance index value to increase. Because of the incoming nutrients, DO levels in the waters fall, and there is an explosion of species in the phytoplankton community.

The rise in COD values from one sampling point to the next indicates an accumulation of organic matter in waters originating from polluted river flows caused by human and pond activities. COD increased the most along the coast, specifically at sampling points 4 and 8. The two sampling points also had the greatest increase in the index value. This is influenced by the fact that coastal areas, which are also the most densely forested with mangrove plants, have higher salinity than estuarine areas with higher phytoplankton abundance.

The greatest increase in nitrate occurred at sampling point 2, which was accompanied by an increase in the dominance index and a decrease in the diversity and evenness index. This demonstrates that high nitrate content can cause an explosion of species in each community and lead to the dominance of certain species in the waters, causing eutrophication. Specific nitrogen that affects phytoplankton abundance is higher in nitrate and nitrite, whereas phytoplankton (diatoms) require nitrate to develop in mangrove habitats (Shoaib, 2017). According to Rizqina (2017), water nitrate levels greater than 0.2 mg/l can cause eutrophication, which can stimulate the rapid growth of phytoplankton (blooming).

With high phosphate levels, there is an explosion of several phytoplankton species, which can lead to dominance in the community and eutrophication. According to Samsidar et al. (2013) and Ramadhan et al. (2016), the abundance of phytoplankton in water is affected by nutrient content, one of which is phosphate. If the levels of orthophosphate compounds are less than 0.004 ppm, they are a limiting factor, whereas levels greater than 1.0 ppm PO₄⁻ can cause blooming or eutrophication (Mackentum in Basmi (1999) in Rizqina (2017); Hendrasarie (2005); Huang (2004). This is indicated by the presence of the *Coscinodiscophyceae* class, which has a higher phosphate content, at sampling points 5-8.

The coastal sampling points have the highest salinity, specifically, sampling points 4 and 8, which also have the highest density of mangroves. Because of the high salinity and density of mangrove plants, there is an abundance of several classes of phytoplankton that are not found in freshwater. *Bacillariophyceae*, which can live in high salinity, are the most commonly found in coastal areas. This is consistent with Nybakken (1988), who claims that this class reproduces quickly and can survive in harsh environments.

Phytoplankton abundance is found at depths where sunlight intensity is still optimal for phytoplankton growth. The highest brightness was found at sampling points 5 to 8 due to lower mangrove density compared to sampling points 1 to 4, and measurements were taken on non-cloudy days. According to Ayuningsih (2014), the brightness of the waters affects the penetration of the intensity of sunlight into the waters because it is closely related to photosynthetic activity and phytoplankton primary production.

High TSS levels reduce the penetration of light into the water and thus the abundance of phytoplankton (Lacuna et al., 2012; Shoaib et al., 2017). Sampling points 5 to 8 had the highest TSS values. However, high TSS values resulted in lower diversity index values at several sampling points, including sampling points 3 and 7, because phytoplankton species in the *Chlorophyceae* class are not susceptible to contaminants.

Starting with sampling points 2 and 6, the current speed in the waters is increasing because it is increasingly leading to coastal or offshore areas. The current speed will influence the migration and dispersal of phytoplankton. Suryanti (2008) in Ayuningsih (2014) confirmed this, stating that current speed would affect the composition and abundance of phytoplankton. Phytoplankton are passive

organisms that move in response to currents. Burhanuddin (2019) confirms that phytoplankton are biota that live in the pelagic zone and float, drift, or swim, but cannot swim against the current.

3.4. Biotic Index and Physical and Chemical Parameter Relationship and Phytoplankton Distribution on the coasts of Gunung Anyar and Wonorejo

The results of correlation and multiple linear regression analysis show a close relationship between phytoplankton abundance and physical and chemical parameters. The multiple regression results revealed a phytoplankton regression equation model = $3087 - 10.9 \text{ TSS} + 0.990 \text{ COD} - 1146 \text{ Phosphate} - 101 \text{ Salinity}$, indicating that the value of COD, TSS, salinity, and phosphate affects the Wonorejo Mangrove by 70%. Furthermore, the best model was produced by multiple linear regression analysis on the Gunung Anyar Mangrove. $-22334 + 877$ is the phytoplankton regression equation. Temperature $- 4.74 \text{ COD} - 21628 \text{ Current strength} - 969 \text{ Salinity}$. It can be concluded that temperature, COD, current strength, and salinity all have an impact 92% of the time. The low DO and high COD content in both mangroves during daytime sampling are one of the main issues. Although the dissolved oxygen content on the coast is low (Brito, 2017), the brightness is high enough that sunlight can penetrate the water layer and support the life of aquatic biota, particularly phytoplankton. With indicators of the absence of excessive blooming in coastal and estuarine waters, such as Minister of Environment Decree No. 51 of 2004, which states that no blooming means no excessive growth, which can cause eutrophication. Excessive plankton growth is influenced by nutrients, light, temperature, current speed, and plankton stability.

Excessive plankton growth is influenced by nutrients, light, temperature, current speed, and the plankton's stability. The picture depicts the distribution of phytoplankton in the estuaries and coastal mangroves of Wonorejo and Gunung Anyar.

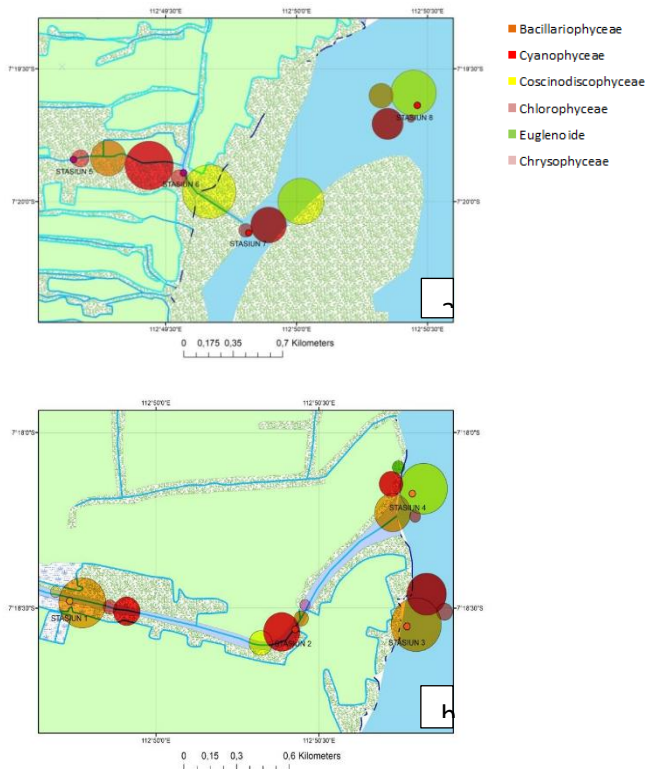


Figure 4 Distribution map of phytoplankton classes in Mangrove Estuaries and Coasts a. Gunung Anyar; b. Wonorejo

According to Figure 4, the *Dinoflagellate* classification is rare because this classification has a brief lifespan (Odum, 1997). The Wonorejo mangrove area has the best community distribution and species

abundance, according to the biotic index of phytoplankton in each mangrove area. The abundance of communities may be influenced by the Wonorejo mangroves' high density of mangroves. It was discovered that the mangroves of Gunung Anyar, did not contain some classes of phytoplankton and that these classes had high diversity index values and low dominance index.

This indicates that pollution in the coastal waters of Gunung Anyar is higher than Wonorejo Beach. This is evidenced by the small abundance of phytoplankton at Gunung Anyar Beach. The abundance of phytoplankton in both waters above, did not experience dominance, indicating the level of pollution in the East Coast of Surabaya can still be tolerated by phytoplankton.

4. Conclusions

According to the diversity index value, the average is 1.998, the average dominance is 0.218, and the average evenness is 0.664, with the highest abundance of phytoplankton from the Bacillariophyceae class in the Wonorejo Mangrove Estuary and Coastal and Coscinodiscophyceae in the Gunung Anyar Estuary and Mangrove Coast. According to the results of statistical analysis of correlation and multiple linear regression, there is a relationship between physical and chemical parameters that can affect the growth and distribution of phytoplankton abundance in the East Coast Region of Surabaya, including the Wonorejo Mangrove, which is 70% influenced by the value of COD, TSS, salinity, and phosphate content; and the Gunung Anyar Mangrove, which is 92% influenced by the parameter values of temperature, COD, current strength. Surabaya's East Coast is moderately polluted but still suitable for aquatic biota habitats.

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