Impact of Environmental Factors on Phytoplankton Community Structure From Two Different River Estuaries, South Sumatra, Indonesia

by Rozirwan Rozirwan

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Abstract. Environmental factors can influence the community structure of phytoplankton in water. This study aimed to assess the abundance, diversity, uniformity, and dominance of phytoplankton from the Musi and Banyuasin river estuaries influenced by environmental factors. The study was conducted by collecting water quality data at 12 stations. Water samples were collected with a plankton net measuring 20 μm. Statistical analysis used an independent sample t-test and principal component analysis (PCA). Musi River Estuary has an abundance of 23–39 cells L^{-1}, low diversity, high uniformity, and not dominance. Banyuasin River Estuary has an abundance of 27–441 cells L^{-1}, low diversity, moderate uniformity, and dominance. Based on variance analysis, the two river estuaries have water quality and abundances that are not significantly different. The results of the PCA analysis indicated that salinity, pH, and phosphate were the main determinants of the causal relationship between phytoplankton abundance and water quality indicators in the Musi River Estuary. While the Banyuasin River Estuary by current speed and light intensity.

Keywords: Banyuasin estuary, community structure, environmental factors, Musi estuary, phytoplankton.

1 Introduction

River estuaries have unique and dynamic physical and chemical properties of water due to the influence of freshwater upstream and seawater downstream [1]. The Musi and Banyuasin river estuaries have a very important role for the coastal communities of South Sumatra because they provide important contributions to various development activities such as ship transportation

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routes, ports, fisheries, and agriculture [2][3]. Some fishing communities use the estuary as a highly productive fishing ground [4]. As is known, the growth and development of industrial activities that genuslly take place on riverbanks and estuaries are where domestic waste is disposed [5][6]. This results in a decrease in water quality due to environmental extrinsic factors that contribute to nutrients and contaminants [7][8]. Water quality parameters, as well as environmental intrinsic factors such as salinity, pH, dissolved oxygen, temperature, light intensity, currents, nitrate, and phosphate levels, strongly influence the biodiversity of estuarine ecosystems [9][10][11]. Changes in water function often result from alterations in the structure and quantitative values of plankton, which can be induced by natural and human activities, along with increased nutrient concentrations. These alterations have the potential to modify primary production patterns [12][13].

Phytoplankton are an important part of aquatic microorganisms and the most important primary producers in estuarine ecosystems [14][15]. Phytoplankton holds a significant position in the food chain and performs an indispensable function in the flow of energy and the cycling of materials [16][17][18]. Several investigations into phytoplankton communities have indicated that environmental factors can influence community traits, including species richness, community diversity, and community evenness [18][19][20][21]. In recent times, there has been significant focus on the influence of phytoplankton salinity. Earlier research has demonstrated that the primary factor causing changes in phytoplankton is the rise in salinity [22]. Generally, salinity is viewed as a constraining factor for phytoplankton in coastal regions and lakes with elevated salinity [23][24].

Ocean acidification and global warming that increase CO_2 concentrations have an influence on phytoplankton composition in coastal areas [25]. Not only that increase the standing stock of small autotrophic phytoplankton, but also cause a shift in the species composition of diatoms and dinoflagellates [26]. Moreover, a rise in the abundance of phytoplankton is accompanied by an elevation in the levels of dissolved oxygen in aquatic environments [27][28]. On a global scale, temperature can change, affecting phytoplankton growth rates and causing variations in phytoplankton diversity [29]. Increased temperature results in species loss, decreased biomass, and reduced abundance [22]. Meanwhile, light variability and intensity show an increase in the rapid reaction to the photosynthetic process in phytoplankton [30][31]. However, there is also a linear relationship between current velocity and phytoplankton growth [32]. Additional research has indicated that the current velocity is interconnected with the phytoplankton community, species richness, community diversity, and species abundance. All of these factors are significant in association with nutrient concentration [33][34].

The presence of phytoplankton in water can be caused by environmental characteristics and parameters. Apart from being an indicator of water quality, phytoplankton also act as food for zooplankton and dissolved oxygen producers for other aquatic biota [35]. Water quality parameters can be important for phytoplankton life. The influx of nutrients due to activities around the river can affect the growth of phytoplankton and the fertility of a water body [11][36]. A comprehension of the factors and mechanisms through which environmental factors influence variations in biodiversity is crucial, not only for environmental managers seeking informed scientific knowledge but also for researchers aiming to gain insights into estuarine ecosystems.

2 Methodology

2.1 Study area

This study was conducted by the survey method in September 2022. Environmental parameters and phytoplankton samples were measured at twelve observation stations (Figure 1). The first location of the Musi River Estuary was determined based on the assumption that there is a dominant freshwater influence and household activities from Sungsang village, fisheries, and agriculture [37][38]. The second location of the Banyuasin River Estuary was determined based on the stronger dominance of seawater from Bangka strait and the activities of shipping lanes, ship loading and unloading, and Tanjung Api-Api port [39][40]. The conditions in both waters are brown in color due to the influx of substances or waste from various human activities in these waters. Sample processing was carried out at the Microbiology Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Sriwijaya University. Nitrate and phosphate analysis was conducted at the Environment and Land Laboratory, Palembang, South Sumatra.

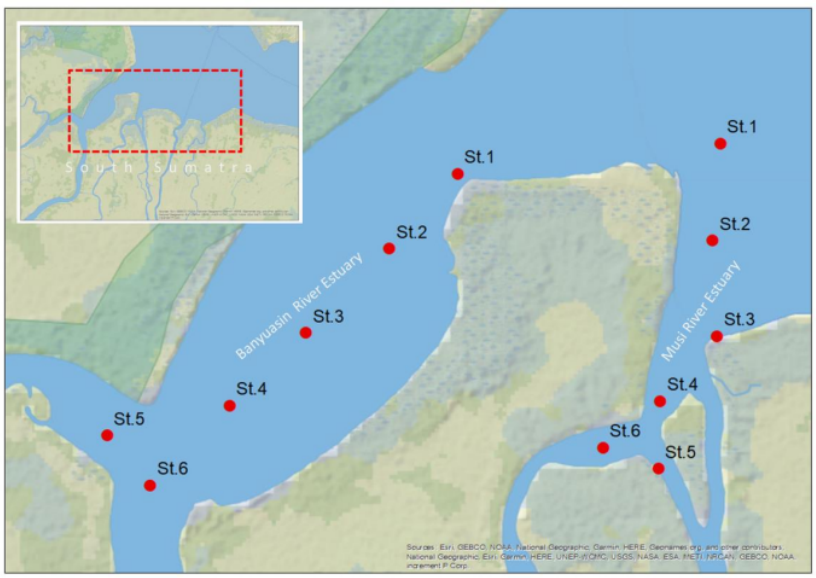


Fig. 1. The sampling area of Musi and Banyuasin river estuaries.

2.2 Sample collection and processing

The method used to determine the sampling point of this study is the purposive sampling method. The sampling points in this study are divided into 12 stations, each of which has 6 stations covering the river area, the estuary area as a meeting of river water and sea water, and the sea area so that the area can be represented. The physical parameters of water chemistry were measured directly at the location. These parameters are salinity, pH, DO, temperature, light intensity, transparency, and current speed. These environmental parameters were measured using multiparameter tools, a secchi disk, and floating drudge. Sampling refers to [14] taking as much as 10 liters of water using plankton net with 3 repetitions, storing it in a 250-ml plankton collection bottle, and then preserving it with 4% formalin that has been diluted. The preserved samples were then put into a cool box.

2.3 Sample identification

Samples analysis were carried out using a microscope with the census method and observation of samples on the SRCC (Sadgwick Rafter Counting Cell) with reference to [41][42].Observations were made by observing 1 ml of samples in the SRCC and repeating 3 times for each sample.

2.4 Statistical analysis

Determination of phytoplankton abundance, diversity, uniformity, and dominance indices using the Shanon-Wiener equation [43]. Data on phytoplankton abundance in the Musi and Banyuasin river estuaries were analyzed using the independent sample t-test method to determine differences in abundance from two different locations [44]. Correlation between environmental parameters such as salinity, DO, light intensity, temperature, brightness, current speed, nitrate and phosphate levels, and phytoplankton abundance using principal component analysis (PCA).

3 Results and Discussion

3.1 Characteristics of environmental parameters

The characteristics of environmental parameters can be assessed from the physical and chemical parameters (Table 1). The physical and chemical parameters of the Musi and Banyuasin river estuaries showed normal characteristics for phytoplankton growth and development.

Table 1. Environmental parameters.

Environmental parameters	Musi River Estuary						Banyuasin River Estuary					
	St.1	St.2	St.3	St.4	St.5	St.6	St.1	St.2	St.3	St.4	St.5	St.6
Temperature (°C)	29	29.3	29	29.6	28.9	28.6	28.8	30	28.6	29.1	29.7	29.1
DO (mg L^{-1})	7.8	6.7	6.3	6.4	7.1	9.5	5.8	6.4	5.9	6.2	6	5.7
Salinity (PSU)	23	16	14	11	14	12	14	11	15	15	7	3
pH	7.51	7.37	7.19	7.11	7.37	7.28	7.13	6.93	7.25	7.29	7.19	7.66
Light intensity (Lux)	637	666	744	748	814	787	397	423	425	529	806	756
Transparancy (%)	134.5	215	50	103.5	52	64.2	23	32.75	51.5	60.5	67.5	38
Current (m/s)	0.39	0.38	0.35	0.35	0.46	0.35	0.06	0.16	0.06	0.03	0.28	0.19
Nitrate (mg L^{-1})	0.6	0.1	0.4	0.1	0.7	0.1	0.1	0.7	0.6	0.2	1	0.1
Phospate (mg L^{-1})	0.025	0.023	0.021	0.018	0.015	0.012	0.024	0.022	0.019	0.017	0.013	0.011

The surface temperature of the Musi and Banyuasin river estuaries shows the same trend in the range of 28.6-30°C and can genuslly support the growth and development of aquatic organisms, especially phytoplankton. Based on the analysis of extensive data sets on the growth rate of freshwater and marine phytoplankton under 40°C, the maximum growth rate of phytoplankton increases exponentially with increasing temperature [45]. The study results [46] show the growth rate of phytoplankton in the temperature range of 8.5–31.5 °C. Based on research in time [47], the lowest average temperature in February (rainy season) was 13.7 ± 2.9 °C and gradually increased to the highest in August (summer) of 24.2 ± 4.7 °C, which resulted in strong stratification. Increasing temperature can cause stratification, which can affect the movement of water, and oxygen must be distributed so as not to become anaerobic due to the water layer of the substrate [48][49].

Dissolved oxygen in both estuaries ranges from 5–9 mg/L. The highest concentration is at station 6 Muara Sungai Musi. This arises due to human activities, such as the discharge of untreated household and industrial waste. If organic material decomposes into inorganic material, the amount of dissolved oxygen in the water can decrease, which causes an increase in nutrients. [50]. Phytoplankton abundance increases or decreases rapidly with changes in DO component concentrations. The results of a study [51] showed that DO controls the dynamics of the phytoplankton community, and the relationship changes with variations in the chemical composition of DO. DO produced by anthropogenic activities can potentially be a warning to phytoplankton [52][53].

The salinity value shows that both river estuaries are classified as brackish water, which ranges from 6–23 PSU and is in a good range for phytoplankton growth. The lowest salinity at Station 6 of the Musi River Estuary is due to the influx of freshwater from the larger river into the seawater. The difference in salinity from the estuary to the open sea is very large due to the influence of the influx of fresh and sea water [54][55]. The results of the study [56] showed that a salinity of 24–32 PSU contributed to a better understanding of the response of the phytoplankton community. Estuarine ecosystems typically have distinct salinity gradients and environmentally complex waters [15].). Similarly, the salinity stratification displayed in the upper layers is higher than that in the deeper layers [57]. The results showed that salinity is a major controlling factor for phytoplankton communities, limiting both abundance and biomass without changing the main type of algae [58].

The measurement results for pH values in both river estuaries ranged from 6.93 to 7.66. In line with the pH value found [59], the Banyuasin River Estuary is more uniform in the range of 7.3 to 8.3, sufficient to support phytoplankton growth. In contrast to the results [60] found that the Musi River Estuary pH value reached 5.12–5.25, which is not the optimum pH for biota. The acidity in the water is impacted by uncovered land upstream, encompassing activities such as oil palm plantations, operations within the palm oil industry, and the nearby population. This is further corroborated by the assertion that the pH tolerance of organisms is contingent on various physical, chemical, and biological factors that determine the optimal pH range for the phytoplankton life cycle, typically falling within 6.5-8 [61][62].

The light intensity of the Musi River Estuary ranges from 666–814 lux, while in the Banyuasin River Estuary ranges from 39–806 lux. The difference in weather resulted in different values at each station. Light causes phytoplankton to tend to rise to the surface of the water to photosynthesize and absorb nutrients [30]. In line with the statement that phytoplankton production varies greatly depending on high light intensity, phytoplankton production increases, and lower production occurs at decreasing light intensity [63]. The transparency values in both estuaries ranged from 23 to 134.5%. Transparency is also strongly influenced by the weather. At the time of measurement, due to cloudy weather, there was too little light entering the water, so the measurement was less than optimal [64]. [65] stated that diminished brightness results from human activities, including the discharge of waste into water bodies, leading to heightened turbidity and a deficiency of light [66].

The current speed of the Musi River Estuary at stations 1 and 2 is moving towards the north with a current speed of 0.38–0.39 m/s, while at stations 3, 4, 5, and 6, the current moves in the opposite direction, namely towards the northeast with a current speed of 0.35-0.46 m/s. In the waters of the Banyuasin River Estuary, the current moves to the northeast with a current speed of 0.03-0.28 m/s. Phytoplankton, whose motion is affected by ocean currents [67][68]. Current speed has a significant impact on phytoplankton abundance in seawater because ocean currents are a major factor limiting the dispersal of biota in aquatic environments [69][70].

The nitrate concentration in the Musi River Estuary was between 0.1 and 0.7 mg/l, while in the Banyuasin River Estuary, it ranged from 0.1 to 1 mg/l. Some activities that are thought to contribute to the increase in nitrate concentrations in the Musi river are fertilizer factories, agricultural, and plantation activities along the watershed. Based on results, the phosphate concentration in the Musi estuary ranged from 0.012–0.025 mg/l, while the Banyuasin River Estuary ranged from 0.011–0.024 mg/l. Phosphates in rivers and estuaries originate from erosion of crustal minerals and anthropogenic activities, such as polyphosphates found in municipal and agricultural waste and laundry detergents. The distribution pattern with higher concentrations towards the coast is due to the proximity of the waters to terrestrial phosphate sources [71]. [13] It was discovered that along the Southeast Coast of India, there was a decrease in nutrients like NO3, PO43, and SiO42 from Southern stations to Northern stations, possibly attributed to human activities such as the release of untreated domestic sewage, industrial wastewater, and agricultural runoff.

3.2 Phytoplankton community structure

The 11 phytoplankton genus found in both estuaries were classified into four groups. Nine genus Bacillariophyceae (980 cells L^{-1}), one genus Cyanophyceae (5 cells L^{-1}), and one genus Dinophyceae (4 cells L-1) (Figure 2). At the genus level, *Coscinodiscus* proved to be dominant in all station observations. In the class Bacillariophyceae, the following genus were identified: *Asterionellopsis, Bacteriastrum, Chaetoceros, Cerataulina, Coscinodiscus, Lioloma, Stephanodiscus, Skeletonema,* and *Thalassionema*. In the Cyanophyceae class also called Cyanobacteriota or Cyanophyta, only the genus *Planktothrix*, and in the Dinophyceae class, the genus *Protoperidinium* were identified (Table 2).

The diatom group of phytoplankton dominated the genus composition. The percentage of phytoplankton genus composition (Figure 3) was dominated by *Coscinodiscus* (75%), while other genus had low abundance (< 20%). This means that the water condition is very suitable for the growth of the *Coscinodiscus*.

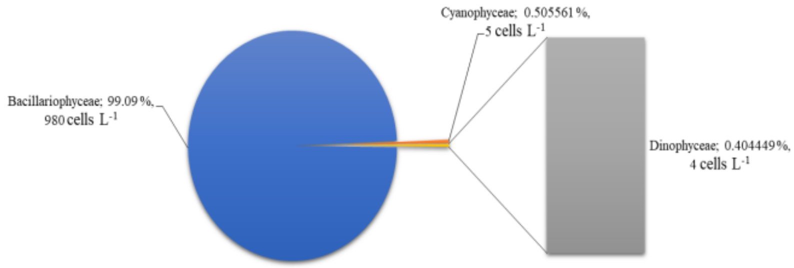


Fig. 2. Phytoplankton composition structure of Musi and Banyuasin river estuaries.

Table 2. Phytoplankton species in Musi and Banyuasin river estuaries.

Class/Species	Musi River Estuary						Banyuasin River Estuary					
	1	2	3	4	5	6	1	2	3	4	5	6
Bacillariophyceae												
Asterionellopsis	-	-	-	-	-	-	-	-	-	-	-	+
Bacteriastrum	-	-	-	-	-	-	+	-	+	-	-	-
Chaetoceros	-	-	-	-	-	-	-	-	+	-	+	-
Cerataulina	-	-	-	-	+	-	-	-	-	-	-	-
Coscinodiscus	+	+	+	+	+	+	+	+	+	+	+	+
Lioloma	-	-	+	+	+	-	+	-	+	-	-	-
Stephanodiscus	+	-	-	-	-	+	+	+	+	-	-	+
Skeletonema	+	+	+	+	-	-	+	+	+	+	+	+
Thalassionema	+	-	-	-	-	-	-	-	-	-	-	-
Cyanophyceae												
Planktothrix	-	-	+	-	-	-	-	+	-	-	-	-
Dinophyceae												
Protoperidinium	-	-	-	-	-	+	-	-	-	-	-	-

(-): not found; (+): 1-2.000 cells L^{-1}

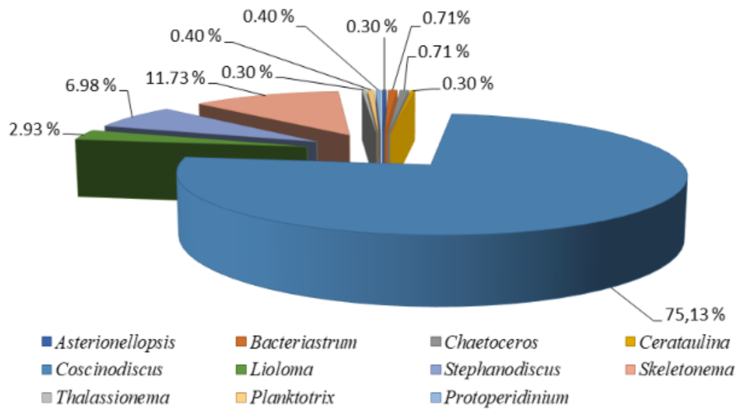
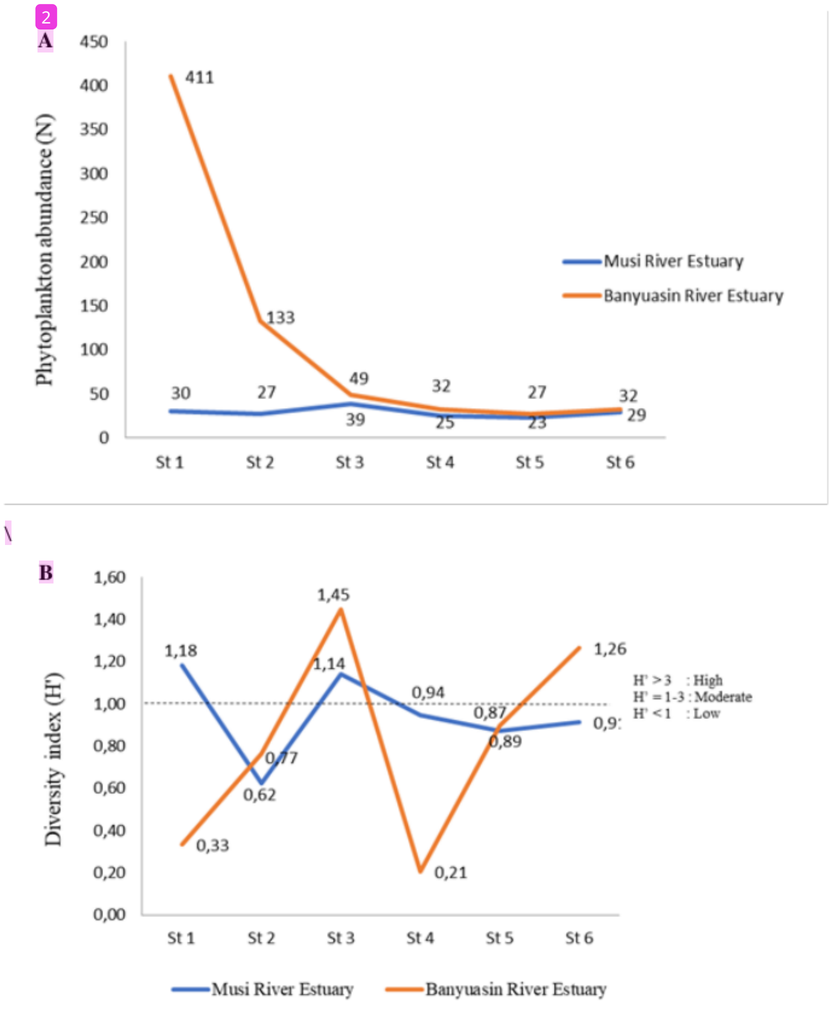


Fig. 3. Percentage of phytoplankton genus in Musi and Banyuasin river estuaries.

Phytoplankton from the Bacillariophyceae class is 99.09% because of its high tolerance to environmental changes and is found in various waters with low slopes [72][73]. The Cyanophyceae and Dinophyceae classes are small because this estuary is vulnerable to environmental changes, which makes these two classes unable to develop easily. In line with the results of research [74], it shows that cyanobacteria show the adaptive ability of microorganisms that have the potential to produce toxins and can increase human exposure to negative health effects [75]. In addition, the Dinophyceae class lives mostly in tropical marine environments [76]. The most common genus is *Coscinodiscus*, which can survive in polluted environmental conditions. The abundance of phytoplankton is aided by the presence of nutrients from anthropogenic waste in the Musi and Banyuasin river estuaries [77][78].

3.3 Distribution of phytoplankton abundance, diversity, uniformity, and dominance

The results of the distribution of abundance, diversity, uniformity, and dominance of phytoplankton are presented in Figure 4. In the Musi River Estuary waters, the range value of phytoplankton abundance was 23–39 cells L^{-1}, with a diversity index (H') showing that phytoplankton were in the low category (H'< 1) except stations 1 and 3 with moderate categories, a high uniformity index (E > 0.6), and no dominance ($0 < C \leq 0.5$). While at the mouth of the Banyuasin River, phytoplankton abundance ranged from 27 to 441 cells L^{-1} with low diversity, with a diversity index (H') showing that phytoplankton were in the low category (H'<1) except stations 3 and 6 with moderate categories, high uniformity index (E> 0.6) except at stations 1 and 4 with low categories, and there was dominance ($0.5 < C < 1$).



A
Phytoplankton abundance (N)
450
400
350
300
250
200
150
100
50
0
411
133
49
32
27
32
30
27
39
25
23
29
St 1
St 2
St 3
St 4
St 5
St 6
Musi River Estuary
Banyuasin River Estuary
B
Diversity index (H')
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
1,18
1,45
1,14
0,94
0,87
0,89
1,26
0,77
0,62
0,33
0,21
H' > 3 : High
H' = 1-3 : Moderate
H' < 1 : Low
St 1
St 2
St 3
St 4
St 5
St 6
Musi River Estuary
Banyuasin River Estuary

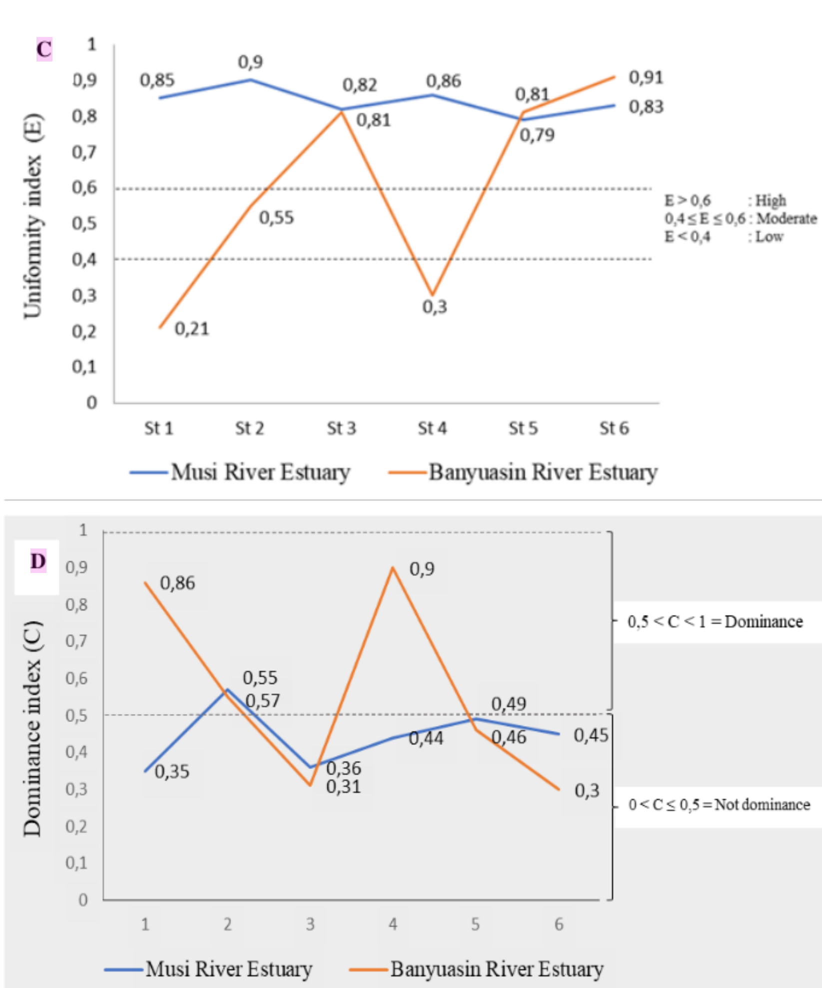


Fig. 4. Distribution of phytoplankton in Musi and Banyuasin river estuaries . (A) abundance, (B) diversity, (C) uniformity, and (D) dominance.

Phytoplankton abundance in the Musi River Estuary ranged from 23–39 cells L^{-1}, and in the Banyuasin River Estuary, it ranged from 27–441 cells L^{-1}. This is influenced by the presence of environmental parameters that can affect the life and development of phytoplankton. When compared with previous research [77], the phytoplankton genus found in the Musi River Estuary at 29 genus. Meanwhile, the Banyuasin River Estuary at 24 genus were found [59]. This can occur due to changes in oceanographic factors that cause low phytoplankton abundance in both river estuaries. Phytoplankton diversity in the Musi River Estuary increases towards marine waters and decreases towards the river, but is still in the low category. While the diversity of the Banyuasin River Estuary varies at each station, the difference in diversity between stations is thought to be due to differences in nutrients between stations. According to [79], nutrient availability and nutrient utilization change diversity and uniformity indicators. Fluctuations in phytoplankton abundance can also be influenced by weather conditions, activities near water bodies, and changes in water quality parameters [80][81]. Low diversity indicates a lack of phytoplankton utilization capacity and tolerance to environmental factors where only certain species are abundant [82].

The uniformity in both waters is included in the high category with a uniformity value > 0.6. A high uniformity index indicates an equal distribution of individuals, and each genus has the same opportunity to use available nutrients such as nitrate and phosphate, even though the amount is limited [83][84]. [85] revealed that a high level of homogeneity between species indicates that the richness of individuals within each species is relatively uniform and certain species are not dominant. The low uniformity index in the Banyuasin River Estuary at stations 1 and 4 is close to zero, indicating the dominance of certain species and ecological pressure in these waters. The dominance of one species can affect the population balance of a community [86].

The highest dominance index value of the Musi River Estuary is found at station 2, and the Banyuasin River Estuary at station 4. Based on this, in these two waters, there is dominance in the genus *Coscinodiscus*. *Coscinodiscus* has a high tolerance for polluted aquatic environments and can grow and develop very quickly [87][88]. Based on the results [6][89], the sampling location was contaminated with pollutants from anthropogenic activities. The low dominance found in these two river estuaries indicated that there was no competition between species [90][91].

3.4 Independent sample t-test

The results of the abundance, diversity, uniformity, and dom11ance indices that have been tested for normality and homogeneity are $p > 0.05$ in both, where the data are normally distributed and homogeneous. The independent sample t-test showed no significant difference in the abundanc19iversity, uniformity, or dominance of phytoplankton found in the two river estuaries (Table 3).

Table 3. Independent sample t-test statistics for differences in average phytoplankton distribution in two river estuaries. Significant differences among affinity groups are represented $p < 0.05$.

Index	Sig.(2-tailed)
Abundance	0.197
Diversity	0.578
Uniformity	0.444
Dominance	0.656

7

The independent sample t-test results show that there is no significant difference in phytoplankton distribution between the two estuarie22Based on Sig. (2-tailed) obtained for the abundance index of 0.197, diversity index of 0.578, uniformity index of 0.444, and dominance index of 0.656. Each index has a significant value exceeding the value of 0.05, indicating that there is no difference in the average phytoplankton distribution between the two river estuaries. This is because overall environmental factors in the Musi and Banyuasin river estuaries tend to be the same. Ecologically, the two estuaries of the Musi and Banyuasin rivers are adjacent and connected into estuarine and coastal areas [92][59].

3.5 Principal component analysis (PCA)

Based on PCA the quality of environmental parameters of the Musi River Estuary has a cumulative eigenvalue of 41.21% and the Banyuasin River Estuary has a cumulative eigenvalue of 45.84% (Figure 5).

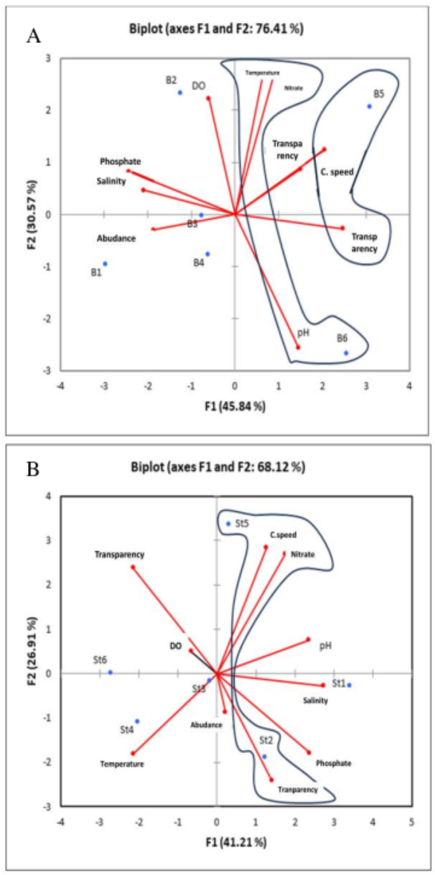


Fig. 5. Correlation between environmental parameters with phytoplankton abundance. (A) Musi River Estuary, (B) Banyuasin River Estuary.

Based on the PCA results, F1's positive contribution to the water quality of the river estuary is in Group 1, which is influenced by salinity, pH, and phosphate parameters. This distinguishing variable affects station 1. The contribution of salinity is 23 PSU, pH 7.51, and phosphate 0.025 mg/l. The value of the three variables is the highest compared to other stations. The PCA results on the F1 axis have positively and negatively correlated groups. Stations 4 and 6 have negatively correlated values with light intensity parameters of 748;787 lux, and temperatures of 29.6 ; 29.7°C. The next contribution of 30.26% is from F2 (positive), group 2 and has current, transparency, and nitrate affecting stations 2 and 5. The current value is 0.38; 0.46 m/s, transparency of 215; 52 %, and nitrate of 0.1; 0.7 mg/l, which is the highest value compared to other stations. While the PCA results indicate the quality of the environmental parameters of the Banyuasin River Estuary, the F1 (positive) contribution is in group 1, which is influenced by the parameters of current and light intensity. The contribution of the current speed parameter at station 5 is 0.28 m/s, and the light intensity is 806 lux. These values are the highest when compared to other stations. Light intensity causes phytoplankton to tend to rise to the surface of the water to carry out photosynthesis, absorb nutrients such as nitrate, sulfate, and phosphate, and also release oxygen [30][93]. In addition to F1 (positive) contributions, F1 (negative) contributions were also obtained in the form of salinity, phosphate, and abundance that affect station 1. Other contributions also occur on the F2 (positive) axis with characteristic variables of temperature, pH, and nitrate that affect station 2. The value of each characteristic variable at station 2 is a temperature of 29.7 °C, a pH of 6.93, and a phosphate of 0.022 mg/l.

4 Conclusion

The phytoplankton found in the Musi River Estuary consisted of 8 genus with the phytoplankton abundance ranged from 23–39 cells L^{-1}, low diversity, high uniformity, and not dominance. While the Banyuasin River Estuary consists of 9 genus with phytoplankton abundance ranged from 27 to 441 cells L^{-1}, low diversity, moderate uniformity, and dominance. The independent sample t-test showed a sig (2-tailed) value ($P > 0.05$), which means that the value of phytoplankton. The principal component analysis showed the highest contribution value in the Musi River Estuary at 41.21% with the characteristic variables of salinity, pH, and phosphate, while in the Banyuasin River Estuary at 45.84% with the characteristic variables of current and light intensity.

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