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Assessment distribution of the phytoplankton community structure at the fishing ground, Banyuasin estuary, Indonesia

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ABSTRACT

The research objective was to describe the distribution of phytoplankton community structure and corelated to the physic-chemical parameters at fishing ground, Banyuasin estuarine waters. The methodology of research was phytoplankton sampling; physicochemical waters parameters data collected such as; dissolved oxygen, pH, temperature, brightness, salinity, current speed, nitrate, and phosphate. Identifications and calculations phytoplankton are based on photography under a light microscope. Data were analyzed by calculated abundance, diversity (H′ index) and dominance (C index), and Principal Component Analysis (PCA). There were 24 species of phytoplankton on the all-observation station grouped in three classes, Bacillariophyceae 91.3%, Dinophyceae 9%, and Cyanophyceae 0.1%. The abundance of phytoplankton species obtained in the range of 666.48 to 184,592.68 cells L^{-1}, were mostly found in high *Chaetoceros affinis* and *Bacteriastrum furcatum*. The distribution of phytoplankton abundance in these waters was found to be more influenced by seawater mass than freshwater. Phytoplankton diversity is considered a moderate category ($1.37 < H' < 2.57$), and there were no species of phytoplankton that dominates ($C < 0.5$). Principal component analyzes showed that waters can be classified based on their physical-chemical characteristics, which were temperature, salinity, pH, transparency, current speed in the south coast around river estuaries, while DO and nutrients on the north coast of the waters. Based on the distribution of phytoplankton abundance is illustrated that the northern part is more potential for fishing area than the southern part with an abundance of phytoplankton >90,000 cells L^{-1} and more stable water dynamics.

1. Introduction

The phytoplankton community structure has an important role in the productivity of marine waters which needs to be constantly monitored, especially the role in the food chain. Information on phytoplankton in waters is needed for various things such as as a fertility bioindicator, aquaculture areas, and fishing zones [1–3]. Besides that, phytoplankton is greatly influenced by the dynamics of changes in the waters physic-chemical parameters such as current velocity, brightness, salinity, pH, nutrients, and so on [1,3–7]. In estuary waters, the supply of freshwater masses from the land will have an impact on turbidity, nutrient concentrations, salinity, and suspended water material. This condition also affects the distribution of phytoplankton abundance and diversity [8,9], and will also reach other marine biota ecosystems through the food web and biogeochemical cycles. [10–14].

Geographically, the Banyuasin estuary waters are located in the western part of the Bangka Strait which are influenced by the large supply of seawater masses from the Malacca Strait and the South China Sea during of the west monsoon and Java seawater masses in the east monsoons. Beside that there is a large number of freshwater mass discharges through rivers from the mainland of Sumatra Island such as Banyuasin River, Musi River and Sembilang River. This physical phenomenon is thought due to a mixing area to the distribution of nutrient concentrations, suspended matter, salinity, dissolved oxygen, currents,

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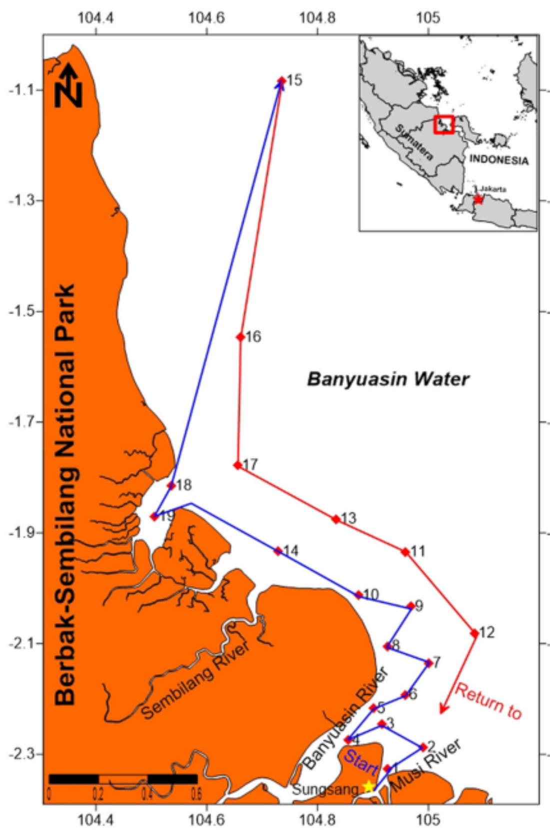

Fig. 1. Map of sampling station in Banyuasin water.

and other environmental factors. According to reports in the adjacent Musi estuary area [15] shows that dissolved oxygen (DO) is around 3.2 to 12.5 mg L^{-1}, temperature 29 to 30.8 °C, salinity 0–15 ppt, the current was very low 2 to 8 cm s^{-1}, water transparency 4.71 to 31.67%, pH 7.6 to 8.1. In addition, marine fishery production in Banyuasin waters is reported to be quite high, around 43,605.50 tons per year [16]. In these waters, fisheries resources are very abundant, such as fish, squid, crustaceans, and shellfish [17–20]. This area is also a potential fishing zone, especially for local fishermen because it is very fertile. This condition is thought to have an important role in the phytoplankton abundance and diversity as primary producers in the waters [2,3,20].

This study intends to describe and analyze the relationship between phytoplankton community structure and environmental factors by data analyzing the distribution of the phytoplankton abundance and diversity at the fishing ground, Banyuasin estuarine waters.

2. Materials and methods

2.1. Study site

Banyuasin Estuary is located in the Bangka Strait of South Sumatra which has high dynamic environmental parameters, it is also a mixing area from the seawater mass from the Melaka Strait and the South China Sea with the Java Sea water period. In addition, there is a large freshwater mass discharge from the mainland of Sumatra Island. This area is also directly connected to the Berbak-Sembilang National Park, where the diversity of marine life is still quite well preserved, and this greatly supports the growth of the surrounding marine biota. In addition, these waters are also a potential fishing zone especially for local fishermen with reported high production of various commodities such as fish, squid, prawns, and shellfish. The area of the study is approximately 9092.37 KM^2. Measurement of the physicochemical parameters of the waters and phytoplankton sampling has been carried out to up to 19 observation stations using tracking for three days, starting from the Sungsang village of Musi Estuary in the south to the north, and back again to the south (Fig. 1).

2.2. Physicochemical data collection

The data of the waters physicochemical waters parameters were measured in-situ in the field such as dissolved oxygen used a DO meter, pH used a pH meter, the temperature was measured with a digital thermometer, brightness was measured with a Secchi disk, salinity was used by a refractometer, current speed was used by a current meter. Nitrate (NO_3) and phosphate (PO_4) data were measured by the spectrophotometer of the water samples taken at each observation station.

2.3. Phytoplankton sampling and analysis

A plankton net (20-μm mesh) was applied to collect samples from the surface water (100*L*) at each observation station. Then, 250 mL of the collected samples preserved 10% Lugol solution was stored into a plastic bottle and sent to the laboratory for qualitative microscopic examination of the phytoplankton cells. Observations and calculations were carried out using a Sedgwick Rafter chamber, 1 mL of each concentrate was counted under a phase-contrast microscope at 400 × magnification [21]. The identification of phytoplankton was referenced to assure accurate species determination [22,23].

2.4. Statistical analysis

Data analysis of the water's physical and chemical parameters was described using surfer 9 software. The phytoplankton diversity calculated by the formula on the Shannon-Winner Index (H′) and the dominance species calculated by the formula on the Simpson (C) Index [24,25]. Principal Component Analysis (PCA) and similarity analysis were carried out to explore the relationship between the physicochemical waters parameters with the phytoplankton abundance and diversity of all observation stations using XLSTAT 2021 software.

3. Results

3.1. Physicochemical parameters of Banyuasin water

In general, the physicochemical conditions in the Banyuasin estuary were very fluctuating such as current, brightness, and nutrients, while the others were found to be relatively more stable. The movement of the surface currents in the Banyuasin waters shows that the currents coming from the north hit the mainland of Sumatra and mostly veered south. The mass of seawater comes from the Melaka Strait and the South China Sea with a weak category of velocity, namely 0.25 ± 0.15 m s^{-1} on average. Water transparency can be classified as very low with an average value of 1.6 ± 1.31 m, and slightly increasing towards the high seas. This condition can certainly cause the photosynthesis layer to be thin so that it affects the abundance of phytoplankton. The distribution patterns of nitrate and phosphate were found to be similar with mean values of 5.31 ± 0.62 mg L^{-1} and 0.16 ± 0.02 mg L^{-1}. Both are found to be higher in the northern than southern waters. The nitrate concentration shows a value higher than the normal requirement for phytoplankton growth, and this can lead to algal blooms. These nutrients may be influenced by the supply of land water and are distributed by currents.

The dissolved oxygen (DO) is categorized as normal and evenly distributed, especially in the North compared to the South in the range

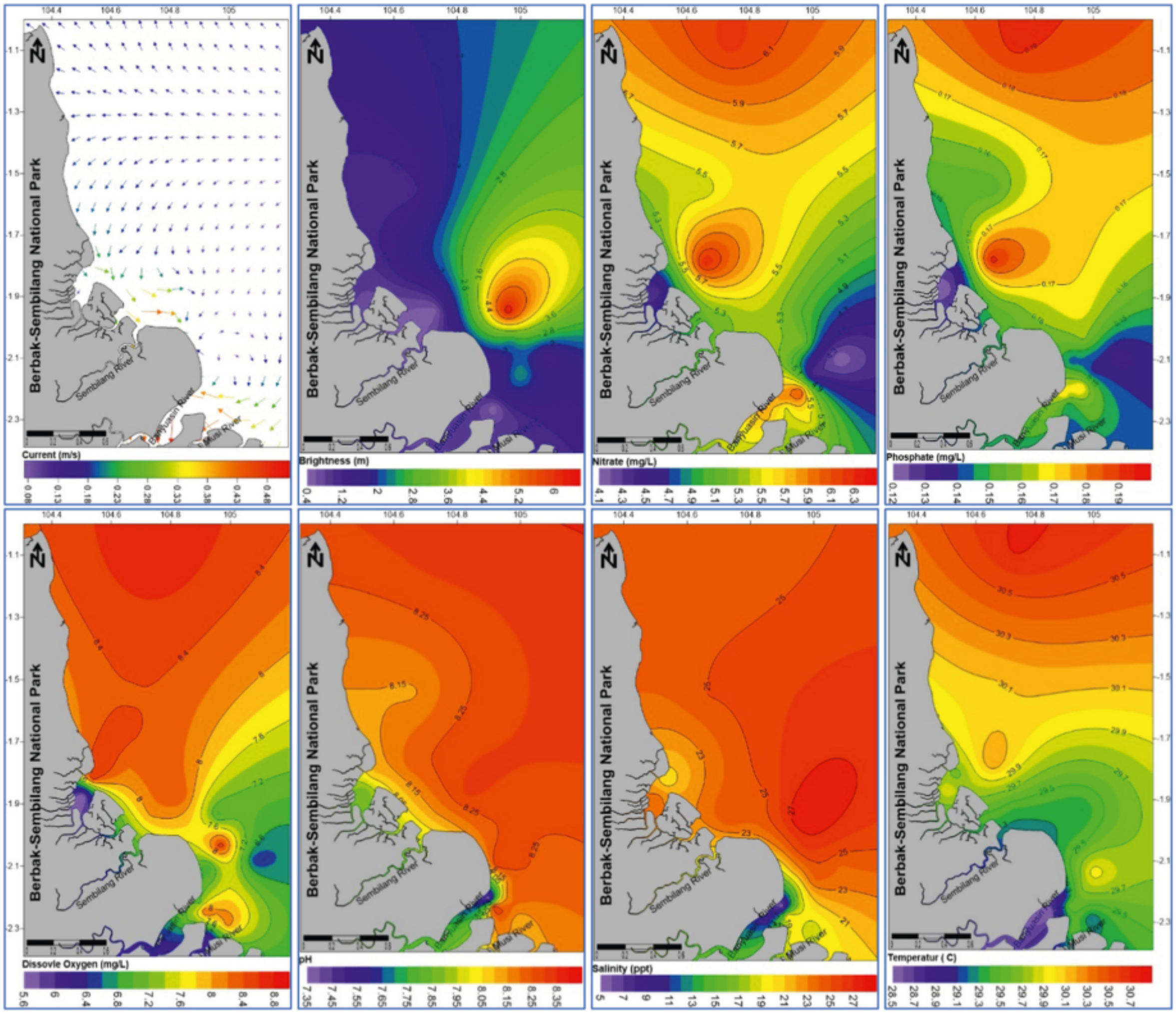

Fig. 2. Physicochemical parameters in Banyuasin water.

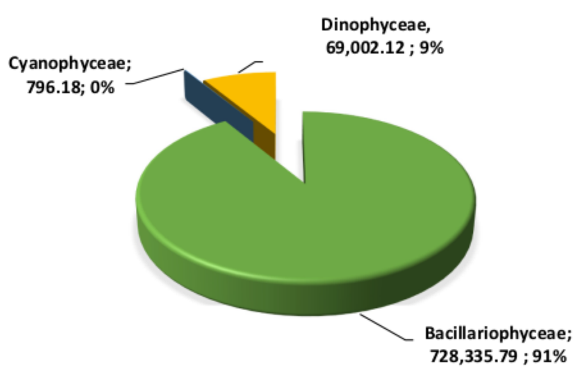

Fig. 3. Phytoplankton community structure in Banyuasin water.

of 5.63 to 8.76 mg L^{-1}. The pH value was found to be more uniform in the range 7.3 to 8.3, it was found to decrease slightly towards the river mouths. The distribution of salinity was found to be similar to pH in that it was more evenly distributed with the brackish water category averaging 21.42 ppt, but it experienced a sharp decrease towards the river up to 5 ppt. This decrease occurred due to mixing with the discharge of freshwater masses from the land. The average temperature ranges from $29.57 \pm 0.51\ ^{\circ}C$, and slightly increases towards the northern part of the sea which is thought to be carried along with the mass of open seawater. This temperature value range is still normal to be found in tropical waters and is categorized as optimum for phytoplankton growth (Fig. 2).

3.2. Phytoplankton community structure

The phytoplankton composition was found to vary widely, it was found that 24 species were grouped into three classes, namely Bacillariophyceae 91.3% as many as 18 species, Dinophyceae 9% as many as five species, and Cyanophyceae 0.1% with only one species. The highest percentage of abundance was in the class Bacillariophyceae which was dominated *by Chaetoceros affinis* and *Bacteriastrum furcatum* (Fig. 3).

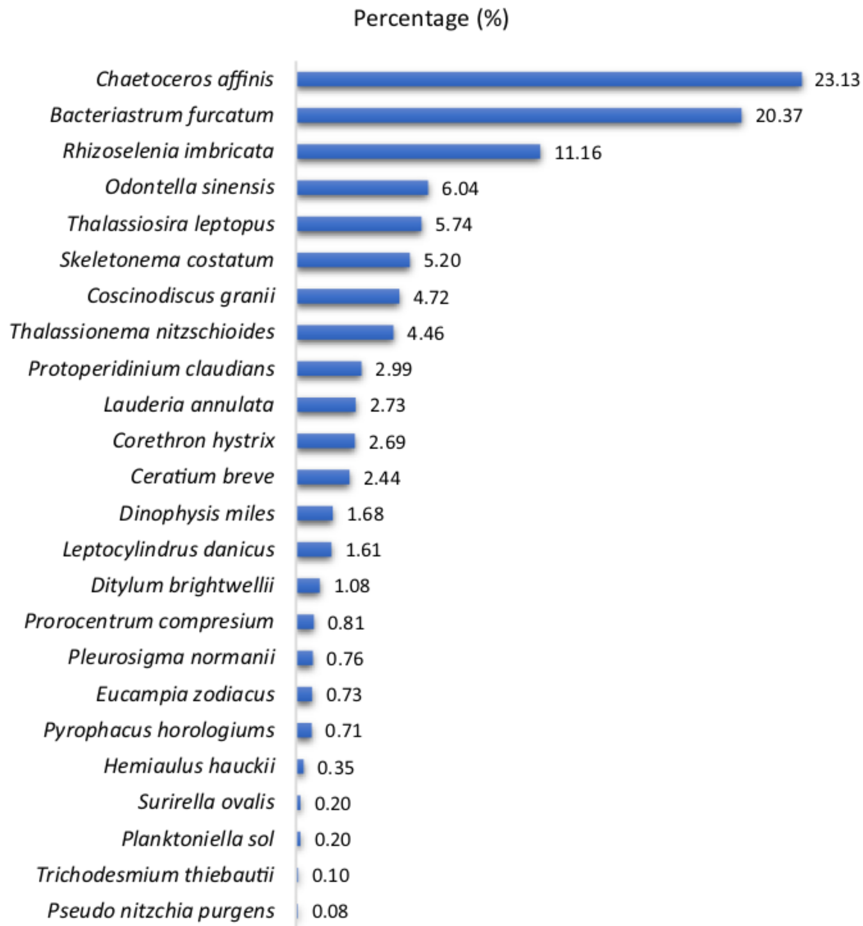

Fig. 4. Percentage of phytoplankton species in Banyuasin water.

The phytoplankton species *Chaetoceros affinis, Bacteriastrum furcatum, Rhizoselenia imbricata, Thalassiosira leptopus, Coscinodiscus granii,* and *Thalassionema nitzschioides* were found in almost every observation station. The highest abundance was shown by *C. affinis* and *B. furcatum* with 89,087.28 cells L^{-1} and 184,592.68 cells L^{-1}. The distribution of several phytoplankton species was also found to be uneven, such as *Pseudo-nitzchia purgens, Surirella ovalis*, and *Trichodesmium thiebautii*, where they were found at only one or two stations, with relatively lower abundances of <1600 cells L^{-1}. (Fig. 4).

3.3. Phytoplankton abundance and diversity

Based on Fig. 4, the percentage of phytoplankton species is shown to be mostly found in *Chaetoceros affinis* and *Bacteriastrum furcatum* with each>20% of the total abundance obtained. In this percentage, there are several phytoplankton species that high abundances, namely the *Rhizoselenia imbricata* (11.16%), *Odontella sinensis* (6.04%), *Thalassiosira leptopus* (5.74%), *Skeletonema costatum* (5.20%), *Coscinodiscus granii* (4.72%), and *Thalassionema nitzschioides* (4.46%). Meanwhile, other species have a low percentage < 3%.

3.4. Distribution and phytoplankton diversity

The distribution pattern of the phytoplankton abundance at the observation site shown a high variation in the northern is >90,000 cells L^{-1} part compared to the southern part is <40,000 cells L^{-1}. This condition is strongly thought to be influenced by the more stable waters in the North due to the influence of seawater mass supply from the Melaka Strait and the South China Sea compared to the southern part which is strongly influenced by the discharge of freshwater masses from the mainland of Sumatra through three major rivers, namely: the Sembilang River, the Banyuasi River. and the Musi River. Besides that, there are also smaller rivers. (Fig. 5).

The total of the phytoplankton abundance was obtained 798,134.09 cells L^{-1} which were dominated by the diatoms group (91.3%). There were 6 species of phytoplankton found to be evenly distributed throughout the observation stations, namely *Chaetoceros affinis, Bacteriastrum furcatum, Rhizoselenia imbricata, Thalassiosira leptopus, Coscinodiscus granii,* and *Thalassionema nitzschioides,* but their abundance was much different (Table 1).

The phytoplankton diversity found to be slightly high in the medium category with an index value of $1.37 < H' < 2.57$. This shows that the phytoplankton species in Banyuasin waters are quite diverse (24 species). In addition, the dominance index showed no dominant species with a value of $0.09 < C < 0.4$ (Fig. 6).

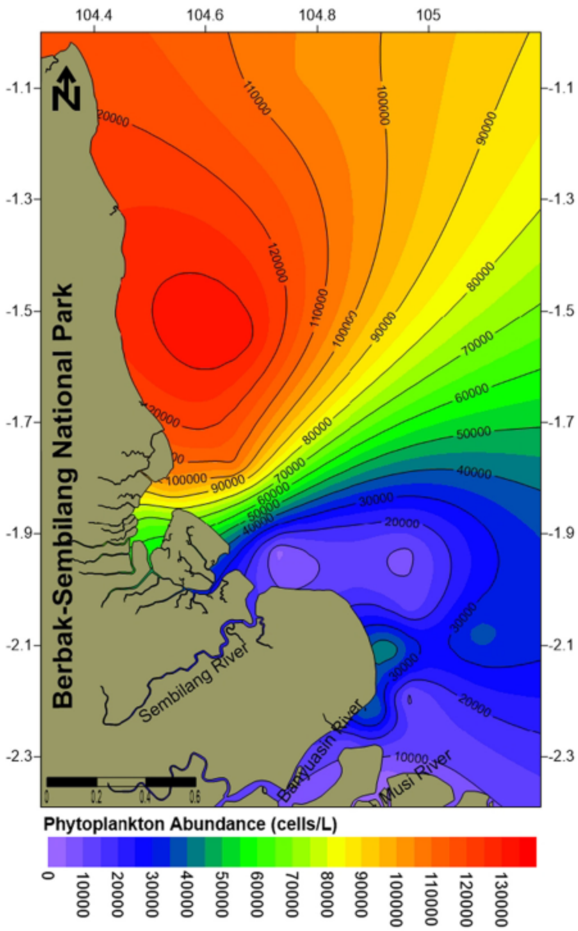

Fig. 5. Distribution of phytoplankton abundance in Banyuasin water.

3.5. Correlation between physicochemical parameters with phytoplankton abundance and diversity of Banyuasin water

The Principal Component Analysis (PCA) showed that the five predominant phytoplankton groups were correlated differently with environmental factors, formed in three axes with a cumulative eigenvalue of 73.03%. Groups 1, 2 and 3 were formed on the relationship between the F1 and F2 axes, and the group 4 and 5 formed on F1 and F3 axes, while the results of the similarity analysis were grouped into three clusters with codes Cs1, Cs2 and Cs3 (Fig. 7).

Based on Fig. 7A and B, the first group formed on the positive F1 axes, it has described at stations 7 dan 8, and with the identifiers of temperature, pH, and salinity more than high, which is followed by an increase in phytoplankton diversity (H′). The second group formed on the negative F1 axis, which depicted stations 2, 4, and 5 with the identifiers of higher current speed at the river mouth, it is shown occurred strong mixing by a higher current speed than others. The third group formed on the positive F2 axis illustrated those stations 15 and 17 with the identifier of higher dissolved oxygen (DO), nitrate (NO3), and phosphate (PO4). This condition is supportive of the metabolic processes of phytoplankton. The fourth group formed on the positive F3 axis described those stations 16, 18, and 19 with the identifier of higher species abundance because it is supported by almost all parameters. The last group formed on the negative F3 axis described those stations 11 and 13 with the identifier of high transparency (bright) with this location more towards the ocean, and is needed in the photosynthesis process for phytoplankton.

The results of the similarity at the observation station in Banyuasin waters were calculated using the Bray-Curtis dissimilarity index (Fig. 7C). It was found that the similarity was significant in the strong category. There were three classes formed (Cs1, Cs2, and Cs3) with an average similarity value of 85%. In addition, the highest value was shown in Cs3, namely 98% which includes: stations 15, 16, 17, and 18 which are located in the northern part of the water. Then, Cs2 92% includes stations 3, 5, 7, 8, 12, 13, and 19 which are located on the coast to the north. Next was the Cs1 cluster with 88% similarity including stations 1, 2, 4, 6, 9, 10, 11, and 14, located precisely at the mouth of the river estuary on the south side. This similarity indicates that the influence of the dynamics of the physicochemical parameters of the waters on the abundance and diversity of phytoplankton at all stations is not much different.

4. Discussion

Overall, the dynamics of the physic-chemical parameters of Banyuasin waters were found to be very supportive for the phytoplankton growth. The distribution pattern is described as fluctuating in dissolved oxygen (DO), brightness, temperature, and nutrients, while the distribution is relatively even in salinity and pH. DO at the observation site was good enough for the growth of marine biota, especially phytoplankton, this is also common in estuary waters [26–29]. Water salinity can also affect phytoplankton diversity [7].

The waters brightness at the observation site is very low or turbidites. This is due to the large suspended material supply from mainland Sumatra. In addition, there was strong stirring by the current which resulted in increased turbidity in the waters. High turbidity will complicate the photosynthesis process of phytoplankton, and growth will be low [30–32].

The temperature at the study site was found to be in the typical range in tropical Indonesia [33,34], but different from other areas such as in the Neva Estuary, Baltic Sea [35], in China's Yangtze Estuary [36], in the Magdalena River mouth, Caribbean Sea [37].

Nutrients in the research location were found to be quite varied where it was seen that in the river it was higher than outside the river, this was a supply from the mainland. High nitrate and phosphate values can have an impact on phytoplankton growth [38–43].

The distribution pattern of the physicochemical parameter values was shown to be higher in the waters of the north than in the south. This variation was strongly thought to have an impact on the flow pattern and velocity of the water masses of the Melaka Strait and the South China Sea which is stronger than the water mass of the Java Sea. In addition, the supply of freshwater mass through the surrounding rivers was found to have a significant impact on the water mass distribution pattern, especially brightness, temperature, and nutrients, while it was not significant for other parameters. This phenomenon of adjacent locations were also reported by [20,44,45].

There are 24 phytoplankton species classified that into three groups found in Banyuasin waters, dominated by in Bacillariophyceae class of the *Chaetoceros affinis* and *Bacteriastrum furcatum*. This number is slightly low than reported by [35,46], but higher than reported by [44], which only 15 species. Bacillariophyceae class are found high abundance has also been reported by [47–50]. These species are thought to be more tolerant of changes in water quality.

Phytoplankton abundance in the Banyuasin waters was around 666.48 to 184,592.68 cells L^{-1}. This value was higher than recorded by [33,49] but lower than reported by [35,44]. Phytoplankton species were shown the most in *C. affinis* and *B. furcatum* with an amount of>20% each. It is different than found by [35,51], which is dominated by the Chlorophyceae class with *Monorahidium contortum* species. [8], that Mixotrophs were dominated by *Chrysochromulina* spp. during the whole

Table 1
Phytoplankton species in Banyuasin water.

Class/ Species	Stations																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Bacillariophyceae																			
Pseudo-nitzchia purgens	–	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Bacteriastrum furcatum	+	+	++	+	+	+	+	++	+	++	–	++	+	+	++++	++++	++++	++++	++++
Corethron hystrix	–	–	–	–	–	–	+	+	–	–	–	–	–	–	++	++	++	++	++
Chaetoceros affinis	+	–	+	–	++	++	++	++	++	++	++	++++	++	+	++++	++++	++++	++++	++
Coscinodiscus granii	+	+	+	+	+	+	++	++	+	++	+	+	++	+	–	+++	++	++	++
Ditylum brightwellii	–	–	–	–	–	–	–	–	–	+	–	–	–	–	++	++	++	++	–
Eucampia zodiacus	–	–	–	–	–	–	+	–	–	+	–	–	–	–	++	+	+	++	+
Hemiaulus hauckii	–	–	–	–	–	–	–	+	–	–	–	–	–	–	++	+	–	–	+
Lauderia annulata	–	–	–	–	–	–	–	++	+	–	–	++	–	–	++	++	+	–	++
Leptocylindrus danicus	–	+	++	++	++	–	+	++	+	–	–	–	–	–	–	+	–	–	–
Odontella sinensis	–	+	++	–	+	+	–	++	–	–	+	++	++	+	++	+++	++	++	–
Planktoniella sol	–	–	++	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pleurosigma normanii	–	–	+	–	+	–	+	++	–	–	–	–	–	–	++	+	+	+	+
Rhizoselenia imbricata	–	–	+	–	–	–	+	+	+	++	+	++	++	–	+++	+++	+++	+++	+++
Skeletonema costatum	+	–	++	++	++	++	++	++	–	–	–	++	++	–	–	–	–	–	–
Surirella ovalis	–	–	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Thalassionema nitzschioides	–	–	+	–	++	+	++	++	++	++	++	++	+	+	++	++	++	++	++
Thalassiosira leptopus	+	++	++	++	++	+	++	++	+	–	+	+	++	+	+	++	++	++	++
Dinophyceae																			
Ceratium breve	+	–	–	+	–	+	++	++	++	+	++	–	++	+	+	++	++	+	–
Dinophysis miles	–	++	–	–	–	–	++	++	+	–	++	+	+	–	–	–	+	–	+
Prorocentrum compresium	–	–	–	+	++	–	+	–	+	–	–	–	–	–	–	+	–	++	+
Pyrophacus horologiums	–	+	++	–	++	–	–	+	++	–	–	–	–	–	–	–	–	+	–
Protoperidinium claudians	+	++	++	+	++	+	++	++	++	–	+	++	+	+	–	–	–	–	+
Cyanophyceae																			
Trichodesmium thiebautii	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–

Noted: - is not found, + <1000 cell L^{-1}, ++: 1000–10,000 cell L^{-1}, 10,000–20,000 and > 20,000 cell L^{-1}.

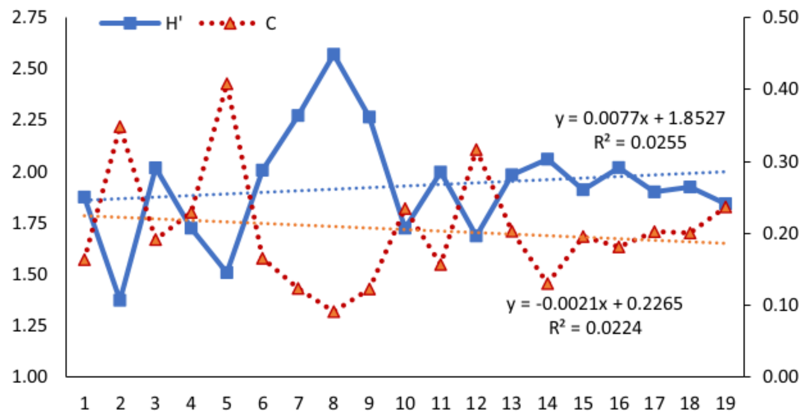

Fig. 6. Phytoplankton diversity index in Banyuasin water.

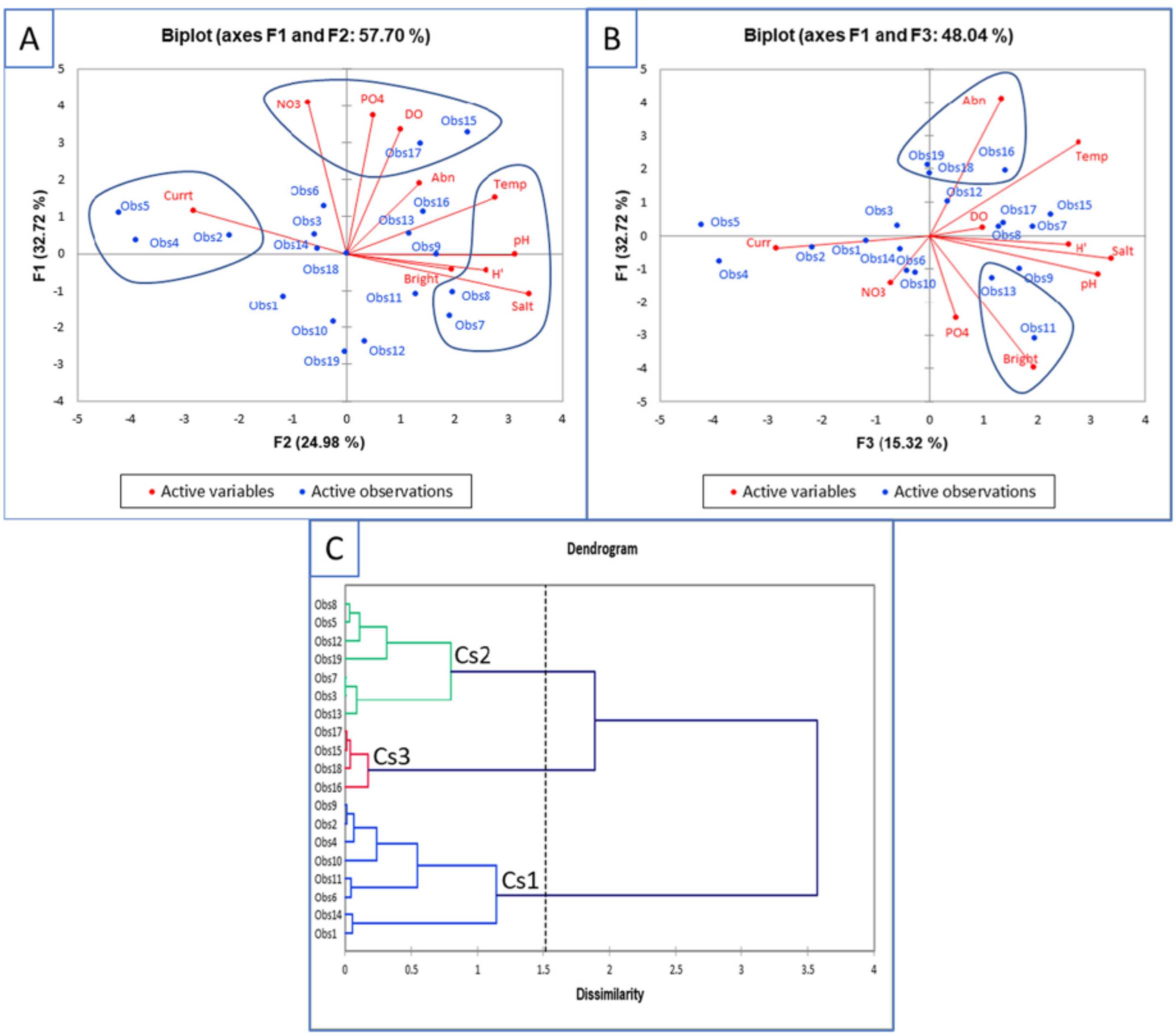

Fig. 7. Correlation between water quality parameters with phytoplankton abundance and diversity, (A) F1 and F2 axes; (B) F3 axis; (C) Dendrogram of dissimilarity between stations based on the phytoplankton abundance and diversity.

study period and *Dinophyceae* spp. were the most abundant class among heterotrophs. [52], that *Thalassionema frauenfeldii* and *Rhizosolenia styliformis* species had higher abundance in surface water but they dominated at 30 m-depth layers.

Based on the PCA results that there was a correlation between the physicochemical parameters of the waters with the abundance and diversity of phytoplankton with characteristics such as temperature, pH, and salinity in the estuary as a mixing area. Freshwater mass discharge affects environmental parameters and has an impact on changes in the distribution of phytoplankton abundance and diversity. The diversity index of phytoplankton in Banyuasin water categorized as moderate is thought to be caused in the estuary area. The same as recorded by [48]. In addition, it is thought to be related to relatively [44].

The abundance of phytoplankton was found to increase to the north at the observation station, where this location has influential parameters, such as DO, and normal or stable nutrients, while turbidity has an impact on reducing the abundance of phytoplankton around the estuaries of rivers in Banyuasin waters. Phytoplankton is significantly influenced by sunlight for photosynthesis [53–55]. Based on the distribution of phytoplankton abundance and its relation to the influence of water quality, it can be said that the potential of the fishing zone in Banyuasin waters is located in the northern part with an abundance of phytoplankton >90,000 cells L^{-1}, and the dynamics of the aquatic environment such as the distribution of DO, nutrients, and transparency are found to be higher. and stable due to the larger seawater mass supply from the Straits of Melaka and the South China Sea.

5. Conclusions

The physicochemical parameters dynamics of Banyuasi waters were found to be in good condition for the growth of phytoplankton. There were 24 species of phytoplankton, which are dominated by Bacillariophyceae class with *C. affinis* and *B. furcatum* species. Phytoplankton abundance calculated to be around 666.48 to 184,592.68 cell L^{-1}. Phytoplankton diversity categorized as moderate, and no species dominate. PCA analysis showed physical-chemical parameters of water characterized by temperature, salinity, pH, transparency, current speed around the mouth of the river, while nutrient and DO were on the north coast of the water. Based on the distribution of phytoplankton abundance in the fish catchment area, it can be said that the northern part is more potential than the southern part with phytoplankton >90,000 cells L^{-1} and stable water conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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