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Diversity and abundance of phytoplankton in Bone Bay, South Sulawesi, Indonesia and its relationship with environmental variables

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Abstract. *Tambaru R, Burhanuddin AI, Haris A, Amran MA, Massinai A, Muhiddin AH, Yaqin K, Firman, Yuliana. 2024. Diversity and abundance of phytoplankton in Bone Bay, South Sulawesi, Indonesia and its relationship with environmental variables. Biodiversitas 25: 624-631.* Ecological studies of phytoplankton have been widely conducted in various bays around the world. However, such research is still limited in Bone Bay, South Sulawesi, Indonesia. Therefore, this study aimed to investigate the diversity and abundance of phytoplankton in Bone Bay and the relationships with environmental factors. Data collection was conducted in the dry season (May to June 2023) at four stations, namely Bajoe Harbor (PB), Cappa Ujung (CU), Libureng (LB), and Tongke-Tongke (TT). At each station, seawater samples were collected and environmental variables were measured including temperature, salinity, pH, currents, and nutrients (i.e. Nitrate, Nitrite, Ammonium, Orthophosphate, and Silicate). In general, the environmental variables in the studied area were within the range of optimal condition for phytoplankton to grow and develop. There were three classes of phytoplankton recorded, namely Bacillariophyceae, Cyanophyceae, and Dinophyceae, with a total of 31 genera were identified. *Chaetoceros*, *Thallasionema*, and *Rhizosolenia* were the dominant genera. The average abundance of phytoplankton was significantly different among stations with the highest was found in CU and PB compared to that in LB and TT (p-value <0.01). PCA analysis showed that phytoplankton abundance was related to high orthophosphate concentrations, silicate, and turbidity at the PB and CU stations, while the opposite condition occured at the LB and TT stations. Based on the diversity and abundance of phytoplankton, Bone Bay, South Sulawesi is now still in good condition, yet monitoring studies are recommended to see the changes in the future.

Keywords: Abundance, Bone Bay, diversity, environment, Indonesia, phytoplankton

INTRODUCTION

As semi-enclosed waters, bay is an important ecological resource (Wu et al. 2021) which delivers various environmental services (Jing et al. 2023). Bays act as protectors of coastlines from environmental disturbances such as storms, strong waves and sea abrasion and intrusion (Jackson et al. 2020), habitat of various organisms such as fish and oysters (Bruce et al. 2021), and recreation and tourism areas which are related to the health and welfare of coastal communities (Hosseini et al. 2020). As an ecological resource, changes in the values of various physical, chemical, and biological components of a bay affect the organisms living in it.

Among various aquatic biotas, phytoplankton are commonly used to inform the interaction of various environmental factors in marine ecosystems including bay. Several physical, chemical, and biological parameters are known to have influence on the spatial and temporal distribution of phytoplankton types and abundance as well as their activities (Tambaru et al. 2021; Wang et al. 2022; Zhang et al. 2023). A number of studies in various parts of the world have widely investigated the ecological and physiological aspects of these microorganisms in relation to environmental status and changes in the bay. In research in the Arabian Gulf, various phytoplankton genera were found due to the interaction of various environmental factors (El Gammal et al. 2017). In Kuwait Bay, phytoplankton diversity varies due to environmental changes (Ahmed et al. 2022).

The high level of primary production in a bay is largely determined by phytoplankton activity through photosynthesis. A study by Zhang et al. (2021) in the Chesapeake Bay of North America reported that phytoplankton growth occurred rapidly due to increased nutrient concentrations. Similar result was also found in Jakarta Bay where phytoplankton abundance increased when nutrient concentrations increased (Damar et al. 2020). Changes in water temperature to certain limits, as well as the availability of light, turbulence, salinity, water turbidity, and tidal currents, are other environmental factors that influence the growth of phytoplankton (Ardyn et al. 2020), as well as the emergence of other types of phytoplankton in the Baffin Bay (Oziel et al. 2019). As reported by Han et al. (2022), every year, the increase in temperature and ice melting during the Austral Spring causes the succession of phytoplankton communities in Gwangyang Bay on the Korean Peninsula.

One event which often occur in a bay is the blooming of phytoplankton (Genitsaris et al. 2019). The occurrence of this event is reasonable because the waters in a bay are relatively calmer than open sea waters, causing phytoplankton to grow faster. In several cases, the species of phytoplankton that blooming are detrimental to the environment which is then called HAB (Harmful Algal Bloom) (Stauffer et al. 2020). HABs usually develop at the beginning of the rainy season since nutrient concentrations experience a massive increase, making the waters very fertile (eutrophication). For example, HAB events occurred in Jakarta Bay were caused by a large addition of organic and inorganic nutrients from river estuaries in the Jakarta area and its surroundings (Damar et al. 2020). Similar event also occurred in the Gulf of Mexico (Cervantes-Urieta et al. 2021). Not only detrimental to the environment, but HABs can also negatively impact humans due to the accumulation of harmful algae in fish and shellfish (Rolton et al. 2022), causing food poisoning in humans if the fish are eaten (Berdalet et al. 2023).

While several studies have been conducted to analyze the presence of phytoplankton in relation to particular events such as algal blooming, limited studies are available in lesser known region such as Bone Bay, South Sulawesi, Indonesia. In this bay, phytoplankton can be found in abundance because the waters are categorized as fertile. This bay receives a great amount of inorganic and organic materials from various anthropogenic activities, such as ponds, agriculture, households, and port activities. This water area also has high fishing activities. However, ecological research on phytoplankton in this bay has never been carried out comprehensively. Therefore, this study aimed to investigate the diversity and abundance of phytoplankton in Bone Bay and the relationships with environmental factors. This research is very important as part of early detection and evaluation to monitor the quality of the waters in the bay to sustain the life of other aquatic organisms at higher trophic levels.

MATERIALS AND METHODS

Study period and area

This research was conducted during the dry season, i.e., from May to June 2023. We established four research stations in the coastal waters of Sinjai and Bone Districts (Figure 1), namely Bajoe Harbor (PB), Cappa Ujung (CU), Libureng (LB), and Tongke-Tongke (TT). Each research station consisted three zones, namely inner zone (zone A: 0.5-1 km from the mainland), middle zone (zone B: 1 km from the inner zone), outer zone (zone C: 1 km from the middle zone/high seas). Sample identification and analysis were conducted at the Chemical Oceanography Laboratory, Department of Marine Sciences, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, Makassar.

Data collection

This study used non-experimental approach in which observations were carried out in natural condition without any intervention from the researcher. Seawater samples were collected from all stations and zones using a Kemmerer Water Sampler with a volume of 2 liters. At each zone of a station, 1 liter of water was taken for phytoplankton precipitation (100 mL), measuring nutrients such as N, P, silicate (250 mL), and turbidity (100 mL). Samples were temporarily stored in bottles and placed in a cool box with ice at a temperature of around 4°C until analyzed in the laboratory (stored in a freezer below 4°C).

Measurement of environmental variables

In situ measurements were carried out at each station to record temperature, salinity, pH, current, and oxygen. Turbidity measurements were carried out in the laboratory. Temperature and salinity measurements were carried out using an STD instrument, Salinity Temperature Bridge type MC and pH measurements using Hanna Instrument HI 8424. The current was measured with a current meter, while turbidity and dissolved oxygen were measured using turbidimeter and DO meter.

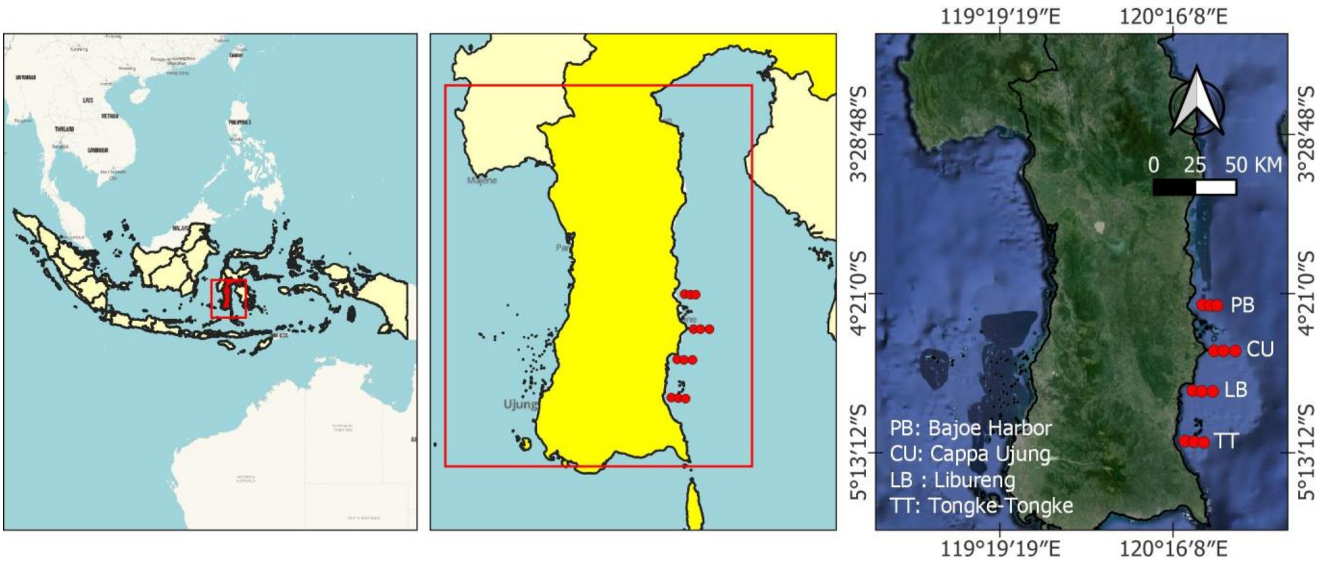

Figure 1. Map of sampling sites in Bone Bay of South Sulawesi, Indonesia

Measurement of nutrient variables

In situ water samples for measuring the concentration of nutrients such as Nitrogen (N), Phosphorus (P), and Silica (Si) were analyzed in the laboratory. The methods for measuring N-type nutrients, in the form of nitrate, nitrite, and ammonia, are the Brucine, Sulfanilamide, and Phenat methods, respectively. For P (orthophosphate), the Stannous Chloride method was used, and for silica, the Molybdosilicate method was used (APHA 2005).

Enumeration of phytoplankton in the laboratory

Sampling of phytoplankton was carried out according to the method developed by Uthermol (1958) as cited in Damar (2003). As much as 100 mL of sub-sample was deposited in a measuring cup (volume 100 mL). The sample was preserved with 1% Lugol for approximately 1 week. The precipitate formed (approximately 10 mL) was separated from the supernatant by siphoning. The precipitate was put into a bottle and added 1% lugol. A total of 1 mL of the sediment was then put into the Sedgwick Rafter Cell with a scaled pipette to calculate the abundance of phytoplankton cells. The method for calculating the abundance of phytoplankton cells was sweeping (census) using Sedgwick Rafter Cell (SRC) (APHA 2005). Several standard identification books, such as Yamaji (1979) and Tomas (1997), were used to identify phytoplankton species.

Statistical analysis

Descriptive analysis was used to explain the presence of the dominant phytoplankton species. One-way ANOVA was used to test the distribution of phytoplankton abundance. PCA was used to analyze the relationship between phytoplankton abundance and environmental parameters. SPSS 16 software was used for the statistical analyzes.

RESULTS AND DISCUSSION

Environmental variables in Bone Bay

Table 1 shows results of measurements of environmental variables at each zone of each station in Bone Bay. In general, the values are still within the range of environmental condition for phytoplankton to grow optimally, even though some of them, such as nitrate, are not in optimal conditions.

Phytoplankton diversity in Bone Bay

Bacillariophyceae, Cyanophyceae, and Dinophyceae were three classes of phytoplankton collected during the research. There were 31 genera identified with Bacillariophyceae had the most number of genera with 25 (*Bacteriastrum, Bidhulphia, Cerataulina, Chaetoceros, Coscinodiscus, Cylindrotheca, Ditylum, Eucampia, Guinardia, Hemialus, Lauderia, Leptocylindrus, Melosira, Navicula, Nitzschia, Odontella, Pleurosigma, Proboscia, Pseudo-nitzschia, Rhizosolenia, Skeletonema, Stephanopyxis, Striatella, Thalassionema,* and *Thalassiosira*), then Dinophyceae with four genera (*Ceratium, Dinophysis, Gymnodinium,* and *Protoperidinium*), and Cyanophyceae with two genera (*Oscillatoria* and *Pseudanabaena*) (Table 2). *Chaetoceros, Rhizosolenia,* and *Thallasionema* were the dominant genera and were always found at every station. These three genera belong to the Bacillariophyceae group.

The number of phytoplankton genera varies at each station. At PB and CU stations, 24 and 26 genera were found, respectively, with the dominant genera being *Chaetoceros, Rhizosolenia,* and *Thallasionema*, while at the LB and TT stations, 25 and 26 genera were found respectively, with the dominant genera being only *Chaetoceros*.

Phytoplankton abundance in Bone Bay

Figure 2 shows the abundance of phytoplankton by station. During the research, the highest average abundance of phytoplankton was found in CU compared to PB, LB, and TT.

Phytoplankton abundance in CU ranged 1,159-2,732 cells/L with an average and standard deviation (SD) of 1,837 cells/L and 933, PB ranged from 773-3,256 cells/L with 1,778 cells/L and 743, LB ranged from 219-527 cells/L with 394 cells/L and 297, and TT ranged from 274-427 cells/L with 329 cells/L and 192 (Table 3).

Table 1. Results of measurements of environmental variables in Bone Bay, South Sulawesi, Indonesia

Environmental variables	Results of measurement		
	Min.	Max.	Average±SD
Nitrate (mg/L)	0.023	0.127	0.044±0.004
Nitrite (mg/L)	0.021	0.085	0.039±0.016
Ammonium (mg/L)	0.007	0.027	0.017±0.004
Orthophosphate (mg/L)	0.015	0.024	0.020±0.002
Silicate (mg/L)	0.004	0.020	0.010±0.001
pH	7.49	7.52	7.50±0.01
Salinity (‰)	28.7	32.0	30.9±0.4
Temperature (ºC)	29.00	31.30	30.25±0.34
Current (m/s)	0.03	0.188	0.111±0.022

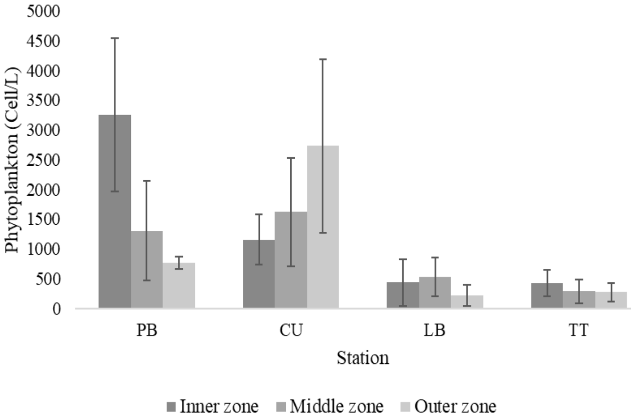

Figure 2. Phytoplankton abundance of each zone and station in Bone Bay, South Sulawesi, Indonesia (mean ± SD)

Table 2. Phytoplankton diversity by station and genera

Class	Genera	Station			
		PB	**CU**	**LB**	**TT**
Bacillariophyceae	*Bakteriastrum*	√	√	√	√
	Bidhulphia		√	√	√
	Berataulina		√	√	√
	Chaetoceros	√	√	√	√
	Coscinodiscus	√	√	√	√
	Cylindrotheca	√	√	√	√
	Ditylum	√	√	√	√
	Eucampia			√	√
	Guinardia	√	√	√	√
	Hemiaulus	√	√	√	√
	Lauderia	√	√	√	√
	Leptocylindrus	√	√	√	√
	Melosira	√	√	√	√
	Navicula	√	√	√	√
	Nitzschia	√			
	Odontella	√			
	Pleurosigma	√	√	√	√
	Proboscia		√		√
	Pseudo-nitzschia	√	√	√	
	Rhizosolenia	√	√	√	√
	Skeletonema	√	√		√
	Stephanopyxis	√			
	Striatella		√	√	√
	Thalassionema	√	√	√	√
	Thalassiosira		√	√	√
Dinophyceae	*Ceratium*	√	√	√	√
	Dinophysis	√			
	Gymnodinium		√	√	√
	Protoperidinium	√	√	√	√
Cyanophyceae	*Oscillatoria*	√	√	√	√
	Pseudanabaena	√	√	√	√

Table 3. Range, average abundance (cells/L), and standard deviation (SD) of phytoplankton at each observation station

Station	Range (cell/L)		Average (cell/L) ± SD
	Minimum	**Maximum**	
PB	773	3,256	1,778 ± 743
CU	1,158	2,732	1,837 ± 933
LB	219	527	394 ± 297
TT	274	427	329 ± 192

The average abundance of phytoplankton differed among stations (Table 3). This difference is further proven by the results of the analysis of variance (ANOVA) to see the significant differences in phytoplankton abundance between stations with a result of p-value <0.01. Based on the Tukey HSD further test, the average value of phytoplankton abundance between CU and PB is in the same group (subset 1) while LB and TT is also in the same group (subset 2). These two groups have different average values of phytoplankton abundance.

Relationship between phytoplankton abundance and environmental variables

The result of PCA analysis showing the relationship between phytoplankton abundance and environmental variables at various stations is shown in Figure 3. Furthermore, using only two axes (axes 1 and 2), the relationship between phytoplankton abundance and environmental variables can be explained by 79.78% of the variables measured. The figure shows phytoplankton abundance related to high orthophosphate concentrations, silicate, and turbidity at PB and CU stations. The opposite condition occurs at LB and TT stations.

Discussion

The measured nitrite and nitrate concentrations in the study area ranged from 0.023-0.127 mg/L and 0.021-0.085 mg/L respectively (Table 1). According to Mackenthum (1969), the range of nitrate requirements for optimal growth of phytoplankton is between 0.9-3.5 mg/L, indicating that nitrate concentration in Bone Bay is below the optimal condition. For ammonia, the concentration ranged between 0.007-0.027 mg/L, a quite low range. This means an oxidation reaction occurred during the research, where PON (Particulate Organic Nitrogen) decomposed into DON (Dissolved Organic Nitrogen). The DON formed is then degraded by bacteria and quickly produces ammonia (NH3). This ammonia is then changed to NH4+ because it reacts with H+ or H2O (Shibata et al. 2021). Then, NH4+ is immediately oxidized to nitrite (NO2-), which turns into nitrate (NO3). Under normal conditions, ammonia concentrations will be low in seawater because it contains quite a lot of dissolved oxygen.

Orthophosphate concentrations ranged from 0.015 - 0.024 mg/L (Table 1). Similar to nitrate, the range of phosphate is not optimal for phytoplankton growth. The optimum phosphate concentration for optimum growth of phytoplankton ranges from 0.09-1.80 mg/L (Mackentum 1969). The silicate concentration ranges from 0.004-0.020. This range is derived from the concentration required for optimally developing phytoplankton, namely above 2 mg/L (Egge et al. 1992). The range of pH was 7.49-7.52 (Table 1).

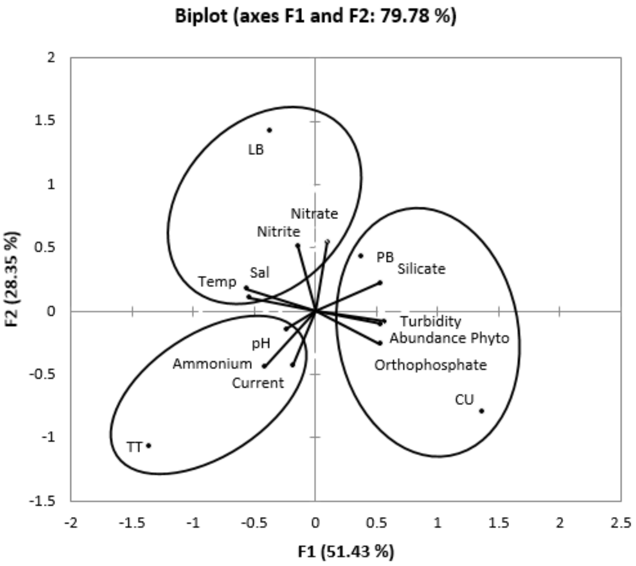

Figure 3. PCA analysis showing the relationship between phytoplankton abundance and environmental variables

The measured pH value tends to be stable and constant, and still within the range of pH needed by phytoplankton to grow and develop. A pH of less than 7.0 or more than 8.5 can inhibit phytoplankton growth (Yang et al. 2019). In addition, the salinity ranged 28.7-32.0 ppt (Table 1). The salinity range reflects the general salinity for Indonesian marine waters, and based on this value, phytoplankton can still develop well.

The temperature ranged 29.00-31.30°C (Table 1), suggesting that the temperature values are not within the optimal range for phytoplankton to grow. The optimal temperature range for phytoplankton is 20°C-30°C (Mesquita et al. 2020).

During the research, the measured current speed ranged from 0.030-0.188 m/s. Generally, the range of measured current speeds is classified as slow currents. Mason (1981) explains that current is classified as slow if its speed is between 0.1-0.25 m/s, and medium current if its speed is between 0.25-0.5 m/s.

Bacillariophyceae was the phytoplankton class with the largest number of genera in this study. Through its adaptability, the genera of this class can tolerate a broad range of environmental conditions. Therefore, compared with genera in other classes, the genera from Bacillariophyceae have a wider distribution (Witkowski et al. 2020), from sea waters, including bay waters, to fresh waters. The genera from Bacillariophyceae have a shorter life cycle, reproduce more quickly, and can be found on almost all substrates. Thus, the history of where they live can be detected. Many species have high sensitivity to environmental changes and can respond quickly to them (Prelle et al. 2019). The genera from Bacillariophyceae are cosmopolitan, have high reproductive capacity, and can survive in extreme conditions (Padisak and Naselli-Flores 2021). Their unique shape and size, resembling a chain or cell collection, makes many genera in this class easy to find and identify. Several genera in the Bacillariophyceae are often used as biological water pollution indicators because they are the autotrophic class that supplies the largest productivity in water areas (Juranek et al. 2020).

The class with the second largest number of genere was Cyanophyceae, also known as cyanobacteria or blue-green algae (Jassim et al. 2023). Cyanophyceae is a group of photosynthetic microbes known for a long time. Through its photosynthetic activity, this class becomes the main group that influences aquatic ecosystems (Ramos et al. 2019). Reproduction of this genera class easily occurs in aquatic environments, especially those related to anthropogenic activities (Zanchett et al. 2013). One of the unique features of several Cyanophyceae genera is that they can fix nitrogen from the air to grow and develop at low nitrogen concentrations level (Bogard et al. 2020). However, several genera from the Cyanophyceae class can produce very strong toxins. Therefore, this endangers the waters if they suddenly bloom and reduce the healthy level for humans and other aquatic organisms (Karlson et al. 2021). Overall, Cyanophyceae are diverse and adaptable microorganisms that can thrive in various aquatic environments, including bay waters.

Several genera of Dinophyceae were also discovered during the research (the class with the third most numerous genera). Dinophyceae is also known as Dinoflagellates. This class is one of the classes of the phylum Pyrrophyta. Its presence in marine waters is also important because it is a primary producer (Pei et al. 2022). However, several genera in the Dinophyceae class can be dangerous if they grow rapidly because they have toxins that can accumulate in the bodies of fish and shellfish (Séchet et al. 2021). Many species in the class Dinophyceae form cysts to survive unfavorable conditions. With this ability, they contribute to their high abundance in certain water areas (Brosnahan et al. 2020). Moreover, high concentrations of nutrients in waters can indirectly change the composition of phytoplankton, including changing the dominant species from diatoms (Bacillariophyceae) to Dinoflagellates (Dinophyceae) (Song et al. 2022). Depending on the species and water conditions, Dinophyceae have beneficial and detrimental effects on marine ecosystems.

During the research, several genera found in abundance were *Chaetoceros*, *Thallasionema*, and *Rhizosolenia*, especially at PB and CU stations. All three are a group of diatoms in the Bacillariophyceae class. They are widespread, diverse, and the most abundant eukaryotic group in the ocean (Baldisserotto et al. 2019), including in the bay (Glibert et al. 2021). They can adapt to changes in environmental conditions including changes in salinity, temperature, light, and pH in marine waters, making these three genera are more abundant and diverse in marine waters compared to other genera. Several research results carried out in bay waters, such as in Hurun Bay, have a high abundance of diatom species, especially *Chaetoceros* (Sidabutar et al. 2022), also *Thalassionema* and *Rhizosolenia* in the Bay of Bengal, Bangladesh (Islam et al. 2021). Similar results were also found in Tiksi Bay in the Russian Arctic (Barinova et al. 2023), Georgian Bay in Canada, Sukhum Bay on the Abkhazian Black Sea coast (Selifonova et al. 2019), and Jiaozhou Bay in China (Liu et al. 2022).

Because the three genera of phytoplankton are adaptable, their distribution varies significantly throughout the world's waters. In several studies, scientists monitor the distribution of these three phytoplankton genera to understand better changes in marine ecosystems, climate, and the health of the marine environment (Abdelmageed et al. 2022). This data is also important for understanding the potential impacts of climate change on phytoplankton abundance and the entire marine ecosystem. The research results explaining this group of diatoms in various bays around the world have been studied extensively. Various findings show that the diatom group is a strong and reliable environmental indicator because it is highly sensitive to environmental changes and water diversity.

The average abundance of phytoplankton differed among stations (Figure 2). The highest average phytoplankton abundance was found in CU when compared with PB, LB, and TT (Table 2). This difference is further proven through the analysis of variance; the difference in phytoplankton abundance is significant between stations with a p-value <0.01 (Table 3).

Furthermore, in the Tukey HSD further test, the average value of phytoplankton abundance at stations CU and PB is considered the same and the same time, higher when compared to LB and TT.

The highest average abundance of phytoplankton in CU and PB can be related to the measurements of several environmental variables. The results of PCA analysis (Figure 3) show that orthophosphate concentrations supported the growth of phytoplankton at stations PB and CU, while the opposite pattern happened at stations LB and TT. Orthophosphate is a form of inorganic phosphate, which is an important nutrient for phytoplankton. This type of nutrient is required to synthesize DNA, RNA, and ATP, which are important components in the growth of phytoplankton cells (Rahav et al. 2022). Sufficient availability of orthophosphate can increase phytoplankton growth. Phytoplankton utilize this orthophosphate for photosynthesis to increase biomass production. Therefore, the availability of orthophosphate influences phytoplankton species' composition (Flander-Putrle et al. 2021). Some phytoplankton species may be more efficient at utilizing phosphorus than others, changing the structure of phytoplankton communities. The availability of orthophosphate also influences the formation and stability of phytoplankton colonies, thus affecting the overall phytoplankton density (Dai et al. 2017). Therefore, the changes in the availability of orthophosphate over time can influence the growth cycle of phytoplankton (Meunier et al. 2020). A fast growth phase can occur when orthophosphate is abundant, while a slow growth phase occurs when its availability is limited. Phytoplankton growth, which is influenced by orthophosphate, will affect the food chain in aquatic ecosystems.

The abundance of phytoplankton also influences the abundance of plankton-eating animals and other organisms in the ecosystem. Excessive availability of orthophosphate can cause eutrophication and increase nutrients (phosphorus and nitrogen) in aquatic ecosystems (Nieder et al. 2018). Eutrophication can result in excessive phytoplankton growth, causing ecosystem changes and health problems such as toxic algal blooms. Notably, the effects of orthophosphate depend on many factors, including the type of phytoplankton, environmental conditions, interactions with other nutrients, and human activities such as waste disposal. Managing the availability of orthophosphate in aquatic ecosystems is important to maintaining ecosystem balance and water quality (Tian et al. 2021).

Silicate is a nutrient that also influences the high abundance of phytoplankton at PB and CU stations compared to LB and TT stations (Figure 3). Silicate is needed by phytoplankton, especially diatoms, to build their strong cell walls. When silicate is available in sufficient quantities, phytoplankton, especially diatoms, can grow rapidly and abundantly. They use silicate to build their cell walls composed of silica compounds (SiO_2) (De Tommasi et al. 2017). Silicate availability affects the balance of aquatic ecosystems; when silicate is abundant, diatoms grow rapidly, creating an abundant food source for the pelagic animals that feed on them (Dinh et al. 2021). This can increase the abundance of animals that prey on phytoplankton, such as zooplankton, small fish, and other invertebrates, thereby affecting the entire food chain. Sometimes, silicate availability may be a limiting factor for phytoplankton growth (Eliasen et al. 2017). If silicate is very limited, the growth of diatoms and other phytoplankton that require it is inhibited, affecting overall phytoplankton abundance (Gomes et al. 2018). Phytoplankton, including diatoms, produce oxygen through photosynthesis. Thus, the abundant growth of phytoplankton triggered by silicate availability increases oxygen production in these waters, benefiting other aerobic organisms in the environment.

Turbidity is another environmental variables related to the high phytoplankton abundance at PB and CU stations compared to LB and TT stations (Figure 3). Moreover, changes in turbidity significantly impact phytoplankton and the marine ecosystem (Remy et al. 2017). The large number of solid particles in water can block sunlight from entering the water layer, which certainly influences phytoplankton activities, especially in photosynthesis. On the other hand, increased turbidity may carry organic and inorganic particles containing nutrients such as phosphate and nitrate. If turbidity decreased, the amount of suspended nutrients available to phytoplankton may also decrease, affecting their growth. The study revealed that different turbidity conditions influence the development of phytoplankton. Some phytoplankton species may be more adaptive to high turbidity, while others may prefer clear water conditions (He et al. 2017). The changes in turbidity conditions can cause competition between phytoplankton species (Hilaluddin et al. 2020). Some species may benefit under certain turbidity conditions, causing changes in their relative abundance.

In conclusion, based on the diversity and abundance of phytoplankton, Bone Bay, South Sulawesi is still in good condition. This is reflected in the abundance of Bacillariophyceae genera represented by *Chaetoceros, Thallasionema*, and *Rhizosolenia*. The variety of phytoplankton types in Bone Bay reflects the sufficient food available for organisms in higher trophic levels; they are a source of nutrition for zooplankton, fish, and other marine organisms. The analysis of phytoplankton abundance among stations shows that the influence of environmental variables on phytoplankton abundance at various stations in this bay is different. The highest abundance was found at CU and PB stations because it was supported by orthophosphate and silicate; the turbidity was higher, and the opposite was true at LB and TT.

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