Plankton community in the waters north of Moyo Island, Sumbawa Regency, Indonesia

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Abstract. Plankton communities can serve as indicators of the health of an aquatic ecosystem. Therefore, collecting data on plankton communities is crucial, especially in areas with high ecological value such as the Moyo-Satonda National Park. This information is beneficial for the management of aquatic resources, particularly in monitoring changes in environmental conditions and supporting sustainable decision-making. This study aims to determine the structure of the plankton community in the waters of Moyo-Satonda National Park, case study in the northern waters area of Moyo Island. Plankton samples and environmental data were collected from 4 research stations. The environmental data collected included temperature, salinity, turbidity, chlorophyll, depth, and nutrients (nitrogen, phosphate, and silicate). The analyses conducted included plankton community structure analysis, Pearson correlation, and principal component analysis. The plankton community structure around Moyo Island was primarily dominated by diatoms, with *Detonula* sp. making up 94% of the phytoplankton. Zooplankton populations were significantly represented by copepods, particularly Calanoida (41%) and Cyclopida (24%), along with appendicularians like *Oikopleura* (19%). The observed dominance of specific phytoplankton and zooplankton suggests an imbalance in the community, as indicated by the ecological index. Statistical analyses highlighted temperature and salinity as the key environmental factors influencing this plankton community structure, suggesting that these conditions play a critical role in shaping the local marine ecosystem.

Key Words: community structure, national park, phytoplankton, zooplankton.

Introduction. Plankton are a group of aquatic organisms with limited swimming capabilities, so they are often found drifting with the currents in the water. Despite their small size, plankton play a significant role in aquatic ecosystems. For example, phytoplankton contribute approximately 48.5 PgC/year out of 104.9 PgC/year of total global productivity, accounting for about 45.2% or nearly half of the global productivity, while land contributes around 55.4 PgC/year or 53.8% (Field et al 1998). This indicates that the photosynthetic activity of phytoplankton is almost equivalent to the total photosynthesis of all terrestrial vegetation (Firdaus & Wijayanti 2019). Another group, zooplankton, serves as a trophic bridge between primary producers (phytoplankton) and secondary consumers (carnivores). Carnivorous marine animals cannot directly consume phytoplankton; instead, they prey on zooplankton that feed on phytoplankton (grazers).

In addition to being a primary food source, plankton can also serve as indicator of aquatic ecosystem health. This is due to plankton has short life span, so it can quickly respond to changes in environmental conditions (Weisse et al 2016; Allende et al 2020), reflected in alterations in its community structure. Environmental changes can occur naturally or as a result of human activities, affecting various important ecological parameters such as composition, abundance, diversity, dominance, and evenness. Therefore, research on plankton communities is crucial, especially in areas with high ecological value, such as national parks. National parks provide diverse ecosystem services, including provisioning services (e.g., food and water), regulating services (e.g., climate regulation and disease control), and supporting services (e.g., nutrient cycling and oxygen production) (Millennium Ecosystem Assessment 2005; Palomo et al 2013). When plankton assessments in these areas reveal unhealthy conditions, the sources of environmental problems can be identified and addressed promptly, ensuring the continued delivery of vital ecosystem services within national parks.

Moyo Island is part of Moyo-Satonda National Park, officially established by the Indonesian government in 2022. Previously, in 2019, the island was designated as Moyo-Satonda Nature Tourism Park, but due to its high ecological value, its status was upgraded to a national park to enhance conservation efforts. Moyo-Satonda National Park is renowned for its natural richness and beauty, particularly its pristine beaches and coral reefs. Research by Edrus et al (2010) in Saleh Bay and its surroundings categorizes the coral reef status around Moyo Island as moderate to good. Furthermore, Edrus et al (2010) noted that well-preserved coral reefs are primarily found in the northern part of Moyo Island, where coverage remains above 50%. This location coincides with the area where the present study was conducted.

To the best of our knowledge, no research has been conducted on the plankton community in the waters around Moyo Island so far. This information is crucial, given that this area is a national park with significant ecological value. Research on plankton communities in this region will provide insights into the health status of the waters and help assess the extent of environmental pressures from human activities. This study aims to offer an overview of the plankton community structure in Moyo Island, along with the water conditions. This data is essential for informing conservation management efforts in Moyo-Satonda National Park. For instance, it can help determine the status of the aquatic ecosystem in the area and serve as a benchmark for analyzing future changes in the water conditions of Moyo Island.

Material and Method

Description of the study sites. This study was conducted in April 2023 in the waters north of Moyo Island, Sumbawa Regency, West Nusa Tenggara Province, Indonesia (Figure 1).

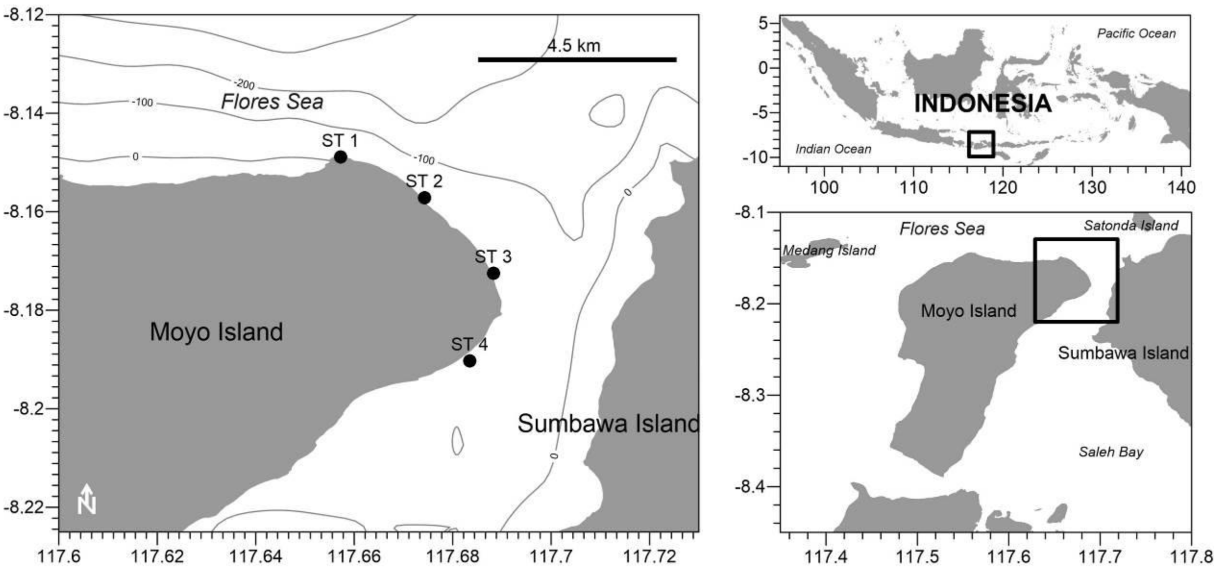

Figure 1. Research stations map.

The sampling period coincided with the end of the west monsoon and the beginning of Transition Season I, the period between the west monsoon (rainy season) and the east monsoon (dry season) (Tomczak & Godfrey 2001). During the study, rainfall was less intense, and the winds were not very strong, gradually shifting from westerly to easterly.

The island itself is located north of Sumbawa Island, bordered directly by Flores Sea to the north and Saleh Bay to the south. Moyo Island covers an area of approximately 315 square kilometers and has an elongated shape running from north to south, measuring 27 kilometers in length (Sutawidjaya & Rachmat 2010). Sampling was conducted at four research stations located on the northeastern side of Moyo Island (Figure 1). The study sites were characterized by shallow water and a reef-covered bottom, with the exception of station 1. Station 1 had very shallow water (around 1 meter) and a sandy bottom. In addition, the water at station 1 was murky, while the others were crystal clear.

Sampling was carried out using a small boat survey method, due to the presence of coral reef ecosystems in the research area. This necessitated careful sampling procedures to avoid damage to the reefs. The locations of the sampling stations were determined using GPS devices, which had pre-entered coordinates for the research stations. The coordinates for each research station can be found in Table 1.

Table 1

Coordinates of research stations

Station	*Longitude*	*Latitude*
ST 1	117° 39' 26.11"	8° 8' 56.06"
ST 2	117° 40' 27.37"	8° 9' 25.76"
ST 3	117° 41' 17.90"	8° 10' 20.95"
ST 4	117° 41' 0.65"	8° 11' 24.98"

Plankton sampling. The plankton sampling method followed Firdaus et al (2020) and Firdaus et al (2023). Plankton samples were collected using a plankton net with mesh sizes of 80 microns for phytoplankton and 300 microns for zooplankton. The use of two different mesh sizes is necessary because phytoplankton typically have a smaller size range compared to zooplankton. Plankton net was manually lowered into the water from the boat until it was close to the bottom. This was done carefully, paying close attention to the presence of coral reefs in the research area. The plankton net was then pulled vertically at a speed of 1-2 meters per second until it reached the surface. The length of the rope used was measured to determine how far the plankton net was towed. The collected plankton samples were transferred into 250 mL sample bottles and preserved with 40 percent neutralized formalin to achieve a final concentration of 4 percent in the sample bottles. Formalin was chosen as it is a relatively affordable preservative that effectively maintains the morphological condition of plankton over extended periods. The bottles containing the samples were labeled and stored in a sample container for transport to the laboratory for analysis.

Environmental data collection. Various environmental data were collected during the study, including physical, chemical, and biological parameters. Depth, temperature, salinity, conductivity, chlorophyll-*a*, and turbidity data were obtained using a CTD Rinko Profiler ASTD/101. This device can record various water quality parameters vertically with a depth resolution of 0.1 meters. The CTD was first turned on and then manually lowered from the boat into the water until it reached the bottom. Afterward, the CTD was pulled back to the surface and turned off. The data from the CTD was downloaded to a computer and saved in CSV format. The data was then processed using Microsoft Excel.

For nutrient parameters such as nitrate, nitrite, phosphate, and silicate, water samples of 50 milliliters were taken using 50 mL Falcon bottles. The water samples were then stored in a container filled with ice and transported to the laboratory. In the laboratory, the water samples were filtered using a 0.45-micron cellulose acetate membrane filter and then analyzed using the Continuous Flow Analyzer SKALAR SAN++. Nutrient analysis in the laboratory (Grasshoff et al 1999).

Plankton species analysis*.* Plankton samples were analyzed in the laboratory using a microscope. For phytoplankton samples, a 1 mL fraction was taken with a pipette from the homogenized sample bottle. This phytoplankton fraction was then placed into a

Sedgewick Rafter Counting Cell (SRCC) and observed under a microscope at magnifications of 40-400 times. For zooplankton samples, a 10 mL fraction was taken with a wide-mouthed pipette and placed into a Bogorov counting chamber. The samples in the Bogorov chamber were examined under a stereo microscope at magnifications of 4-20 times. Plankton identification was conducted according to Newell & Newell (1973), Wickstead (1965), and Yamaji (1966).

Plankton community analysis. This study performed several basic analyses of the plankton community, including abundance (Heip et al 1998), diversity (Shannon 1948; Spellerberg & Fedor 2003), dominance (Simpson 1949), and evenness (Pielou 1966).

Abundance (N). Abundance analysis is the most fundamental analysis for understanding a community of living organisms. Abundance data is necessary for various advanced analyses within community analysis, such as diversity, dominance, and evenness analyses. In this study, the abundance analysis performed was absolute abundance, calculated using the formula below, where N is the total absolute abundance, and *ni* is the number of individuals of species i.

$$N = \sum^{S}_{i=1} n_i \qquad \text{Equation 1}$$

Diversity (H'). Diversity analysis aims to measure how varied or diverse the species in an ecosystem are. This analysis not only measures the number of existing species but also considers the distribution of each species within a community. Therefore, proportionally, the diversity index will be directly proportional to the evenness index (J) and inversely proportional to the dominance index (D). In this study, diversity was calculated using the Shannon diversity index, given by the formula below, where H' is the value of the Shannon diversity index, pi is ni divided by N; ni is the number of individuals of species i, and N is the total absolute abundance:

$$H' = -\sum_{i=1}^{S} p_i . \ln p_i \qquad \text{Equation 2}$$

Dominance (D). Dominance analysis is useful for measuring the presence of dominance of certain species within a community. A high dominance index indicates that a few species have very high abundances while others are low. This means that in communities with a high dominance index, the abundances of each species are uneven. High dominance of certain species can lower the diversity index, even if the number of species is high. In this study, the dominance index was calculated using the formula below, where D is the Simpson dominance index; ni is the number of individuals of species i, and N is the total absolute abundance:

$$D = \Sigma \left(\frac{ni}{N}\right)^2 \qquad \text{Equation 3}$$

Evenness (J'). Evenness analysis aims to determine how evenly the species in a community are distributed. A high evenness index indicates that the species within a community are distributed evenly, with no species having excessively high or low abundances. This principle is contrary to the dominance index. Therefore, communities with high evenness indices will have low dominance index values but high diversity indices, even with a relatively low number of species. The evenness index in this study was calculated using the formula below, where E is the evenness index, H' is the diversity index, Hmax is ln S; and S is the number of species.

$$E = H'/H_{max} \qquad \text{Equation 4}$$

Data analysis. In this study, several data analyses were conducted related to the structure of the plankton community and its environmental parameters, specifically correlation analysis and principal component analysis (PCA). Correlation analysis functions to identify the relationship between two variables, such as ecological index variables and environmental parameter variables. Correlation analysis can provide information about the direction of the relationship between the two variables, whether it is direct (positive correlation) or inverse (negative correlation). Additionally, correlation analysis can indicate the strength of the relationship between the two variables, whether it is very weak (correlation value close to zero) or very strong (correlation value close to 1). In this study, correlation analysis was performed using Pearson correlation analysis method with Microsoft Excel.

PCA is a multivariate statistical analysis that serves to visualize the relationships among complex variables in ecological research. This statistical analysis helps provide an overview of patterns and relationships among variables that are difficult to see when the data is still in table form. PCA in this study was conducted using PAST software.

Results

Community structure. The study of plankton community structure in the northern waters of Moyo Island was conducted in April 2023. This research successfully identified 16 genera of phytoplankton and 37 taxa of zooplankton (Figures 2 and 3).

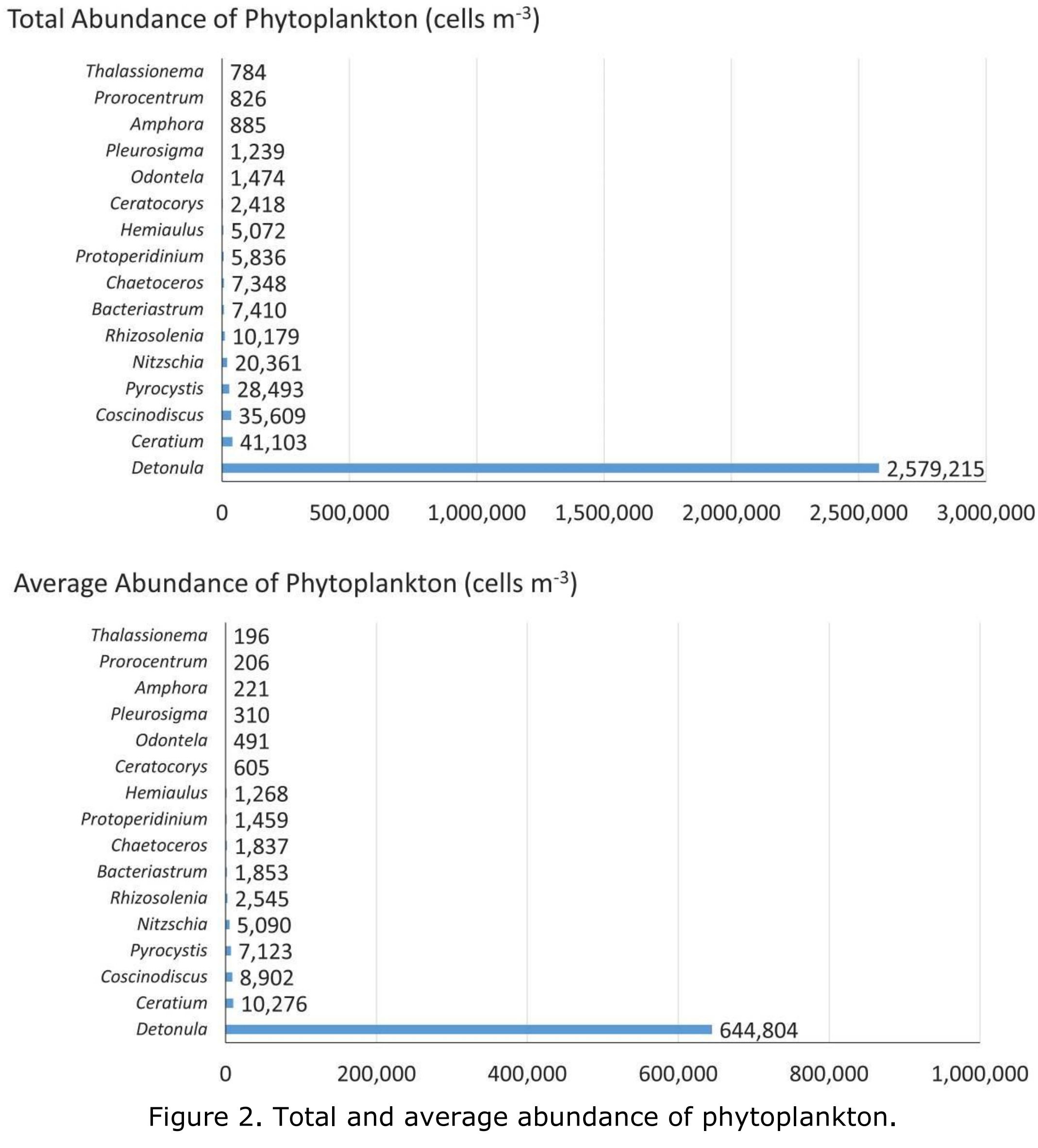

Figure 2. Total and average abundance of phytoplankton.

The total abundance of phytoplankton ranged from 423,000 to 980,000 cells m^{-3}, with the highest abundance recorded at Station 2 and the lowest at Station 3 (Figure 4).

Meanwhile, the total abundance of zooplankton was found to be lowest at Station 1 and highest at Station 2, ranging from 223 to 855 individuals m^{-3} (Figure 4). Based on the abundance per genus and taxon, the average abundance of each phytoplankton genus ranged from 196 to 644,804 cells m^{-3}, with *Detonula* from the diatom group being identified as the genus with the highest average abundance. For zooplankton, the average abundance per taxon ranged from 1 to 216 individuals m^{-3}, with *Calanoida* being the taxon with the highest average abundance (Figure 3).

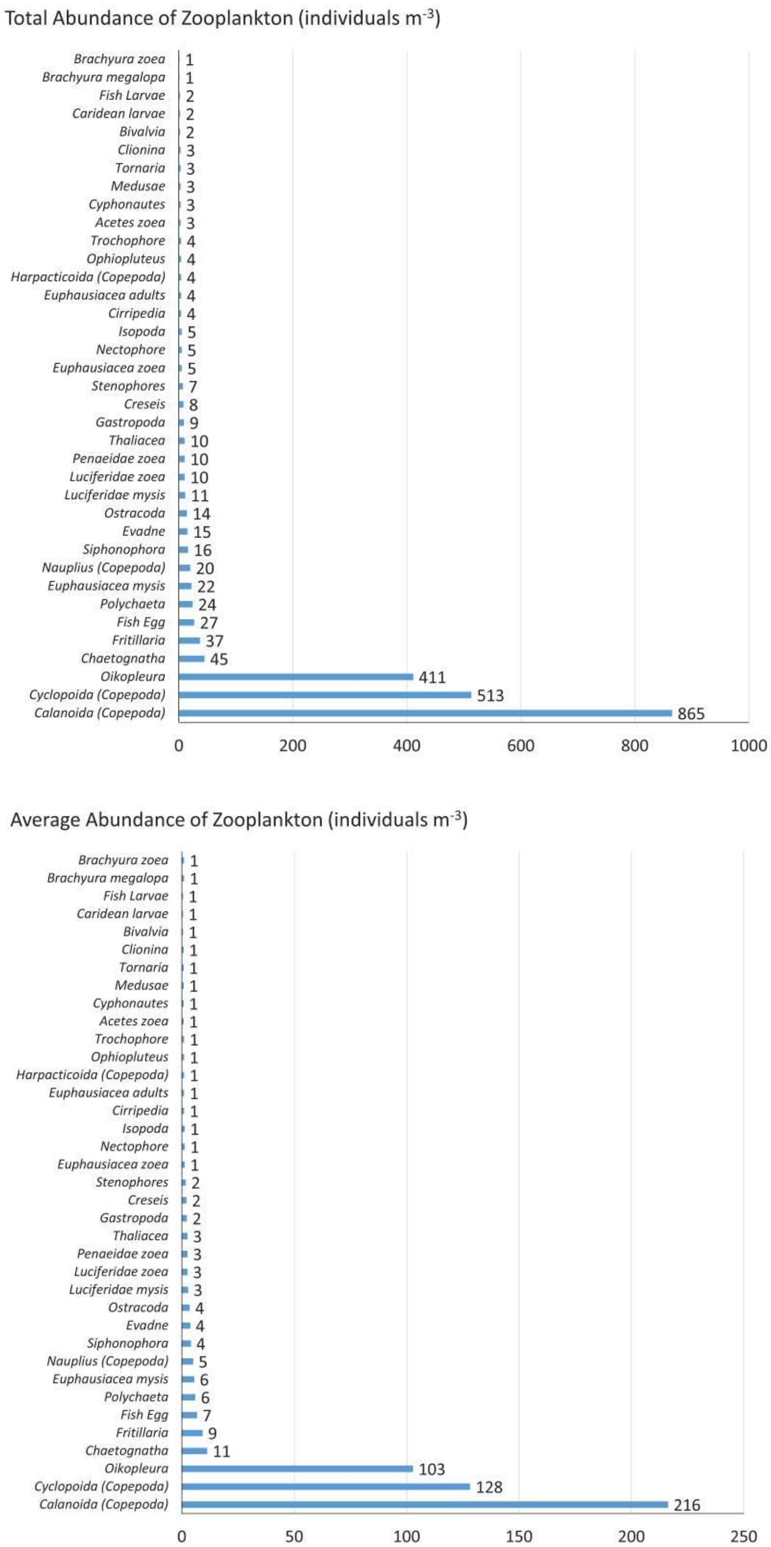

Figure 3. Total and average abundance of zooplankton.

From the diversity aspect, it was found that the diversity index of zooplankton was higher than that of phytoplankton. The zooplankton diversity index ranged from 1.57 to 1.88, while the phytoplankton diversity index ranged from 0.28 to 0.46 (Figure 4). The low diversity index value indicates the dominance of certain species within the phytoplankton community. This is evident from the phytoplankton dominance index, which is also higher than that of zooplankton. The phytoplankton dominance index is nearly approaching 1, ranging from 0.84 to 0.90 (Figure 4). A dominance index close to one indicates very strong dominance within the community. The zooplankton dominance index was recorded as lower, ranging from 0.23 to 0.32 (Figure 4). A lower dominance index indicates that the zooplankton community has a relatively more even distribution of species compared to phytoplankton. This is reflected in the evenness index of zooplankton, which is relatively higher than that of phytoplankton. The zooplankton evenness index ranged from 0.21 to 0.34, while the phytoplankton evenness index ranged from 0.11 to 0.15 (Figure 4).

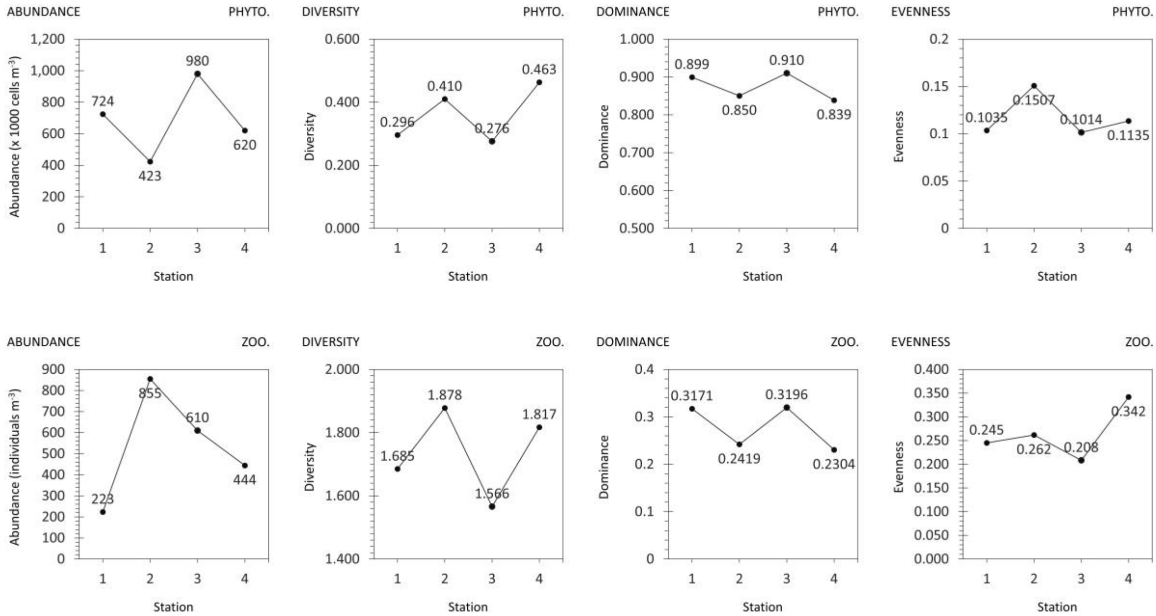

Figure 4. The abundance, diversity, dominance, and evenness of plankton communities in the waters north of Moyo Island during the study.

Environmental parameters. Data on the water conditions at each research station can be seen in Figure 5. Generally, the temperature and salinity of the water were relatively similar across stations, ranging from 28.8 to 29.38°C for temperature and 31.59 to 31.69 PSU for salinity. However, the turbidity parameter showed a significant difference, especially between station 1 and the other stations (2, 3, and 4). Station 1 had a turbidity of 7.07 NTU, while the other stations had only 0.01 NTU. This was observed during sampling, where the water at station 1 appeared much murkier compared to the clearer waters at the other stations.

For the chlorophyll-a parameter, values ranged from 0.59 to 12.65 mg L^{-1}. Chlorophyll-a levels are commonly used as a proxy to estimate the primary productivity of a water body, as they have a direct relationship with phytoplankton abundance. This is reflected in the highest chlorophyll-a value found at station 3, where phytoplankton abundance was also at its peak. Phytoplankton abundance is closely related to nutrient availability in the water. In this study, nutrient levels varied significantly among the stations, particularly total silicate, which ranged from 7.12 to 26.13 mg L^{-1}. Total nitrogen levels ranged from 0.006 to 0.011 mg L^{-1}, while total phosphate ranged from 2.49 to 3.14 mg L^{-1} (Figure 5).

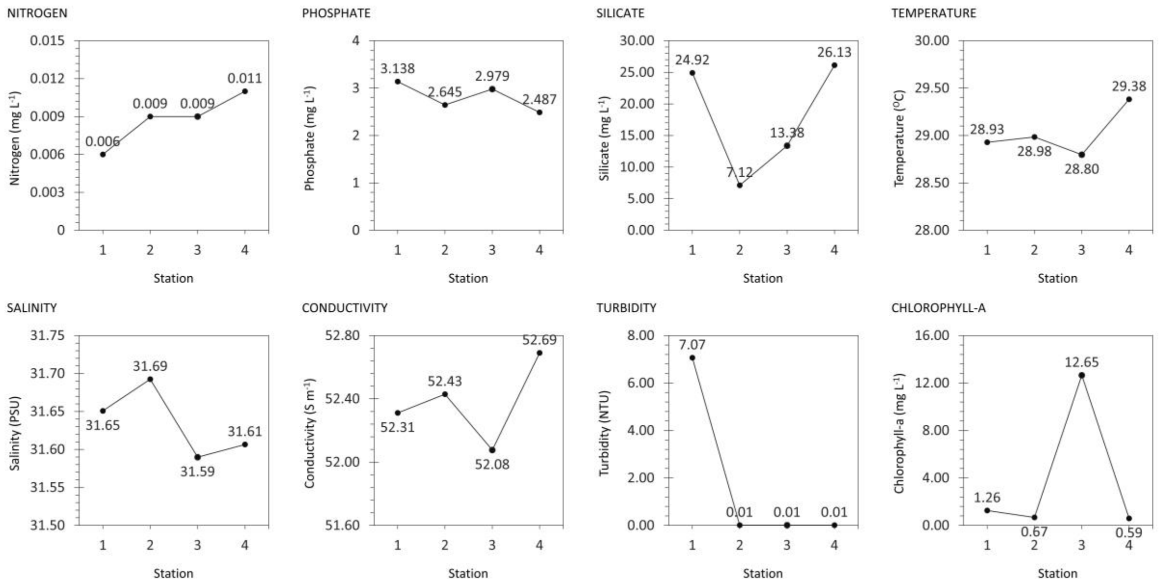

Figure 5. The environmental parameters in the waters north of Moyo Island during the study.

The results of the correlation analysis between community structure parameters and environmental parameters are presented in Table 2. In this analysis, correlation is viewed from two perspectives: the correlation between community structures and the correlation between community structure and environmental parameters. From the perspective of the correlation between community structures - specifically between phytoplankton and zooplankton - the correlation indicates a relatively strong relationship. This suggests a strong interaction between the phytoplankton and zooplankton community structures in the research area. In terms of the correlation between plankton and environmental parameters, the plankton community structure in the northern waters of Moyo Island shows a relatively strong correlation with various measured environmental parameters. The analysis showed several very strong correlations ($r > 0.8$): temperature is very strongly correlated with phytoplankton diversity, phytoplankton dominance, and zooplankton dominance. Salinity is very strongly correlated with phytoplankton abundance and phytoplankton evenness. Phosphate is very strongly correlated with phytoplankton diversity, while silicate is very strongly correlated with zooplankton abundance.

The PCA revealed several findings related to the structure of the plankton community and environmental conditions in the northern waters of Moyo Island (Figure 6). First, PCA indicated differences in environmental characteristics and plankton communities distinguishing station 1 from the others. For instance, station 1 is characterized by higher turbidity and phosphate levels but lower total nitrogen and N ratios. For example, at station 1, turbidity was 7.07 NTU, while at the other stations, it was 0.01 NTU. Stations 2 and 4 have relatively similar environmental conditions, characterized by higher temperatures and lower total phosphate levels. Station 3, on the other hand, is characterized by higher chlorophyll levels and lower salinity and temperature. This characteristic shape different community structure of plankton in station 1. These characteristics shaped a different community structure of plankton at station 1. Based on the plankton community, station 1 was characterized by a lower density of zooplankton (225 individuals m^{-3}) and a higher dominance of phytoplankton (0.899) and zooplankton (0.317) (Figure 4). Furthermore, the PCA identified that temperature is the most influential factor in shapping the community structure of plankton in location study. As shown in Figure 6, temperature is closely associated with several community structure indices, such as diversity, evenness, and dominance of both phytoplankton and zooplankton. Regarding abundance, it was determined that the abundance of both phytoplankton and zooplankton strongly was influenced by salinity.

Table 2

Correlation matrix between plankton community structure and environmental parameters (the color indicates that the darker the color, the stronger the correlation)

	Phytoplankton abundance	*Phytoplankton diversity*	*Phytoplankton dominancy*	*Phytoplankton evenness*	*Zooplankton abundance*	*Zooplankton diversity*	*Zooplankton dominancy*	*Zooplankton evenness*
Phytoplankton abundance	1.00							
Phytoplankton diversity	-0.75	1.00						
Phytoplankton dominancy	0.82	-0.99	1.00					
Phytoplankton evenness	-0.86	0.57	-0.65	1.00				
Zooplankton abundance	-0.37	0.28	-0.34	0.77	1.00			
Zooplankton diversity	-0.98	0.88	-0.92	0.82	0.37	1.00		
Zooplankton dominancy	0.79	-0.99	0.99	-0.68	-0.43	-0.91	1.00	
Zooplankton evenness	-0.55	0.91	-0.87	0.20	-0.13	0.70	-0.83	1.00
Depth	0.29	0.20	-0.15	0.02	0.56	-0.14	-0.25	0.05
Temperature	-0.48	0.88	-0.84	0.13	-0.16	0.63	-0.80	1.00
Salinity	-0.81	0.22	-0.32	0.80	0.34	0.66	-0.30	-0.02
Chlorophyll-a	0.86	-0.67	0.71	-0.49	0.16	-0.84	0.63	-0.69
Turbidity	0.11	-0.48	0.47	-0.40	-0.77	-0.25	0.56	-0.23
Nitrogen	-0.17	0.72	-0.67	0.24	0.46	0.37	-0.72	0.61
Phosphate	0.61	-0.95	0.94	-0.56	-0.47	-0.76	0.96	-0.80
Silicate	0.19	0.10	-0.02	-0.66	-0.91	-0.12	0.06	0.50
N:P	-0.33	0.83	-0.79	0.32	0.41	0.52	-0.83	0.74

Color						
Value	0	0 < 1.9	2.0 < 3.9	4.0 < 5.9	6.0 < 7.9	8.0 < 1.0
Correlation	Not correlated	Very weak	Weak	Moderate	Strong	Very strong

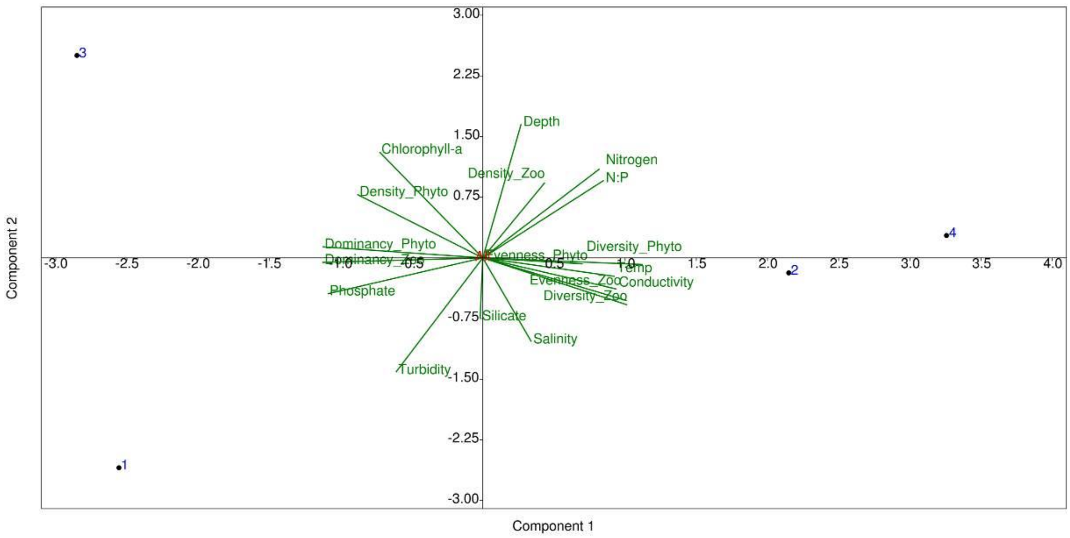

Figure 6. Principal component analysis.

Discussion. In this study, the diatom group was dominated by the genus *Detonula*, which accounted for over 90% of the community in all stations. The high proportion of *Detonula* resulted in a high dominance index value within the plankton community at the study site, nearly approaching 1. This high dominance index value may reflect localized ecological conditions that favor the proliferation of *Detonula*. *Detonula* is known to thrive in nutrient-rich media (Guillard & Ryther 1962), which could explain its dominance in the northern coastal ecosystem of Moyo Island. The dominancy of *Detonula* can suppresses other phytoplankton groups, leading to decreased diversity and evenness. This is evident from the very low diversity and evenness indices of phytoplankton in the study area.

Diatoms are known to be a dominant group of phytoplankton in many waters of Indonesia, including the waters off the western coast of Sumatra, Banggai, Jakarta Bay, Sangihe-Talaud, and Gili Manuk Bay (Thoha 2007; Thoha & Rachman 2013; Sriwijayanti et al 2019; Wijayanti et al 2020; Firdaus et al 2020; Rozirwan et al 2021; Firdaus et al 2023). The dominance of diatoms in the waters is supported by their high nutrient uptake capacity and growth rates. For instance, diatoms can absorb phosphate three times more efficiently and nitrogen ten times more than other groups (Litchman et al 2006). Furthermore, the growth rate of diatoms is nearly three times higher (1.47/day) compared to other groups, such as dinoflagellates, which only grow at 0.52/day. Hence, they can compete with other species more effectively, even in nutrient-poor conditions. This pattern aligns with the findings in this study, where *Detonula* sp. dominated the plankton community.

The zooplankton community in the waters around Moyo Island is dominated by the taxa Calanoida and Apendicularia. Calanoida is part of the copepod taxa, a group of zooplankton known for their strong swimming abilities. This capability gives copepods, such as Calanoida, an advantage in competing for prey. Consequently, copepods dominate the zooplankton community structure in nearly all marine waters, with an estimated 50% of the world's zooplankton composition made up of copepods (Longhurst 1985). However, their proportion varies by latitude; in tropical regions like Indonesia, the proportion of copepods is about 35%, while in polar areas it can reach 70% (Longhurst 1985).

Apendicularians, or larvaceans, are filter-feeding zooplankton found in nearly all marine waters. Besides the study site, they are also relatively abundant in other locations in Indonesia, such as the western waters of Sumatra, Jakarta Bay, Lembeh Strait, and Keffing Island (Thoha 2007; Thoha & Rachman 2013; Firdaus et al 2020; Mulyadi & Lekalette 2020; Firdaus et al 2023). The Apendicularia found in abundance in this study is *Oikopleura* sp. This organism feeds on various small microorganisms, such as phytoplankton and bacteria. This genus is known to produce mucus around its body to filter food. The production of mucus is so intense that it plays a role in the carbon cycle in marine waters.

Plankton distribution in waters is generally influenced by physical, chemical, and biological parameters. However, not all these parameters necessarily exert a strong simultaneous influence. Various water characteristics will determine which factors become limiting. The PCA in this study recorded that temperature and salinity were the most influential factors affecting plankton community structure in the northern waters of Moyo Island. According to Schabhüttl et al (2013) and Chen et al (2015), temperature can influence photosynthesis rates and phytoplankton productivity in waters.

Conclusions. The plankton community structure in the northern waters of Moyo Island in April 2023 was dominated by diatoms, copepods, and appendicularians, with proportions of *Detonula* sp. (94%), Calanoida (41%), Cyclopida (24%), and *Oikopleura* sp. (19%). The ecological index indicates an imbalance in community structure of plankton, defined as the disproportionate dominance of a few taxa, leading to reduced diversity and evenness. Statistical analysis identifying temperature and salinity as the most influential parameters. Favorable conditions for *Detonula* sp. suggest nutrient-enriched waters, potentially indicating eutrophication. Dominance of certain zooplankton taxa, such as Calanoida and Cyclopida, may reflect shifts in food web dynamics.

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Conflict of interest. The authors declare that there is no conflict of interest.

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