

# Phytoplankton communities in different season in the coastal area of Kawasi, the western part of Obi Island, North Maluku, Indonesia

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**Abstract.** Plankton communities are one of the groups monitored to assess environmental conditions. West Obi Island is known for its fisheries resources and is one of Indonesia's largest Nickel mining areas in North Maluku, Indonesia. However, few studies have discussed phytoplankton structure in this region, and this study aimed to assess the distribution and community structure in the western part of Obi Island, Halmahera Selatan. Vertical sampling was conducted to collect phytoplankton and zooplankton from 13 stations during the dry and wet seasons in 2023. We identified 46 species phytoplankton during dry season and 24 species during wet season. During the wet season, phytoplankton is more abundant at specific locations, such as ports and estuaries, and less abundant in coral reef areas. In contrast to the wet season, there was a significant increase in phytoplankton abundance across all locations during the dry season, which could relate to nitrate. *Chaetoceros* sp., *Coscinodiscus* sp., and *Rhizosolenia* sp. were the predominant genera in both seasons. During the dry season, phytoplankton were predominantly concentrated in the strait area between Obi and Mala-Mala Island. In contrast, the phytoplankton were more concentrated in the harbor and estuary areas in the wet season.

## 1. Introduction

Plankton, a diverse collection of microscopic organisms that float in aquatic environments, is an essential indicator of ecological balance and environmental health. These organisms are bioindicators of water quality and the ecosystem's trophic status as they respond quickly to environmental changes [1]. Phytoplankton communities act as crucial indicators of environmental shifts, as they mirror the effects of increasing nutrient concentrations and tend to respond more strongly to the interaction of multiple stressors than to any single stressor

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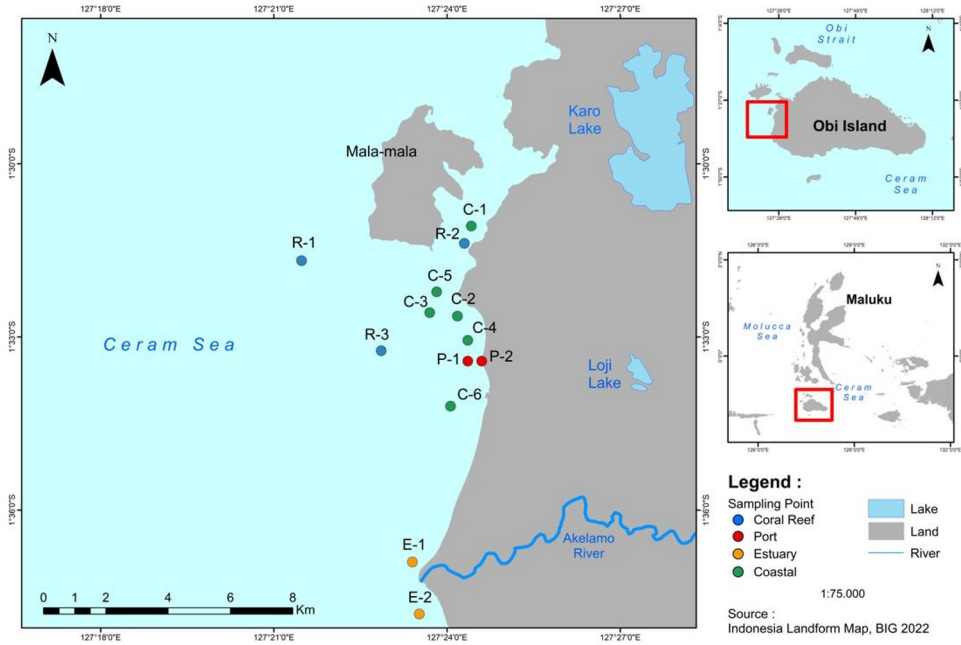
[2,3]. Plankton can act as a sensitive barometer responding to temperature, water quality, nutrients, and other environmental conditions [4,5,6].

Phytoplankton diversity is an important indicator of how efficiently resources are used in ecosystems and is crucial for maintaining the stability of ecosystem functions across varying environmental conditions [7,8]. Phytoplankton play a crucial role in the food chain of aquatic ecosystems as primary producers. They are microscopic organisms capable of photosynthesis, producing oxygen, and serving as an energy source for various trophic levels within the aquatic ecosystem. The dynamic of environmental factors can directly affect the composition and variety of phytoplankton communities and indirectly indicate the collective influence of various habitats [9,10]. Seasons significantly influence phytoplankton dynamics via changes in light, temperature, water stratification, and nutrient availability changes. These patterns directly affect the marine food chain and aquatic ecosystems as a whole. Seasons substantially affect phytoplankton in tropical regions, although seasonal changes in these areas are not as extreme as those in subtropical or polar regions. Some key factors affecting phytoplankton dynamics in tropical regions include rainfall, which increases river flow and land runoff and carries nutrients into coastal waters. This can stimulate phytoplankton growth but may also cause water stratification due to differences in salinity. During the dry season, increased salinity and deeper light penetration can affect phytoplankton composition and abundance. Upwelling can bring nutrients from deeper layers to the surface in some areas, thereby enhancing primary productivity.

West Obi Island is part of the Obi Islands in South Halmahera Regency, North Maluku Province, Indonesia. The island is known for its rich natural resources, including fisheries, tropical rainforests, marine biodiversity, and abundant mineral resources. Obi Island is one of the most productive waters in eastern Indonesia and serves as a meeting point between two large oceans: the Pacific Ocean and the Indian Ocean. The Indonesian Throughflow (ARLINDO) passes through the northern part of Obi via the north of Bisa Island, the western part of Obi, and the southern part through the south of Gamumu Island. This makes the waters around Obi Island highly productive. However, few studies have discussed the phytoplankton structure in this region. This study focuses on the coastal area of Kawasi, which is located in the western part of Obi Island and tries to explore the comparative patterns of plankton diversity in two different seasons and relate them to habitat types, such as estuaries, coral reefs, and coastal activities, such as ports and settlements.

## **2. Method**

Research activities were carried out in the western part of Obi Island, also known as the coastal area of Kawasi, in May and December 2023, representing the dry and wet seasons, respectively. Thirteen sampling locations represent different types of coastal areas, such as estuaries, coral reefs, ports, and settlements (Figure 1).



**Fig. 1.** Study locations of plankton communities in the coastal area of Kawasi, Western Part of Obi Island

As shown in Figure 1, Stations R-1, R-2, and R-3 represent the coral reef areas, P-1 and P-2 represent port areas, E-1 and E-2 represent estuaries, and C-1 to C-6 represent coastal areas of Kawasi. Phytoplankton samples were collected vertically using a plankton net. The net circular opening with a diameter of 30 cm, length of 150 cm, collection volume of 250 ml, and the mesh of 20  $\mu\text{m}$ . Plankton sampling was performed using vertical towing [11]. The vertical towing method was carried out at a water depth of 10 m in calm water conditions (with no strong currents or waves) to ensure that the net remain vertical. The volume of the filtered sample was measured using a cylindrical volume. Water being collected in the field may have a time gap of several days before reaching the laboratory. To preserve the samples and maintain their representation of the natural conditions of the water, preservation is necessary before laboratory processing. Phytoplankton samples were preserved in Lugol. The following are the field treatment activities for each parameter before transport to the laboratory [12].

Plankton abundance refers to the concentration of individuals or cells within a given volume. The population of individual plankton was determined using the following formula [13]:

$$K = \frac{1}{A} \times \frac{B}{C} \times \frac{V}{v} \times n$$

Note: K = phytoplankton abundance ( $\text{cell}/\text{m}^3$ ); n = number of identified phytoplankton; B = total area/container area of Sedgwick-Rafter Counting cell ( $\text{mm}^2$ ); V = volume of filtered water (30 ml); v = concentrate volume of Sedgwick Rafter Counting Cell (ml); A = volume of filtered water sample (50 l); C=observation area ( $\text{mm}^2$ ).

The diversity index was based on the Shannon and Wiener index [13]:

$$H' = \sum_{i=1}^n pi \ln ln pi$$

Note:  $H'$  = Shannon-Wiener diversity index;  $\pi_i = n_i/N$ ;  $n_i$  = number of individual species- $i^{\text{th}}$ ;  $N$  = total number of individuals.

The Evenness index was determined using the following formula [13]:

$$E = \sum_{i=1}^s \frac{H'}{\ln \ln S}$$

Note:  $E$  = Evenness index;  $H'$  = Shannon-Wiener diversity index;  $\ln S$  = Natural logarithm of species richness;  $S$  = total number of species.

The dominance index was determined using the following formula [13]:

$$C = \sum_{i=1}^s \left( \frac{n_i}{N} \right)^2$$

Note:  $C$  = Simpson dominance index;  $n_i$  = number of individual- $i^{\text{th}}$ ;  $N$  = total number of individuals;  $S$  = number of genera

Water samples were collected from all sampling zones and analyzed using standard methods [14]. Phosphorus in water is commonly found as an orthophosphate ( $\text{PO}_4^-$ ). Phosphate is crucial for the growth of organisms and can limit primary productivity in aquatic environments. The APHA 4500-P F. Automated Ascorbic Acid reduction method determines the orthophosphate concentration in water. This method involves the reaction of ammonium molybdate and potassium antimonyl tartrate with orthophosphate in an acidic medium. The resulting antimony-phosphomolybdate complex was then reduced with ascorbic acid to produce a blue color. Photometric measurements were then performed at 650–660 nm or 880 nm wavelengths. Interference from silica, arsenate,  $\text{NO}_2^-$ , and  $\text{S}^{2-}$  can be addressed by adding reagents, whereas turbidity and color that may affect photometric readings can be removed through filtration. Nitrate ( $\text{NO}_3^-$ ) measurements followed APHA 4500- $\text{NO}_3^-$  (2012). In this method, nitrate in a sample is reduced to nitrite ( $\text{NO}_2^-$ ) using a column containing cadmium (Cd) granules activated with copper sulphate ( $\text{CuSO}_4$ ). The resulting  $\text{NO}_2^-$  is then analyzed colorimetrically after undergoing diazotization with sulfanilamide and reacting with N-(1-naphthyl)-ethylenediamine dihydrochloride to form an azo dye. Interference can be caused by suspended particles, heavy metals, oils, fats, and residual chlorine, which can be mitigated using filtration, ethylenediaminetetraacetic acid (EDTA), organic solvents, or sodium thiosulfate. After reduction, the color was developed using a specific reagent and measured at a wavelength of 543 nm to determine the nitrate concentration in the sample. Ammonia ( $\text{NH}_3\text{-N}$ ) measurement uses the APHA 4500- $\text{NH}_3$  F. The phenate method for ammonia testing relies on forming indophenol, a blue compound, through the reaction of ammonia, hypochlorite, and phenol in the presence of sodium nitroprusside as a catalyst. The process involves adding a phenol solution, sodium nitroprusside, and an oxidizing agent to the sample and then allowing the color to develop at room temperature for at least one hour. The resulting color was measured spectrophotometrically at a wavelength of 640 nm. A standard curve was used to determine the ammonia concentration. Interference from magnesium and calcium ions can be eliminated with citrate, whereas turbidity can be removed through distillation or filtration.

### 3. Result

#### 3.1 Phytoplankton diversity and distribution

The results of identifying phytoplankton species and abundance in the Kawasi coastal area during two different seasons, the dry and wet seasons, showed fluctuations and dynamics in

biodiversity and phytoplankton species composition (Table 1 and 2). There were 46 species identified in the dry season, consisting of four families: Bacillariophyceae, Chlorophyceae, Cyanophyceae, and Dinophyceae (Table 1). The diversity index during the dry season ranges from 1,72 to 2,61, while the evenness index ranges from 0,61 to 0,84, and the dominance index ranges from 0,11 to 0,32. The highest diversity was found at the coral reef station R-3, high evenness was observed at the coastal stations C-2 and C-3, while the highest dominance was found at estuary station E-2.

In contrast, fewer phytoplankton species were found during the wet season, in 24 species from the three families Bacillariophyceae, Cyanophyceae, and Dinophyceae. The Bacillariophyceae showed the highest diversity in both seasons, *Chaetoceros* sp., *Coscinidiscus* sp., *Rhizosolenia* sp., and *Trichodesmium* sp. were found to be abundant during the dry season. The diversity index was generally higher during the dry season than during the wet season. The diversity index during the wet season ranges from 1,04 to 2,01, while the evenness index ranges from 0,59 to 0,95, and the dominance index ranges from 0,17 to 0,61. The highest diversity was found at the estuary station (E-1), high evenness was observed at the coral reef stations (R-3), and the highest dominance was recorded at the coastal station (C-2).

**Table 1.** Phytoplankton diversity and abundance during the dry season in the coastal area of Kawasi, the western part of Obi Island (R = Coral Reef; P = Port; E = Estuary; C = Coastal)

Organism	Stations												
	R-1	R-2	R-3	P-1	P-2	E-1	E-2	C-1	C-2	C-3	C-4	C-5	C-6
<b>BACILLARIOPHYCEAE</b>													
<i>Achnanthes</i> sp.	-	-	++	-	++++	++++	++++	-	-	-	-	-	-
<i>Amphiprora</i> sp.	-	++	++	-	-	++++	++	++++	-	-	-	-	-
<i>Amphora</i> sp.	++	++	-	-	-	++++	-	++	++	-	-	-	-
<i>Asterionella</i> sp.	-	-	++	-	-	-	-	-	-	-	-	-	-
<i>Bacteriastrium</i> sp.	-	++	++	++	-	++	-	-	++++	-	-	-	-
<i>Biddulphia</i> sp.	++	-	-	-	-	-	-	++	++++	-	-	-	++
<i>Chaetoceros</i> sp.	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++
<i>Corethron</i> sp.	-	-	++	-	-	-	-	-	++	++	-	++	-
<i>Coscinodiscus</i> sp.	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++
<i>Cyclotella</i> sp.	++	++++	++	++++	-	++	-	++++	++	++	++++	-	++
<i>Diploneis</i> sp.	++	++	-	-	-	-	-	-	-	-	-	-	-
<i>Fragilaria</i> sp.	-	-	-	-	-	-	-	++	-	-	-	-	++
<i>Gomphonema</i> sp.	++	-	-	-	-	-	-	-	-	-	-	-	-
<i>Guinardia</i> sp.	++++	++++	++++	-	++++	++++	-	++++	++++	++++	-	-	++++
<i>Hemiaulus</i> sp.	-	++	++++	++++	++++	++	++	++	++++	++++	++++	++++	-
<i>Lauderia</i> sp.	-	-	-	-	++++	-	++	-	-	-	-	++++	-
<i>Leptocylindrus</i> sp.	-	++	++++	-	-	-	++	++++	++++	-	++	++++	++++
<i>Melosira</i> sp.	-	-	-	-	++++	-	++	-	-	-	++++	++++	++++

Organism	Stations													
	R-1	R-2	R-3	P-1	P-2	E-1	E-2	C-1	C-2	C-3	C-4	C-5	C-6	
<i>Navicula</i> sp.	++	++	++	-	++++	++++	++	++	++	++++	++	++++	++	
<i>Nitzschia</i> sp.	++	++	++	++	-	++++	-	-	-	-	++	-	++	
<i>Pinnularia</i> sp.	-	++	-	-	-	++++	-	-	-	-	-	++	-	
<i>Pleurosigma</i> sp.	++++	++++	-	++++	-	-	++	++++	++++	++	++	++	++++	
<i>Rhizosolenia</i> sp.	++++	++++	-	++++	++++	++++	++++	++++	++++	++++	++++	++++	++++	
<i>Skeletonema</i> sp.	++++	++++	++++	++++	++++	-	-	++++	-	-	++++	-	++++	
<i>Thalassiothrix</i> sp.	++	++	++++	-	++++	++	++	-	++	++	++	++++	++	
<i>Thalassionema</i> sp.	-	-	++	++++	-	-	-	-	-	-	-	-	-	
<i>Eucampia</i> sp.	++++	++++	++	++++	-	++	-	++++	++++	++++	++++	-	++++	
<i>Synedra</i> sp.	-	++	++	-	++	-	++	++	-	-	++	+++	++	
<i>Thalassiosira</i> sp.	-	-	++++	-	-	-	-	-	-	-	-	-	-	
<i>Triceratium</i> sp.	-	++	-	-	-	-	-	-	-	-	-	++	-	
<i>Ditylum</i> sp.	-	-	-	-	-	-	-	-	-	-	++	-	-	
<i>Cerataulina</i> sp.	-	-	-	-	-	++++	-	-	-	++++	-	-	-	
<i>Bellerophora</i> sp.	-	-	-	-	-	-	-	-	-	++++	-	-	-	
<i>Grammatophora</i> sp.	-	-	++	-	-	-	-	-	-	-	-	-	-	
<i>Detonula</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	+++	
<b>CHLOROPHYCEAE</b>														
<i>Cosmarium</i> sp.	-	++	-	-	-	-	-	++	-	-	-	-	-	
<i>Staurastrum</i> sp.	-	++	-	-	-	-	-	++	-	-	-	-	-	
<i>Selenastrum</i> sp.	-	++	-	-	-	++++	-	-	-	-	-	-	-	
<b>CYANOPHYCEAE</b>														

Organism	Stations													
	R-1	R-2	R-3	P-1	P-2	E-1	E-2	C-1	C-2	C-3	C-4	C-5	C-6	
<i>Microcystis</i> sp.	-	++++	++	-	++++	++++	++	++	++	++++	++++	++++	-	
<i>Oscillatoria</i> sp.	++	++	++	++	++	++	++	-	-	++++	-	++	++	
<i>Trichodesmium</i> sp.	+++++	+++++	++++	+++++	-	-	-	+++++	+++++	-	+++++	-	+++++	
<b>DINOPHYCEAE</b>														
<i>Ceratium</i> sp.	++++	++++	++	++++	++	-	++	++	++	++	++++	++++	++	
<i>Dinophysis</i> sp.	-	++	-	-	-	++	-	-	++	++	++	-	++	
<i>Ornithocercus</i> sp.	-	-	-	++++	-	-	-	-	-	-	++	-	-	
<i>Peridinium</i> sp.	++	++++	++++	++	-	++++	++	++	++	++	++++	++	++	
<i>Ceratocorys</i> sp.	-	++	-	-	-	-	-	++	++	++	++	++	-	
<b>Number of Taxa</b>	19	30	25	16	15	21	17	20	19	19	22	19	22	
<b>Total abundance (cell/m<sup>3</sup>)</b>	899.808	1.680.315	399.353	887.676	873.521	741.078	311.394	679.406	450.915	450.915	618.744	726.923	1.048.428	
<b>Diversity Index (H')</b>	1,99	2,30	2,61	1,96	2,10	2,47	1,73	2,12	2,49	2,49	2,40	2,29	2,31	
<b>Evenness Index (E)</b>	0,68	0,68	0,81	0,71	0,78	0,81	0,61	0,71	0,84	0,84	0,78	0,78	0,75	
<b>Dominance Index (C)</b>	0,18	0,14	0,10	0,21	0,17	0,12	0,32	0,19	0,11	0,11	0,12	0,15	0,12	

Note: (-) = 0 cell/ m<sup>3</sup>; (+) = 1-100 cell/ m<sup>3</sup>; (++) = 101-1000 cell/ m<sup>3</sup>; (+++) = 1001-10000 cell/ m<sup>3</sup>; (++++) = 10001-100000 cell/ m<sup>3</sup>; (+++++) = >100000 cell/ m<sup>3</sup>

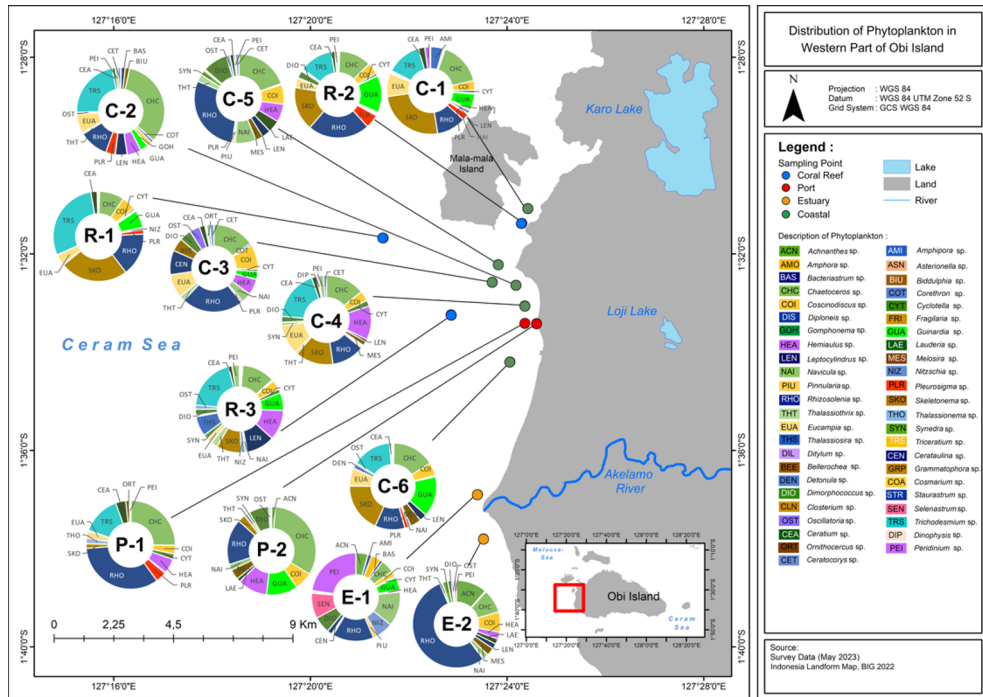
**Table 2.** Phytoplankton diversity and abundance during the wet season in the coastal area of Kawasi, the western part of Obi Island (R = Coral Reef; P = Port; E = Estuary; C = Coastal)

Organism	Stations												
	R-1	R-2	R-3	P-1	P-2	E-1	E-2	C-1	C-2	C-3	C-4	C-5	C-6
<b>BACILLARIOPHYCEAE</b>													
<i>Achnanthes</i> sp.	-	-	-	-	-	++	-	-	-	-	-	-	-
<i>Campylodiscus</i> sp.	-	-	-	-	-	-	-	-	-	-	++	-	-
<i>Chaetoceros</i> sp.	-	-	-	++++	++	-	-	++++	-	-	++	++	-
<i>Coscinodiscus</i> sp.	++	++	-	++	++	++	-	++	-	++	++++	++++	++
<i>Guinardia</i> sp.	-	-	-	-	-	++	++	-	-	-	-	-	-
<i>Hemiaulus</i> sp.	-	-	-	-	-	-	-	-	-	++	-	-	-
<i>Leptocylindrus</i> sp.	-	-	-	-	-	-	++	-	-	-	-	-	-
<i>Lithodesmium</i> sp.	-	-	-	-	-	++	-	-	-	-	-	-	-
<i>Navicula</i> sp.	-	-	-	-	-	++++	-	-	-	-	-	-	-
<i>Nitzschia</i> sp.	-	-	-	-	-	++	++	-	-	++	-	-	++
<i>Pleurosigma</i> sp.	++	-	-	++	++	++	++	++	-	++	-	++	++
<i>Rhizosolenia</i> sp.	++	-	-	++++	++	++++	++++	++++	+++	-	+++	++	++
<i>Synedra</i> sp.	-	-	++	-	-	++	-	-	-	-	++	-	-
<i>Thalassionema</i> sp.	-	++	-	-	-	-	-	-	-	-	-	-	-
<i>Triceratium</i> sp.	++	-	-	-	-	++	-	-	-	-	++	-	-
<b>CYANOPHYCEAE</b>													
<i>Microcystis</i> sp.	-	-	-	++++	-	++++	-	-	++	+++	-	-	-
<i>Oscillatoria</i> sp.	-	-	-	++	-	-	-	++	-	-	-	-	-
<i>Trichodesmium</i> sp.	-	-	-	-	-	-	-	-	-	+++	-	-	-

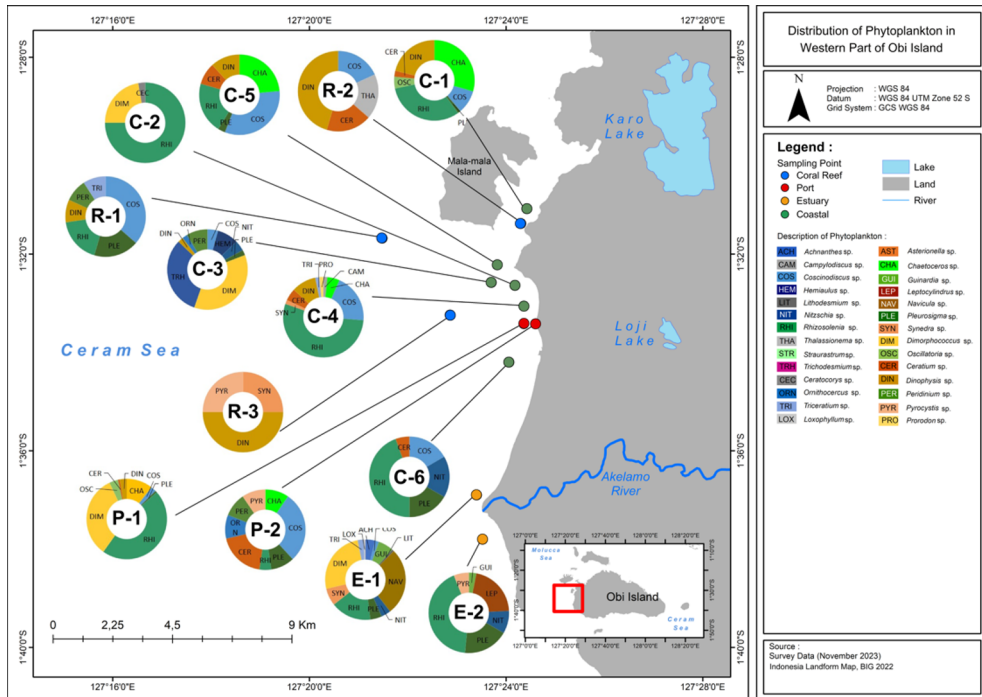
Organism	Stations													
	R-1	R-2	R-3	P-1	P-2	E-1	E-2	C-1	C-2	C-3	C-4	C-5	C-6	
<b>DINOPHYCEAE</b>														
<i>Ceratium</i> sp.	-	++	-	++	++	-	-	++	-	-	++	++	++	++
<i>Ceratocorys</i> sp.	-	-	-	-	-	-	-	-	++	-	-	-	-	-
<i>Dinophysis</i> sp.	++	++	++	++	-	-	-	++++	-	++	++	++	++	-
<i>Ornithocercus</i> sp.	-	-	-	-	++	-	-	-	-	++	-	-	-	-
<i>Peridinium</i> sp.	++	-	-	-	++	-	-	-	-	++	-	-	-	-
<i>Pyrocystis</i> sp.	-	-	++	-	++	-	++	-	-	-	-	-	-	-
<b>Number of Taxa</b>	6	4	3	8	8	12	6	7	3	9	9	6	5	5
<b>Total abundance (cell/m<sup>3</sup>)</b>	11.121	11.121	4.044	143.565	21.231	129.411	33.364	85.937	36.397	47.518	60.661	34.375	18.198	18.198
<b>Diversity Index (H')</b>	1,64	1,29	1,04	1,33	1,94	2,01	1,50	1,56	0,65	1,67	1,45	1,60	1,42	1,42
<b>Evenness Index (E)</b>	0,92	0,93	0,95	0,64	0,93	0,78	0,84	0,80	0,59	0,76	0,66	0,89	0,88	0,88
<b>Dominance Index (C)</b>	0,22	0,31	0,38	0,34	0,17	0,18	0,27	0,24	0,61	0,25	0,35	0,22	0,28	0,28

Note: (-) = 0 cell/ m<sup>3</sup>; (+) = 1-100 cell/ m<sup>3</sup>; (++) = 101-1000 cell/ m<sup>3</sup>; (+++) = 1001-10000 cell/ m<sup>3</sup>; (++++) = 10001-100000 cell/ m<sup>3</sup>; (+++++) = > 100000 cell/ m<sup>3</sup>

Figure 2 shows the distribution of phytoplankton composition at 13 observation stations in the coastal area of Kawasi, western Obi Island, during the dry season. In contrast, Figure 3 presents the distribution during the wet season. Phytoplankton composition varied between stations during each season. Each season showed distinct patterns of phytoplankton distribution across the observation stations.



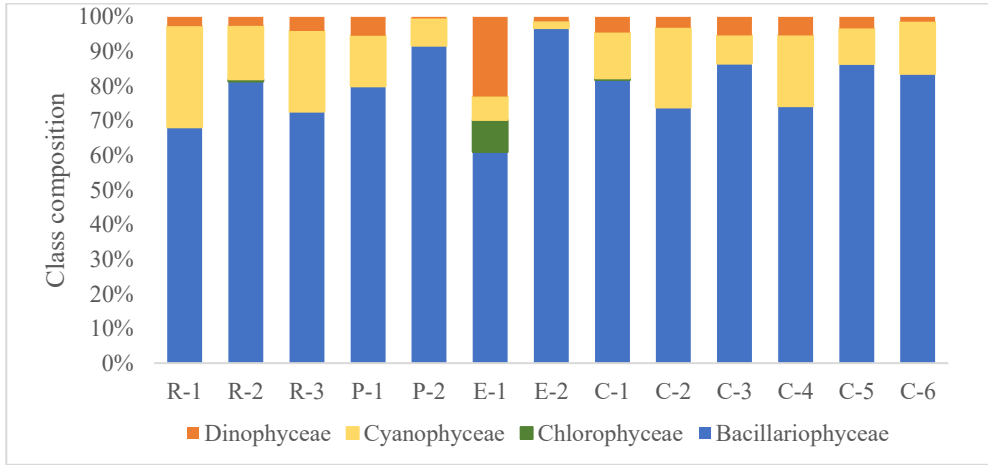
**Fig. 2.** Distribution of phytoplankton composition during the dry season in the coastal area of Kawasi, the western part of Obi Island (R = Coral Reef; P = Port; E = Estuary; C = Coastal)



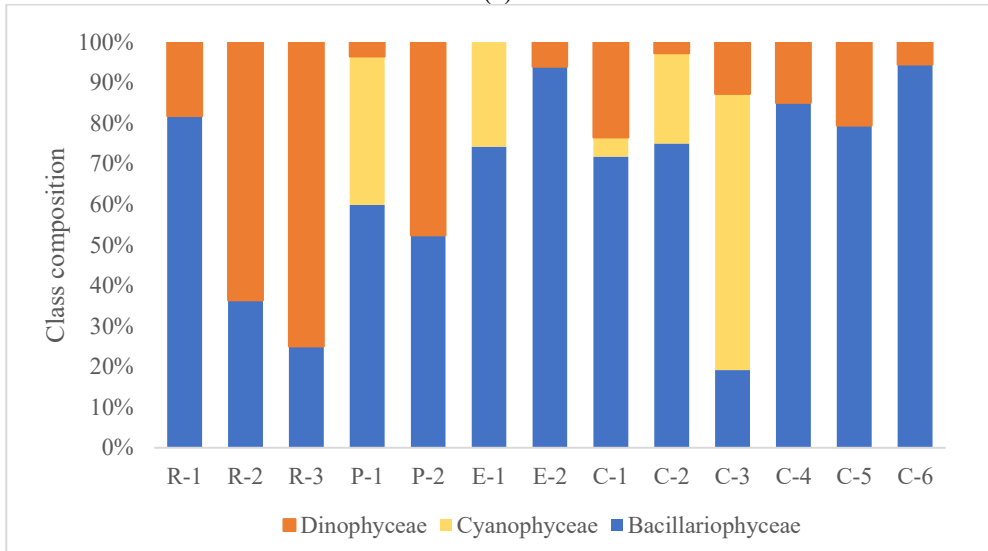
**Fig. 3.** Distribution of phytoplankton composition during the wet season in the coastal area of Kawasi, the western part of Obi Island

### 3.2 Class composition and abundance of phytoplankton in different seasons

Bacillariophyceae are a class of phytoplankton commonly found at all stations during the dry season. More than 60% of this class was found during the dry season. Bacillariophyceae are one of the classes within the algae group known as diatoms, which are a very important type of phytoplankton in aquatic ecosystems. In addition to Bacillariophyceae, Cyanophyceae, Chlorophyceae, and Dinophyceae were also found during the dry season (Figure 4a). The composition of phytoplankton classes during the wet season was slightly different from that during the dry season, with Dinophyceae being found in several locations such as R-2, R-3, and C-1 (Figure 4b), and Cyanophyceae was also abundant in P-1 and C-3. Chlorophyceae were not found during the wet season; this class was only present in the dry season at C-1, R-2, and E-1 (Figures 4a and 4b). *Selenastrum* sp. was the most commonly found species in the E-1. This species is commonly found in freshwater environments and serves a vital role in aquatic ecosystems as a primary producer, generating oxygen and forming the foundation of the food chain. Since Station E-1 is located in an estuarine area, its presence is likely affected by the interaction between seawater and river water.



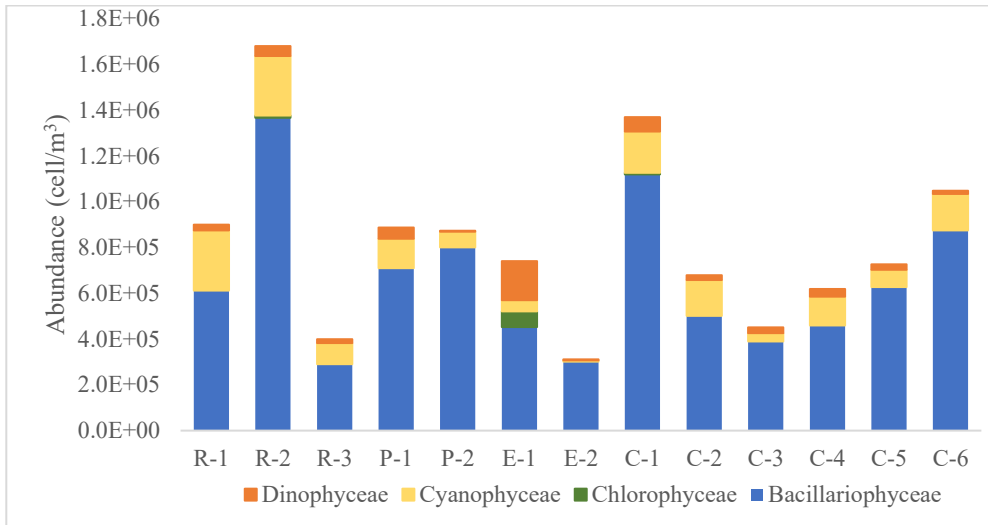
(a)



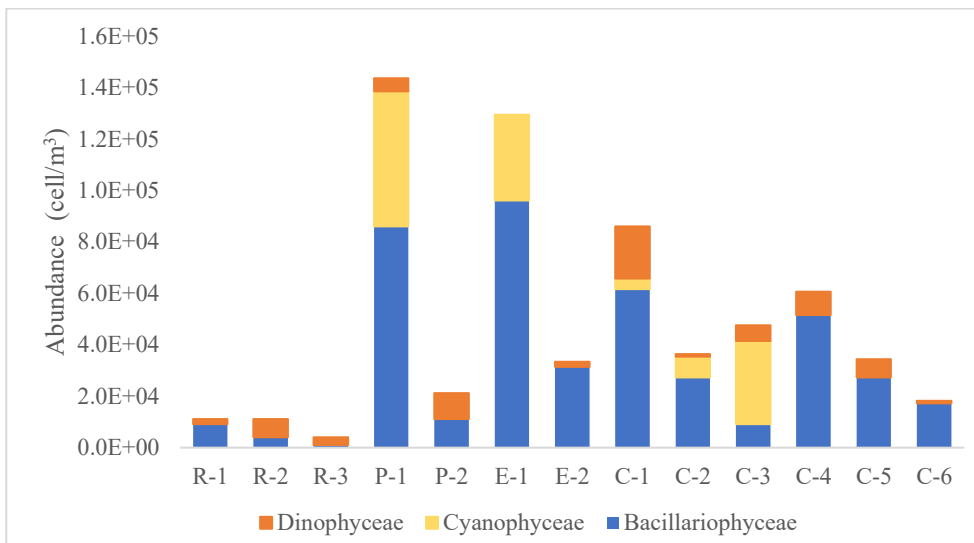
(b)

**Fig. 4.** The class composition of phytoplankton in the coastal area of Kawasi, the western part of Obi Island: (a) dry season; (b) wet season

Phytoplankton abundance was higher during the dry season than during the wet season. Coral Reef station R-2, located between Obi Island and Mala-Mala Island, had the highest abundance compared to all other stations (Figure 5a). The total abundance range at each station varies between  $3,1 \times 10^5 - 1,7 \times 10^6$  cells/m<sup>3</sup>, while the phytoplankton abundance range during the wet season is between  $4,0 \times 10^3 - 1,4 \times 10^5$  cells/m<sup>3</sup>. During the wet season, the highest abundance was found at P-1, a port, and E-1, an estuary area, whereas the lowest abundance was found in R-1, R-2, and R-3, coral reef areas (Figure 5b).



(a)



(b)

Figure 5. Class abundance of phytoplankton in the coastal area of Kawasi, western part of Obi Island: (a) dry season; (b) wet season

### 3.3 Nitrate and phosphate

The results of the nitrate and phosphate measurements fluctuated during each season. During the dry season, nitrate concentrations ranged from 0,005 to 0,102 mg/L; in the wet season, they ranged from 0,05 to 0,37 mg/L. Phosphate concentrations during the dry season ranged from 0,05 to 0,15 mg/L, whereas in the wet season, they ranged from 0,05 to 0,11 mg/L (Table 3). The concentrations of nitrate and phosphate at each station during the different seasons are shown in Table 3.

**Table 3.** The concentrations of nitrate and phosphate during the dry and wet seasons in the coastal area of Kawasi, the western part of Obi Island

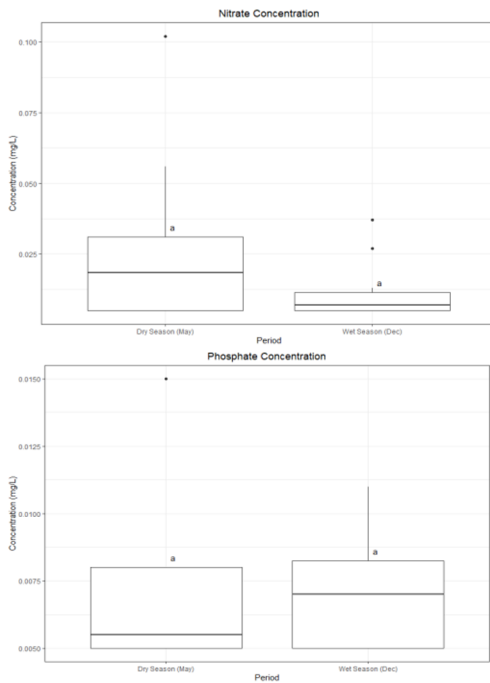
Station	Nitrate (mg/L)		Phosphate (mg/L)	
	Dry Season	Wet Season	Dry Season	Wet Season
R-1	0,005	0,037	0,015	0,005
R-2	0,005	0,007	0,005	0,011
R-3	0,005	0,027	0,015	0,005
P-1	0,021	0,011	0,008	0,005
P-2	0,021	0,011	0,008	0,005
E-1	0,029	0,005	0,005	0,007
E-2	0,102	0,013	0,005	0,008
C-1	0,005	0,007	0,005	0,011
C-2	0,037	0,006	0,006	0,007
C-3	0,005	0,005	0,005	0,008
C-4	0,016	0,006	0,005	0,007
C-5	0,056	0,005	0,008	0,009
C-6	0,046	0,005	0,005	0,006

R = Coral Reef; P = Port; E = Estuary; C = Coastal

During the dry season, the nitrate concentration in the coral reef ecosystem (R-1, R-2, R-3) showed the same value at all stations, which was 0,005 mg/L. During the wet season, there was an increase in the range of 0,007–0,037 mg/L, with R-1 having the highest nitrate concentration. In the port ecosystems (P-1 and P-2), nitrate concentrations during the dry season were measured at 0,021 mg/L and decreased to 0,011 mg/L during the wet season at both stations. The nitrate concentrations varied in the estuary ecosystems (E-1 and E-2). During the dry season, E-1 had a concentration of 0,029 mg/L, whereas E-2 showed the highest value among all stations at 0,102 mg/L. In the wet season, the nitrate concentrations at these two stations decreased to 0,005 mg/L and 0,013 mg/L. In the coastal ecosystem (C-1 to C-6), nitrate concentrations varied more than in the other ecosystems. During the dry season, nitrate concentrations ranged from 0,005 to 0,056 mg/L, with C-5 showing the highest value. During the wet season, the range was lower, between 0,005 and 0,009 mg/L, with the highest concentration recorded at C-1 (Table 3).

The phosphate concentration in the coral reef ecosystem during the dry season ranged between 0,005 and 0,015 mg/L, with R-1 and R-3 having the highest concentrations. In the wet season, phosphate concentrations at all coral reef stations decreased, ranging from 0,005 to 0,011 mg/L. In the port ecosystem (P-1 and P-2), phosphate concentrations were measured at 0,008 mg/L during the dry season, whereas in the wet season, it decreased to 0,005 mg/L at both stations. In the estuary ecosystems (E-1 and E-2), phosphate concentrations ranged from 0,005 to 0,008 mg/L in the dry season, whereas in the wet season, there was a slight increase, ranging from 0,007 to 0,008 mg/L. In the coastal ecosystem, phosphate concentrations during the dry season ranged from 0,005 to 0,009 mg/L, with the highest value at C-2. During the wet season, phosphate concentrations remained within the same range of 0,005–0,009 mg/L, with the highest value recorded at C-3 (Table 3).

Based on statistical analysis, neither nitrate nor phosphate concentrations showed significant seasonal differences. However, the average nitrate concentration during the dry season was higher than that during the wet season (Figure 6).



**Fig. 6.** Nitrate and phosphate concentration during (a) dry and (b) wet seasons in the coastal area of Kawasi, the western part of Obi Island

## 4. Discussion

The Bacillariophyceae class of diatoms is widely distributed globally and often dominates phytoplankton communities [11,15,16]. Their dominance in marine environments is attributed to their superior adaptability to environmental conditions compared with other phytoplankton classes [17,18]. Additionally, Bacillariophyceae exhibit a high reproductive rate and can double within 18–36 h [18,19,20]. They have a high cell division rate under optimal conditions, allowing them to dominate nutrient-rich water quickly. In this study, the most abundant species during the dry season were *Chaetoceros* sp., *Coscinodiscus* sp., and *Rhizosolenia* sp.

Diatoms can store nitrogen and phosphorus in their vacuoles, allowing them to survive when nutrient availability decreases. They can grow rapidly when nutrient levels increase owing to upwelling from the ocean floor to the surface, often making them the dominant species in phytoplankton blooms. Their hard frustules make it more difficult for zooplankton to consume diatoms than for phytoplankton without rigid cell walls. The process of forming silica cell walls requires less energy than synthesizing carbon-based cell walls, as observed in dinoflagellates, making diatoms more efficient under nutrient-limited conditions. Some diatoms can form dormant spores when environmental conditions are unfavorable and resume growth when environmental conditions improve. Cyanophyceae (Cyanobacteria), commonly known as blue-green algae, thrive in water contaminated with organic matter [21]. Some types of Cyanophyceae, such as *Trichodesmium* sp., reproduce more rapidly during the dry season because of good light penetration in the water and optimal temperatures for cell division [22].

During the dry season, the highest phytoplankton abundance was found at C-1 and R-2, which are located in the strait between Obi Island and Mala-Mala Island, respectively. Strong currents in a narrow strait can cause high turbulence, affecting the distribution of organisms and suspended particles. This factor contributes to the high phytoplankton growth in this area. In addition, the high ship traffic in the strait area could be a source of organic waste from shipping activities.

Generally, the phytoplankton abundance was lower across all observation sites during the wet season. The reduced average nitrate levels may be a contributing factor to this decline. Some studies have suggested that nutrient levels increase along the coast due to nutrient runoff. Obi Island has a relatively low population density compared to the main islands. Human activities are concentrated in Kawasi Village and the Nickel Industry, where waste management systems may already be in place to minimize eutrophication and nutrient runoff into the sea. If human any human activities are conducted irresponsibly in the future, they may result in harmful consequences, including rising CO<sub>2</sub> levels [23], increasing nutrients and runoff from household activities [24], and harmful metal loading to the water [25].

The highest phytoplankton abundance was observed during the wet season in the port area (P-2) and estuary (E-1). In contrast, coral reef sites (R-1, R-2, and R-3) showed lower phytoplankton abundance. Notably, at site R-2, phytoplankton abundance was extremely low, suggesting an oligotrophic condition similar to that of the other two coral reef sites. The highest concentration of nitrate nutrients was found at E-2, which is located at the southernmost point of the study area. However, this did not show the same pattern as the phytoplankton abundance at that particular station. These results indicate that nutrients could influence the seasonal fluctuations of the phytoplankton community in the coastal waters of Kawasi. However, the study has not yet confirmed how nutrients are distributed and whether land-based runoff, currents, or water mass dynamics contribute to seasonal changes in both nutrients and phytoplankton in this region.

## 5. Conclusion

Bacillariophyceae was the most common phytoplankton class at all stations during the dry and wet seasons. *Chaetoceros* sp., *Coscinodiscus* sp., and *Rhizosolenia* sp. were the predominant genera in both seasons. During the dry season, phytoplankton are predominantly located in the strait area between Obi and Mala-Mala Island. In contrast, they are more concentrated in the harbor and estuary areas during the wet season. The highest overall abundance occurred during the dry season, which was linked to the higher average nitrate levels in the water during this time. The waters in the western part of Obi Island have high plankton diversity with no dominance, meaning that there are many species of phytoplankton living in the area and indicates that the aquatic ecosystem has environmental conditions that support the growth and development of various phytoplankton species. This study provides information on phytoplankton's diversity and community composition in the western part of Obi Island.

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