Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(4): 2483 – 2498 (2025)
www.ejabf.journals.ekb.eg

Abundance and Diversity of Phytoplankton as Determinants of Waters Quality of Lake Ngade Ternate, North Maluku, Indonesia

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ARTICLE INFO

Article History:
Received: June 1st, 2025
Accepted: July 17, 2025
Online: Aug. 6, 2025

Keywords:
Ecological indices,
Lake Ngade,
Phytoplankton

ABSTRACT

Lake Ngade holds significant potential as a source of fisheries resources and ecotourism in Ternate City. At present, the lake is utilized by the local community for various activities, including fish rearing using floating net cage systems, tourism, and fishing. This research aimed to analyze the abundance and diversity of phytoplankton in Lake Ngade, assess its water quality, and examine the relationship between phytoplankton abundance and the physicochemical parameters of the lake. The study was conducted from March to April 2023 at five sampling stations. Sampling was carried out four times at two-week intervals. Phytoplankton specimens were collected using the filtering method. The results revealed 64 genera of phytoplankton, representing five classes: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, and Euglenophyceae. Phytoplankton abundance ranged from 23,649 to 212,181 cells per liter. The ecological index values showed a diversity index (H') ranging from 0.9086 to 2.8132, an evenness index (E) ranging from 0.3542 to 0.8354, and a dominance index (D) ranging from 0.0900 to 0.5419. Based on the diversity index values, Lake Ngade is classified as mesotrophic, indicating moderate fertility. These conditions suggest that the lake is ecologically suitable for fish farming activities.

INTRODUCTION

Freshwater ecosystems are generally classified into two types: lotic waters (flowing water bodies such as rivers and streams) and lentic waters (still water bodies such as lakes and ponds). Lakes, as examples of lentic water bodies, are widely utilized and often formed by volcanic activity or earthquakes **(Yuliana & Irfan, 2018)**. These water bodies typically have a surface elevation higher than sea level **(Utomo & Chalif, 2014)**. Lakes represent one of the most important freshwater resources, with significant potential for development and utilization to support various human interests, including fish farming **(Irianto, 2011)**.

One such freshwater resource in Indonesia is Lake Ngade. Located in the southern part of Ternate City, North Maluku Province, Lake Ngade has great potential as a source of inland fisheries and ecotourism. Numerous studies have been conducted on the lake, including investigations into the fluctuation and abundance of phytoplankton **(Yuliana & Tamrin, 2007)**, optimal incubation times for measuring primary productivity **(Yuliana & Irfan, 2018)**, and assessments of trophic status **(Samman *et al.*, 2023)**. However, no studies have specifically examined the suitability of the lake for fish farming based on the structure of the phytoplankton community.

Given the increasing ecological pressure from various community activities around the lake, it is crucial to study the carrying capacity of Lake Ngade. Historically and up to the present, the lake has been used for multiple purposes, including fish rearing in floating net cages, tourism, recreational fishing, and supporting nearby poultry farms and plantations. These activities contribute to nutrient enrichment and fluctuations in water quality, which may negatively impact aquatic biota.

The lake's ecosystem supports various aquatic organisms forming complex communities, including nekton, benthos, and plankton **(Yuliana & Irfan, 2018)**. Among planktonic organisms, phytoplankton are autotrophic and capable of producing their own food by converting inorganic substances into organic matter through photosynthesis **(Wetzel, 1983; Parsons *et al.*, 1984)**. In contrast, zooplankton are heterotrophic consumers that rely heavily on phytoplankton as a primary food source.

Phytoplankton are widely recognized as biological indicators of water fertility and pollution levels. Their presence and abundance serve as important parameters for assessing water quality, aligning with Sustainable Development Goal (SDG) 6: Clean Water and Sanitation, which emphasizes water quality monitoring. Furthermore, their relevance to SDG 14: Life Below Water highlights their ecological role in supporting aquatic biodiversity and their potential utility in promoting sustainable aquaculture practices.

In this context, the purpose of this research was to analyze the abundance and diversity of phytoplankton in Lake Ngade, assess the water quality of the lake, and determine the relationship between phytoplankton abundance and the physicochemical parameters of the lake water.

MATERIALS AND METHODS

1. Study sites

This research was conducted from March to April 2023 at five sampling stations in Lake Ngade, located in Ternate, North Maluku Province, Indonesia (Fig. 1). Sampling was carried out four times at fortnightly intervals.

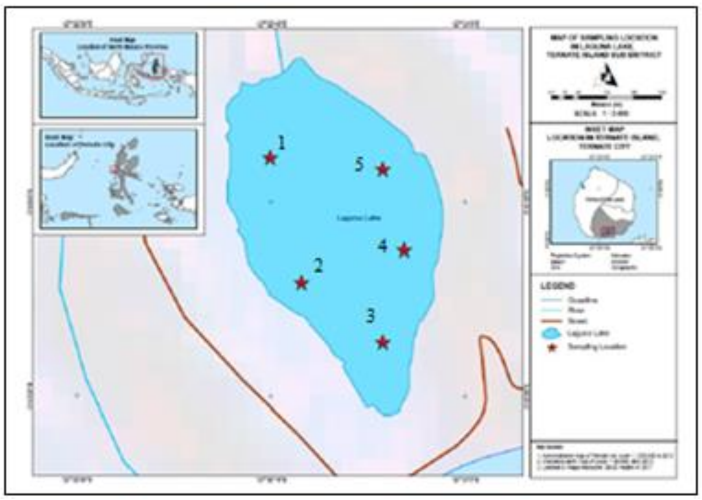

Fig. 1. Research location in Lake Ngade Ternate, North Maluku, Indonesia

2. Survey method

A total of 30 liters of water samples were filtered for phytoplankton specimens using a 25µm plankton net. The filtered results were put into a sample bottle and preserved with 4% Lugol's solution. Samples were identified based on the identification books of **Davis (1955)**, **Needham and Needham (1963)** and **Sachlan (1982)**.

3. Abundance of phytoplankton

The equation according to **APHA (2005)** was used to calculate the abundance of phytoplankton species:

$$N = \frac{O_i}{O_p} \; x \; \frac{V_r}{V_o} \; x \; \frac{1}{V_s} \; x \; \frac{n}{p}$$

Where, N = Number of individuals per liter

Oi = Area of the cover glass (mm^2)

Op = Area of one field of view (mm^2)

Vr = Volume of filtered water (ml)

Vo = Observed volume of water (ml)
Vs = Filtered water volume (L)
n = Total plankton in the entire field of view
p = Number of visual fields observed

4. Ecological indices

The species diversity index was calculated using the Shannon-Wiener index, while the evenness and dominance indices were calculated using formulas provided by **Odum (1998)**:

1. Shannon-Wiener diversity index:

$$H' = -\sum_{i=1}^{s}\left({ni}/{N}\right)\ln\left({ni}/{N}\right)$$

2. Evenness index

$$E = {H'}/{H_{max}}$$

3. Dominance index:

$$D = \sum_{i=1}^{s}\left({ni}/{N}\right)^2$$

Where, H’ = Shannon-Wiener diversity index
E = Evenness index
D = Simpson dominance index
ni = Number of individuals of genus i
N = Total number of individuals of all genera
H_{max} = Maximum diversity index (= ln S, where S = Total type)

5. Data analysis

Phytoplankton data and water physicochemical parameters were analyzed descriptively and presented in tables and graphs. Pearson correlation analysis was employed to determine the relationship between phytoplankton abundance and the physicochemical parameters of Lake Ngade. Data analysis was performed using IBM SPSS version 23, Minitab version 16, and ExcelStat 2017.

RESULTS

1. Physicochemical parameters

The results of the physicochemical parameter measurements of Lake Ngade during the study are presented in Table (1).

Table 1. Physicochemical parameters during research in the Lake Ngade Ternate of North Maluku, Indonesia

Observation time	Station	Parameters				
		pH	Temperature (°C)	TDS	Nitrate (mg.L^{-1})	Phosphate (mg.L^{-1})
Period I	1	7.2	30.8	120	0.0387	0.0425
	2	7.9	30.5	66	0.0326	0.0409
	3	6.6	31.0	66	0.0618	0.0436
	4	7.8	31.1	66	0.0364	0.0414
	5	7.6	30.9	66	0.0395	0.0444
Period II	1	8.7	31.8	74	0.0187	0.0510
	2	8.5	31.8	68	0.0218	0.0494
	3	8.3	32.5	72	0.0179	0.0524
	4	8.1	32.8	64	0.0202	0.0502
	5	8.2	32.6	56	0.0164	0.0515
Period III	1	8.4	30.5	81	0.0379	0.0415
	2	8.3	30.6	68	0.0333	0.0395
	3	8.3	31.1	67	0.0464	0.0426
	4	8.5	31.3	67	0.0618	0.0429
	5	8.5	31.5	63	0.0626	0.0434
Period IV	1	8.6	31.1	155	0.0726	0.0406
	2	8.3	31.6	62	0.0487	0.0402
	3	7.9	31.1	62	0.0526	0.0420
	4	8.3	31.5	66	0.0441	0.0409
	5	8.3	30.9	66	0.0549	0.0445

2. Composition of phytoplankton

The composition of phytoplankton found during research in Lake Ngade consisted of 64 genera from 5 classes, namely Bacillariophyceae (30 genera), Chlorophyceae (17 genera), Cyanophyceae (10 genera), Dinophyceae (7 genera), and Euglenophyceae (1 genus). The complete composition of phytoplankton types is presented in Table (2).

Table 2. The composition of phytoplankton during research in the Lake Ngade Ternate of North Maluku, Indonesia

Class	Order	Family	Genus
Bacillariophyceae	Mastogloiales	Achnanthaceae	*Achnanthes*
	Naviculales	Amphipleuraceae	*Amphiprora*
		Neidiaceae	*Neidium*
		Pinnulariaceae	*Pinnularia*
		Stauroneidaceae	*Stauroneis*
		Pleurosigmataceae	*Gyrosigma*

	Cymbellales	Rhoicospheniaceae	*Rhoicosphenia*
		Cymbellaceae	*Cymbella*
		Gomphonemataceae	*Gomphonema*
	Zygnematales	Desmidiaceae	*Staurastrum*
	Thalassiosirales	Stephanodiscaceae	*Stephanodiscus*
	Thalassiophysales	Catenulaceae	*Amphora*
	Centrales	Mediophyceae	*Cyclotella*
		Melosiraceae	*Melosira*
		Coscinodiscaceae	*Cossinodiscus*
		Rhizosoleniaceae	*Rhizosolenia*
	Eunotiales	Eunotiaceae	*Eunotia*
	Fragilariales	Fragilariaceae	*Meridion*
		Skletonemaceae	*Skeletonema*
		Thalassiosiraceae	*Thallassiosira*
	Tabellariales	Tabellariaceae	*Tabellaria*
	Thalassionematales	Thalassionemataceae	*Thalassionema*
	Biddulphiales	Biddulphiaceae	*Biddulphia*
			Triceratium
	Pennales	Fragilariaceae	*Synedra*
		Tabellariaceae	*Diatoma*
	Achnanthales	Cocconeidaceae	*Cocconeis*
		Naviculaceae	*Navicula*
		Nitzschiaceae	*Nitzschia*
		Surirellaceae	*Surirella*
Chlorophyceae	Chlorococcales	Oocystaceae	*Chlorella*
		Chlorococcaceae	*Chlorococcum*
		Desmidiaceae	*Cosmarium*
			Glocosystus
		Scenedesmaceae	*Scenedesmus*
	Desmidiales	Closteriaceae	*Closterium*
		Desmidiaceae	*Hyalotheca*
			Micrasterias
			Gronbladia
	Ulotrichales	Microsporaceae	*Microspora*
	Chlorellales	Oocystaceae	*Oocystis*
	Certaesedis	Xantophyceae	*Polyedrium*
	Chlamydomonadales	Sphaerocystidaceae	*Sphaerocystus*
		Volvocaceae	*Pleodorina*
	Zygnematales	Zygnemataceae	*Spirogyra*
		Mesotaeniaceae	*Netrium*

	Sphaeropleales	Treubariaceae	*Treubaria*
Cyanophyceae	Oscillatoriales	Oscillatoriaceae	*Trichodesmium*
			Oscillatoria
			Pelagothrix
		Microcoleaceae	*Lyngbya*
	Nostocales	Aphanizomenonaceae	*Aphanizomenon*
		Rivulariceae	*Calothrix*
		Oscilatoriaceae	*Spirulina*
	Sinekokocus	Merismopediaceae	*Merismopedia*
	Chroococcales	Microcystaceae	*Mycrocystus*
	Chladophorales	Chladophoraceae	*Tetrapedia*
Dinophyceae	Prorocentrales	Prorocentraceae	*Prorocentrum*
	Dinophysiales	Dinophysiaceae	*Dinophysis*
			Noctiluca
	Gonyaulacales	Gymnodiniceae	*Gymnodinium*
			Gonyaulax
		Ostreopsidaceae	*Alexandrium*
	Peridinales	Peridineaceae	*Peridinium*
Euglenophyceae	Euglenales	Euglenaceae	*Euglena*

The genera with high abundance during the study at Lake Ngade are presented in Fig. (2). The relative abundance (%) of each genera are as follows: *Chlorella*: 42%, *Glocosystus*: 17%, *Chlorococcum*: 8%, *Nitzschia*: 5%, *Triceratium*: 4%, and *Tabellaria*: 4%.

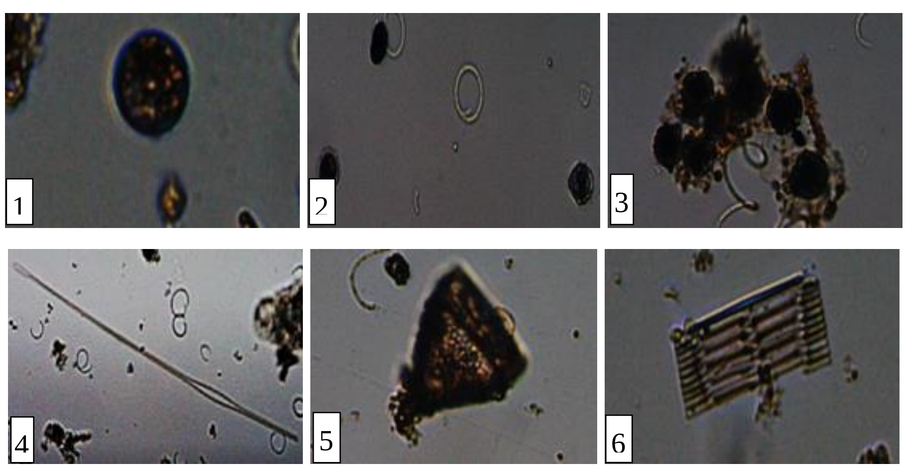

Fig. 2. The genera of phytoplankton that had high abundance during research in the Lake Ngade Ternate of North Maluku, Indonesia: (1). *Chlorella*, (2). *Glocosystus*, (3). *Chlorococcum*, (4). *Nitzschia*, (5). *Triceratium*, and (6). *Tabellaria*

The species composition of phytoplankton found during the study is presented in Fig. (3).

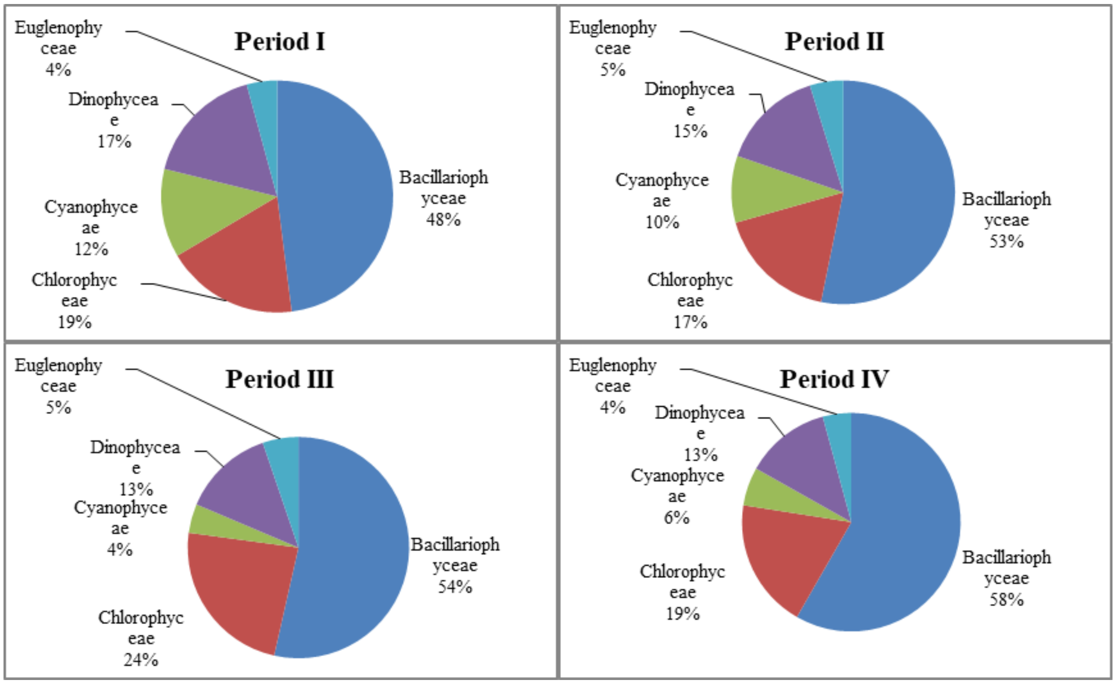

Fig. 3. The composition of the phytoplankton class during research in Lake Ngade Ternate of North Maluku, Indonesia.

3. Abundance of phytoplankton

The phytoplankton abundance values during the study was 23,649-212,181 cells.L^{-1}. The complete value is presented in Table (3).

Table 3. Phytoplankton abundance (cells.L^{-1}) during research in Lake Ngade Ternate of North Maluku, Indonesia

Station	Observation time				Average
	Period I	Period II	Period III	Period IV	
1	34,553	60,435	67,793	87,631	62,603
2	30,480	69,107	104,448	68,975	68,253
3	36,261	134,009	117,061	68,581	88,978
4	34,685	88,814	151,745	71,209	86,613
5	23,649	130,199	212,181	77,515	110,886
Average	31,926	96,513	130,646	74,782	

The abundance of phytoplankton based on class during study is presented in Fig. (4).

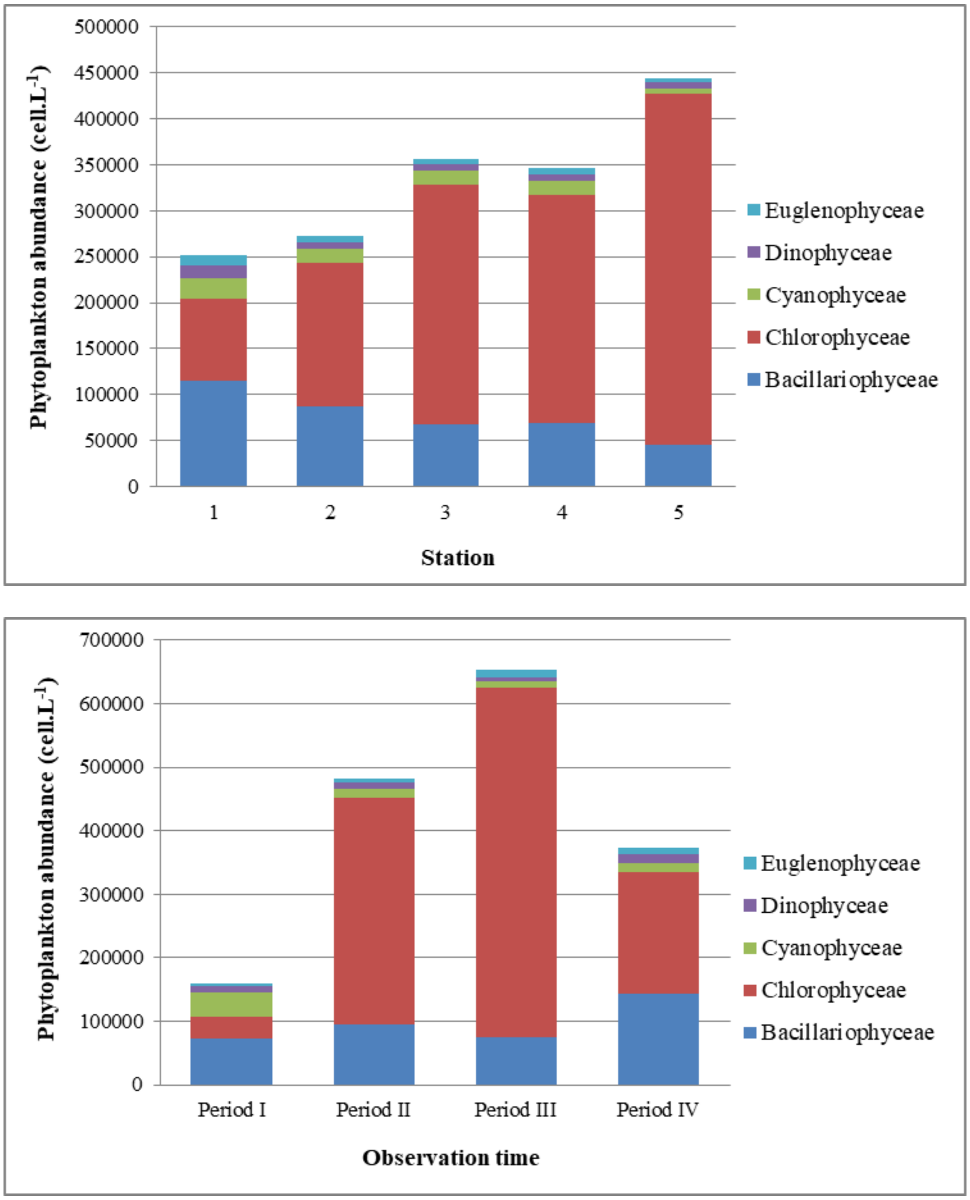

Fig. 4. Phytoplankton abundance at each station (top) and observation period (bottom) in Lake Ngade Ternate of North Maluku, Indonesia

4. Phytoplankton ecological indices

The ecological indices analyzed in this study are the diversity index (H'), evenness index (E), and dominance index (D). The completed value for each index is presented in Table (4).

Table 4. Phytoplankton ecological indices values during research in Lake Ngade Ternate of North Maluku, Indonesia

Observation time	Station	Ecological indices		
		H'	E	D
Period I	1	2.8132	0.8354	0.0900
	2	2.3782	0.7939	0.1298
	3	2.5877	0.7942	0.1203
	4	2.5959	0.8065	0.1139
	5	2.4014	0.7888	0.1366
Period II	1	2.5849	0.8244	0.1000
	2	2.2693	0.7341	0.1520
	3	1.4209	0.4743	0.4011
	4	1.9535	0.6230	0.2000
	5	1.5981	0.5641	0.2709
Period III	1	2.2892	0.7112	0.1969
	2	1.8703	0.6243	0.2588
	3	1.2305	0.4179	0.4803
	4	1.3898	0.4373	0.4535
	5	0.9086	0.3542	0.5419
Period IV	1	2.5036	0.7513	0.1425
	2	2.1199	0.6963	0.1924
	3	1.8173	0.5969	0.3094
	4	1.9027	0.5773	0.3228
	5	1.8810	0.5999	0.3204

Description : H '= Diversity index, E = Evenness index, and D = Dominance index

5. The correlation between the phytoplankton abundance with the physicochemical

The correlation between phytoplankton abundance and water physicochemical parameters was carried out using pearson correlation analysis. The complete analysis results are presented in Table (5).

Table 5. Pearson correlation value between phytoplankton abundance and water physicochemical parameters in Lake Ngade Ternate of North Maluku, Indonesia

Parameters	Nitrate	Phosphate	pH	Temperature	TDS
Abundance of Phytoplankton	0.149	0.208	0.544	0.397	-0.144

*Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

The Bacillariophyceae class exhibited the highest number of genera among all phytoplankton classes found in Lake Ngade. This dominance suggests that the environmental conditions of the lake are favorable for the growth of Bacillariophyceae. Their prevalence is supported by their adaptive characteristics, including resistance to extreme conditions, high reproductive capacity, and cosmopolitan distribution. These traits make them one of the most commonly encountered phytoplankton in various freshwater environments **(Putra & Hasan, 2012; Arifin *et al.*, 2015)**.

In contrast, the Euglenophyceae class showed the lowest diversity, represented by only a single genus—*Euglena*—indicating limited adaptability of this class under the current environmental conditions in Lake Ngade (Fig. 4).

Based on phytoplankton composition, Bacillariophyceae accounted for 48–58% of the total population, while Euglenophyceae comprised only 4–5% (Fig. 3). These findings align with earlier studies, such as that of **Yuliana and Irfan (2018)** in Lake Laguna (57% Bacillariophyceae) and **Manamani and Bensouilah (2023)** in Lake Meggarine Ouargla, Algeria (51%). However, **Wulandari *et al.* (2023)** reported Chlorophyceae as the most dominant group in the Jatigede Reservoir, Sumedang, with over 30%, highlighting geographical and ecological variability.

The highest phytoplankton abundance, recorded at station 5 during period III, was 212,181 cells·L^{-1}, while the lowest, at station 5 during period I, was 23,649 cells·L^{-1} (Table 3). The higher abundance in period III is attributed to favorable physicochemical parameters, such as nitrate (0.0626 mg·L^{-1}), phosphate (0.0434 mg·L^{-1}), temperature (30°C), and pH (8) (Table 1). Although nitrate and phosphate levels were below optimal concentrations cited by **Mustofa (2015)** (0.09–3.5 mg·L^{-1} for nitrate) and **Fajar *et al.* (2016)** (0.08–1.8 mg·L^{-1} for phosphate), they were within tolerable ranges. Notably, **Taufiq (2017)** suggests that Bacillariophyceae can absorb nitrate at levels as low as 0.001–0.007 mg·L^{-1}. Low phosphate availability may reflect natural utilization by macrophytes and algae **(Snook, 2009)**.

Temperature and pH measurements also supported phytoplankton growth. The recorded temperature (30°C) falls within the optimal range of 20–30°C and the pH (8) is within the suitable range for photosynthesis, which occurs most efficiently between pH 6 and 8 **(Ramadani *et al.*, 2012; Harmoko *et al.*, 2019)**.

The lowest abundance at station 5 period I was not due to poor water quality, as physicochemical values were relatively consistent across stations. Instead, it is likely due to biological factors, particularly higher grazing pressure from zooplankton and planktivorous fish **(Jiang *et al.*, 2014; Yuliana *et al.*, 2023)**. Phytoplankton are a primary food source for zooplankton, which explains the commonly observed negative correlation between the two groups **(Yuliana *et al.*, 2021)**.

Spatially and temporally, Chlorophyceae showed the highest abundance, indicating greater adaptability under the prevailing environmental conditions. This class is known for its wide distribution and ecological flexibility across diverse freshwater habitats **(Sartika *et al.*, 2012; Kim *et al.*, 2018)**. Its members, such as *Chlorella*, possess chlorophylls a and b, enhancing photosynthetic efficiency and metabolic rates **(Fachrul, 2008; Fauziah & Laily, 2015)**. Conversely, Euglenophyceae had the lowest abundance, with only *Euglena* detected.

In terms of genus-level abundance, *Chlorella* (Chlorophyceae) was the most dominant, while *Amphiprora* (Bacillariophyceae), *Hyalotheca*, *Polyedrium*, and *Sphaerocystis* (Chlorophyceae), *Calothrix* and *Lyngbya* (Cyanophyceae), and *Alexandrium* (Dinophyceae) had the lowest counts. These results differ from **Yuliana and Irfan (2018)**, who reported *Microcystis* as the most dominant genus in Lake Laguna. At that time, intensive aquaculture activities with many floating net cages led to higher nutrient inputs, classifying the lake as eutrophic. In contrast, current activity levels are much lower, resulting in reduced nutrient levels and different phytoplankton community structures. Similarly, **Ilham *et al.* (2020)** found *Phacus* to be dominant *in situ* Gunung Putri, Bogor, likely due to different ecological and geographical conditions. As **Yuliana *et al.* (2023)** noted, phytoplankton species have specific ecological requirements, and habitat variation significantly influences community composition.

Diversity, evenness, and dominance indices

The Shannon-Wiener diversity index (H') across most stations ranged from 0.9086 to 2.8132 (Table 4), placing Lake Ngade in the moderate diversity category based on **Odum (1998)**. Only station 5 period III recorded a value < 1, indicating low diversity. The overall moderate H' values suggest fairly even phytoplankton distribution, with no extreme dominance of specific taxa.

Lower diversity values, particularly at station 5 period III, may be attributed to low competition tolerance among certain species. As noted by **Arinardi *et al.* (1996)** and **Odum (1998)**, lack of competitiveness and uneven species abundance can reduce diversity.

The evenness index (E) ranged from 0.3542 to 0.8354 (Table 4). Most stations exhibited moderate (0.4–0.6) to high (>0.6) evenness, except for station 5 period III, which fell below 0.4. According to **Krebs (1998)**, E values below 0.4 indicate low evenness, while values above 0.6 reflect high evenness. In general, the phytoplankton community in Lake Ngade displayed a balanced species distribution. High evenness is also associated with ecosystem stability **(Wijaya & Hariyati, 2012)**.

The dominance index (D) ranged from 0.0900 to 0.5419 (Table 4). All values were below 0.5, except for station 5 period III. Referring to **Odum (1998)**, these results suggest an absence of extreme dominance by any one species in most sampling sites. Higher dominance, such as observed at station 5 period III, may indicate resource competition or environmental stress **(Sirait *et al.*, 2018)**.

Correlation between phytoplankton abundance and water quality

The Pearson correlation analysis (Table 5) revealed the following relationships between phytoplankton abundance and selected physicochemical parameters:

- Nitrate and phosphate showed a positive but very weak correlation, indicating that although these nutrients support growth, their influence was minimal during the study period.
- pH had a positive and strong correlation, suggesting it significantly affects phytoplankton abundance.
- Temperature showed a positive and moderate correlation, aligning with its known role in influencing metabolic and reproductive rates.

Conversely, total dissolved solids (TDS) exhibited a very weak negative correlation with phytoplankton abundance (P= 0.544), indicating no statistically significant relationship. This may be due to the short duration of the study, which may not have captured seasonal TDS patterns or long-term ecological trends in Lake Ngade.

CONCLUSION

Phytoplankton abundance in Lake Ngade ranged from 23,649 to 212,181 cells·L^{-1}. The phytoplankton community consisted of 64 genera distributed across five classes: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, and Euglenophyceae. Ecological index values observed during the study included a diversity index (H') ranging from 0.9086 to 2.8132, an evenness index (E) ranging from 0.3542 to 0.8354, and a dominance index (D) ranging from 0.0900 to 0.5419. Based on the diversity index, Lake Ngade is classified as mesotrophic, indicating moderate fertility. These conditions suggest that the lake is ecologically suitable for fish farming activities.

ACKNOWLEDGMENTS

The author would like to thank to the Khairun University through the Higher Education Excellence Competitive Research Program (PKUPT) fund at the Faculty of Fisheries and Marine Science in 2023, with Agreement Letter Number: 03/PEN-PKUPT/PG.12/2023.

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