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Composition and Diversity of Algal Flora in Jahanara Imam-Pritilota Hall Sorobar (JP) Lake of Jahangirnagar University Campus, Savar, Dhaka, Bangladesh

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Authors' contributions

This work was carried out in collaboration between both authors. Author CD organized the research, conducted the statistical analysis, and drafted the manuscript. Author SNJ supervised the entire study's inspection and approved the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The study aimed to evaluate the composition and diversity of algae in the JP Lake of Jahangirnagar University campus. The research was carried out between the period of December 2021 to November 2022. A total of 72 water samples were used to carry out the investigation. Shannon and Simpson diversity indexes were used to determine the level of diversity. 234 phytoplankton species under 98 genera were found belonging to 8 classes (Cyanophyceae, Chlorophyceae, Bacillariophyceae, Synurophyceae, Euglenophyceae, Cryptophyceae, Dinophyceae, and Xanthophyceae). According to the generic percentage composition, Chlorophyceae comprised 46%, followed by Bacillariophyceae (20%) and Cyanophyceae (18%). At the species level, Euglenophyceae were found to dominate (34%) the studied sites that were followed by Chlorophyceae (31%) and Cyanophyceae (18%). The total density of phytoplankton was

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387.34×10^5 ind/l. The highest phytoplankton density was found in April, and the lowest one was in November. Cell dispersion was below average in May for Cyanophyceae, Bacillariophyceae, Cryptophyceae, and Synurophyceae. *Oscillatoria*, *Monoraphidium*, *Actinastrum*, *Cosmarium*, *Trachelomonas*, and *Euglena* dominated the surveyed region. The Shannon Diversity Index (H) showed a value of 1.51, while Simpson's Diversity Index (D) showed a value of 0.28. The overall variation (80.73%) among the classes was represented by PCA cells. According to the Shannon and Simpson Diversity Indexes, the diversity was low.

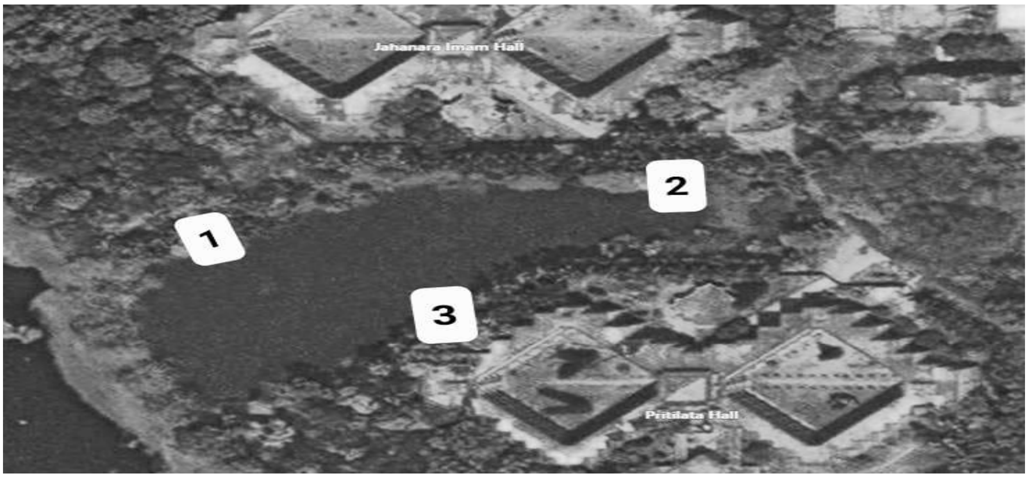
Keywords: Algal diversity; phytoplankton density; dominant phytoplankton; principal component analysis (PCA).

1. INTRODUCTION

The most crucial element in forming the landscape and controlling the climate is water. It is regarded as one of the most important compounds that affect life. There are very few instances of natural lakes or genuine lakes in Bangladesh [1]. The variety of phytoplankton reacts very quickly to shifts in the aquatic environment, particularly in connection to the availability of nutrients [2]. There are many different taxonomic classes of unicellular and colonial species that make up the complex group known as phytoplankton. These organisms have a wide range of morphological and color variations and usually float with the movement of water. The quality of the water, as well as the number and variety of phytoplankton and zooplankton, are directly impacted by human activity, urbanization, and industrialization. Aquatic ecosystems are exceptional examples of ecological communities since their surrounding environments are in constant flux [3]. In freshwater and marine water ecosystems, plankton diversity was considered a crucial ecological parameter [4]. The possibility of light deprivation challenges the phytoplankton, which results in diatom predominance. In contrast, during the rainy season, the shallow mixed layer has a lower Zm: Zeu ratio, favoring high-light-adapted phytoplankton such as green algae and cyanobacteria. [5]. Because algae respond rapidly to changes in water conditions, both in terms of the species makeup of their populations and the densities of those populations, algae are valuable indicators of the state of the ecosystem [6]. The use of various multivariate statistical techniques, such as principal component analysis (PCA), facilitates the interpretation of complex data matrices in order to better understand the water quality and ecological status of the studied systems, enables the identification of potential factors/sources that influence water systems, and provides a useful tool for the reliable management of water resources as well as the quick resolution of contamination issues [7]. In order to assess the condition of an aquatic ecosystem, it is necessary to consider the correlation between the species diversity indices and the levels of pollution in the water bodies. The overall ecological picture of the research region can be expressed by comparing the amount and quality of phytoplankton across sites and seasons [8]. The soil of the campus of Jahangirnagar University is a reddish-brown color, and the majority of the water bodies in this region are highly turbid due to the presence of silt, sand, and clay, which appears to result in poorer primary production [9]. The purpose of this research was to identify monthly and seasonal variations in the phytoplankton composition of Jahanara Imam Pritilota hall sorobar lake on the Jahangirnagar University campus, Savar, Dhaka, Bangladesh.

2. MATERIALS AND METHODS

The experiment was conducted at Jahangirnagar University's JP lake (Jahanara Imam-Pritilota Hall Sorobor) from December 2021 to November 2022. The lake was selected due to its biodiversity (Fig. 1). A Schindler's Sampler with a 5 L capacity was used to gather water samples from 50 cm depth in the lake's coastal zone. The sampler was submerged in water gradually before being retrieved. The water was then transferred to a 5-litre black plastic carboy for analysis. Each water sample was treated with Lugol's iodine solution and left to settle for 48 hours to assess the phytoplankton's number and quality. Phytoplankton cells were counted using a Hawksley microplankton counting chamber with a modified Neubauer Ruling (Hawksley Ltd., Lancing, UK) and a 400 Nikon compound microscope (Japan). Phytoplankton dispersion patterns were reported during the studied period. The sedimented phytoplankton material was randomly checked for identification to the species level under high magnification before the



JP-Lake

Fig. 1. Photograph (satellite view) of the studied lake

individual phytoplankton count was performed. Algal pieces of literature, Bangladeshi publications, international monographs, and books were studied for identification [1,10–15]. The following seasons [16] were considered: summer (March to May), monsoon (June to early October), autumn (late October to November), and winter (December to February).

The Shannon index was calculated with the following equation: $H = \sum[(P_i) \times ln(P_i)]$. Where, H: The Shannon Diversity Index; S: The total number of unique species; P_i= The proportion of the entire community made up of species i. The greater the value of H, the greater the species diversity in a given community. The lower the value of H, the less diverse the population. A value of $H = 0$ represented a community with a single species. The Shannon Equitability Index was a method for measuring the diversity of a community's species. The term "evenness" refers to the degree to which the abundances of different species in a community are comparable [17]. This index, denoted E_H, was calculated as follows: $E_H = H/\ln(S)$. The Simpson's Diversity index was calculated with the following equation: $D = \sum n_i(n_i - 1)/N(N - 1)$. Where, n_i : The number of organisms that belong to species i; N: The total number of organisms. Simpson's Diversity Index has a range between 0 and 1. The greater the value, the less diverse the population. As this interpretation was somewhat counterintuitive, Simpson's Index of Diversity (sometimes referred to as a Dominance Index) was calculated as $1 - D$. The greater the value of this indicator, the greater the variety of species. Calculation of the reciprocal index of Simpson, which was $1/D$. This index had a minimum value of 1 and a maximum value equal to the number of species [18]. Across the research period, the average cell density of the phytoplankton classes was represented. At JP lake, a heatmap of phytoplankton classes was utilized to report data for the chosen month. From December 2021 to November 2022, monthly observations of phytoplankton cell densities were made in the surface waters of JP Lake using principal component analysis (PCA). Phytoplankton classes found during the four seasons were also presented. Finally, Excel and R programming languages (4.2.2) were used to calculate and represent the dominant phytoplankton species in different months.

3. RESULTS AND DISCUSSION

3.1 Composition of Phytoplankton

234 phytoplankton species belonging to 98 genera and eight classes were found at the selected site in this investigation. These included Chlorophyceae (genus-45, species-72), Bacillariophyceae (genus-19, species-23), Cyanophyceae (genus-18, species-43), Euglenophyceae (genus-6, species-80), Cryptophyceae (genus-5, species-10), Dinophyceae (genus-1, species-2), Synurophyceae (genus-1, species-1), Xanthophyceae (genus-3, species-3) (Fig. 3, Fig. 4a and Fig. 4b). During the present research period, Chlorophyceae was found to dominate the studied sites and occupied 46% of the total area according to the generic percentage composition, followed by Bacillariophyceae (20%), Cyanophyceae (18%), Euglenophyceae (6%), Cryptophyceae (5%), Xanthophyceae

(3%), Synurophyceae (1%), and Dinophyceae (1%) (Fig. 2). On the other hand, Euglenophyceae inhabited 34% at the species level, followed by Chlorophyceae (31%), Cyanophyceae (18%), Bacillariophyceae (10%), Cryptophyceae (4%), Xanthophyceae (1%), Synurophyceae (1%), and Dinophyceae (1%), among others (Fig. 2). The class with the highest mean was Euglenophyceae (9.11), followed by Cyanophyceae (6.18), Chlorophyceae (5.64), and Dinophyceae (3.05). The class with the lowest mean was Synurophyceae (1.04), followed by Xanthophyceae (1.41) and Cryptophyceae (2.53). Overall, each class had a wide range of values, with some classes having a more extensive range (e.g., Euglenophyceae) than others (e.g., Synurophyceae) (Table 1).

In the present study, Xanthophyceae, Synurophyceae, and Dinophyceae comprised a comparatively small proportion of the total algal group, despite a similar pattern having been observed in prior research on Lake Ashura's Limnology. Euglenophyceae (42.86%) similarly dominated the phytoplankton community regarding species diversity [1]. However, in the study of phytoplankton distribution characteristics and its relationship with bacterioplankton in Dianchi Lake, 29 species of Chlorophyta (34%) predominated at the species level [19]. Comparatively, in several freshwater wetlands and seasonal changes of phytoplankton flora of freshwater wetlands in the larger Dhaka district, the number of genera for the Chlorophyceae family was the most significant [20]. However, similar results were observed in the water bodies in the Dhaka Export Processing Zone (DEPZ), Savar, Dhaka, Bangladesh. The composition of these water bodies revealed that Chlorophyceae dominated the study locations, occupying 49% and 35.68%, respectively. In contrast, Chlorophyceae (43%) dominated at the species level. In several studied areas, the maximum phytoplankton densities were observed in the months of May and June, while the lowest densities were observed in the months of November and September [21].

Nearly similar types of genus and species were found in the limnological studies on Ramsagar, Dinajpur, Bangladesh [15]; in some estuaries from Ratnagiri district of Maharashtra (India) by Nivrutti Dhumal & Baburao Sabale, 2014 [3]; in Turag River of Bangladesh [8]; in the chapter of the Xanthophyte, Eustigmatophyte, and Raphidophyte Algae [22]; in the study of an ice-free high Arctic fjord (Adventfjorden, West Spitsbergen) [23]; in the limnological studies of lake Ashura [1]; and in a lake on the Jahangirnagar University campus, both of which are located in Bangladesh [2] and in lake Bogakain, Bandarban, Bangladesh [24]. However, In Lake Bogakain, Bandarban, Bangladesh, both the number of species and the percentage of Euglenophyceae were the highest [24]. Two members of the Dinophyceae were also found in Lake Ashura, Bogakain, and in angiospermic records for Bangladesh [1,14,24].

At Sulur Lake, in the phytoplankton biodiversity in the two perennial lakes of Coimbatore, Tamil Nadu, India, the groups Chlorophyceae were also found to be predominant with 44%, followed by Cyanophyceae (27%), species of Bacillariophyceae (25%) and Euglenophyceae (4%) [4]. In the investigation of phytoplankton diversity and evaluation of water quality at Ongc Pond, Hazira in India, the Chlorophyceae group showed the highest percentage (52%) and Euglenophycae the lowest (4%) [25]. However, the phytoplankton species composition in Durankulak and Shabla-Ezeretz lakes was observed in algological investigations of Bulgarian coastal wetlands. Darunkulak Lake's phytoplankton had the highest species diversity (241 taxa). Phytoplanktons from the other lakes were analyzed, including 176, 161, and 162 species. Green algae comprised 61%, 55%, 53%, and 51% of the total lake biomass in the investigated lakes [26].

Table 1. Comparison of phytoplankton densities among the classes

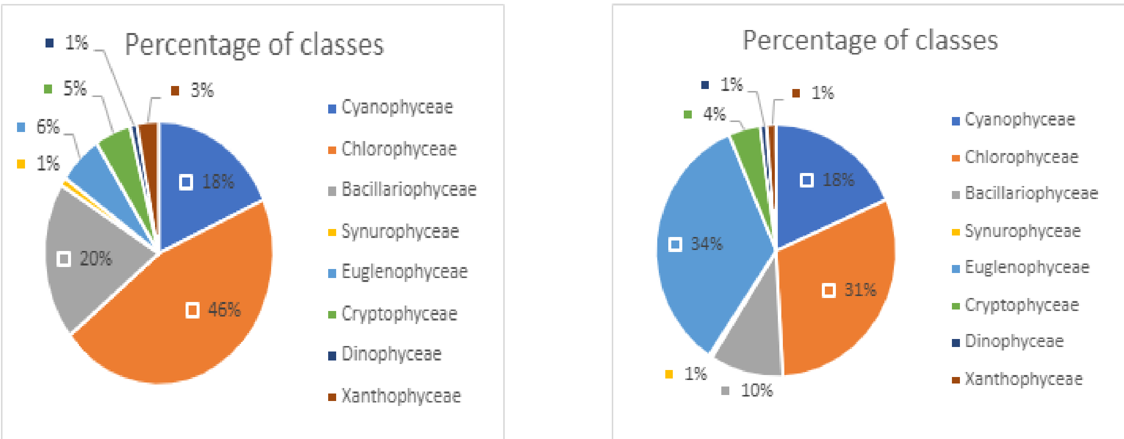
Class	Min	1st Qu.	Median	Mean	3rd Qu.	Max
Cyanophyceae	1.90	3.55	6.47	6.18	7.08	13.50
Chlorophyceae	2.37	4.86	5.57	5.64	6.80	8.93
Bacillariophyceae	1.62	2.59	3.31	3.32	4.09	4.99
Euglenophyceae	3.39	4.24	6.34	9.11	11.00	24.71
Cryptophyceae	0.94	1.91	2.60	2.53	3.15	4.12
Dinophyceae	1.12	1.46	2.37	3.05	3.92	8.67
Synurophyceae	0.10	0.97	1.17	1.04	1.27	1.85
Xanthophyceae	0.21	1.02	1.12	1.41	1.43	4.80

The study of reservoir phytoplankton species composition and relative dominance in Sri Lanka: indicators of environmental quality concluded that at the generic level, Chlorophyceae and Cyanophyceae contributed 27.3% each, whereas Zygnemaphyceae contributed 15.9%, Diatomophyceae contributed 13.6%, Euglenophyceae contributed 4.5%, Xanthophyceae contributed 4.5%, Dinophyceae contributed 3.4%, Crytophyceae contributed 2.3%, and Chrysophyceae accounted for 1.1%. In terms of species, Zygnemaphyceae dominated with 34%, followed by Chlorophyceae with 24%, Cyanophyceae with 21.5%, Diatomophyceae with 8.5%, Euglenophyceae with 4.5%, Xanthophyceae with 3.0%, Dinophyceae with 2.5%, Crytophyceae with 1.5%, and Chrysophyceae with 0.5% [27]. However. the analysis of phytoplankton distribution, biomass, and diversity within and between Pantanal wetland habitats in Brazil, revealed that Cyanobacteria, Chrysophyceae, and Chlorophyceae were the most abundant algal groups, with mean values of 1761, 423, and 273 ind mL-1, respectively [28]. In a study of the phytoplankton community structure and water quality in an ecological restoration area of Baiyangdian Lake, China, Chlorophyta and Bacillariophyta were found to have the highest species richness of the total phytoplankton (66 species; 46.2%) and Bacillariophyta (28 species; 19.6%), respectively [29].

3.2 Dispersion of Cell Densities

Here in Fig. 5, the phytoplankton density of the Cyanophyceae (8.3×10^5 ind/l), Bacillariophyceae (4.4×10^5 ind/l), and Xanthophyceae (2.01×10^5 ind/l) were highest during the monsoon and lowest throughout the summer (2.98×10^5 ind/l), winter (2.05×10^5 ind/l), and autumn (0.42×10^5 ind/l). The highest phytoplankton density was recorded by the Chlorophyceae (7.63×10^5 ind/l) and Euglenophyceae (17.3×10^5 ind/l) in the summer (2.7×10^5 ind/l) and the lowest in the autumn (3.72×10^5 ind/l). The phytoplankton density was highest for Cryptophyceae (3.84×10^5 ind/l), Dinophyceae (6.06×10^5 ind/l), and Synurophyceae (1.43×10^5 ind/l) in the winter and lowest during the monsoon (1.7×10^5 ind/l), summer (1.3×10^5 ind/l), and autumn (0.19×10^5 ind/l) (Fig. 5). In the present research, the total phytoplankton density was 387.34×10^5 ind/l. The highest phytoplankton density was found in April (43.84×105 ind/l), and the lowest was in November (20.48×10^5 ind/l).

The distribution of cell densities was illustrated in the graph (Fig. 6) by displaying the densities below and above the average using a discrete color range. Clustering dendrograms of chart cells were displayed on the JP lake chart (Fig. 7), which appeared to the left and right of the heatmap. According to the levels of expression, the colors were subdivided and grouped. The Euglenophyceae, Bacillariophyceae, Synurophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Cryptophyceae, and Xanthophyceae groups were all prominent at various times throughout the period. Cluster analysis allowed for comparing two or more samples based on their underlying functional differences, while the heatmap helped visualize changes in the abundance of individual taxa [19], [30].



At the generic level — At the species level

Fig. 2. Percentages of different classes

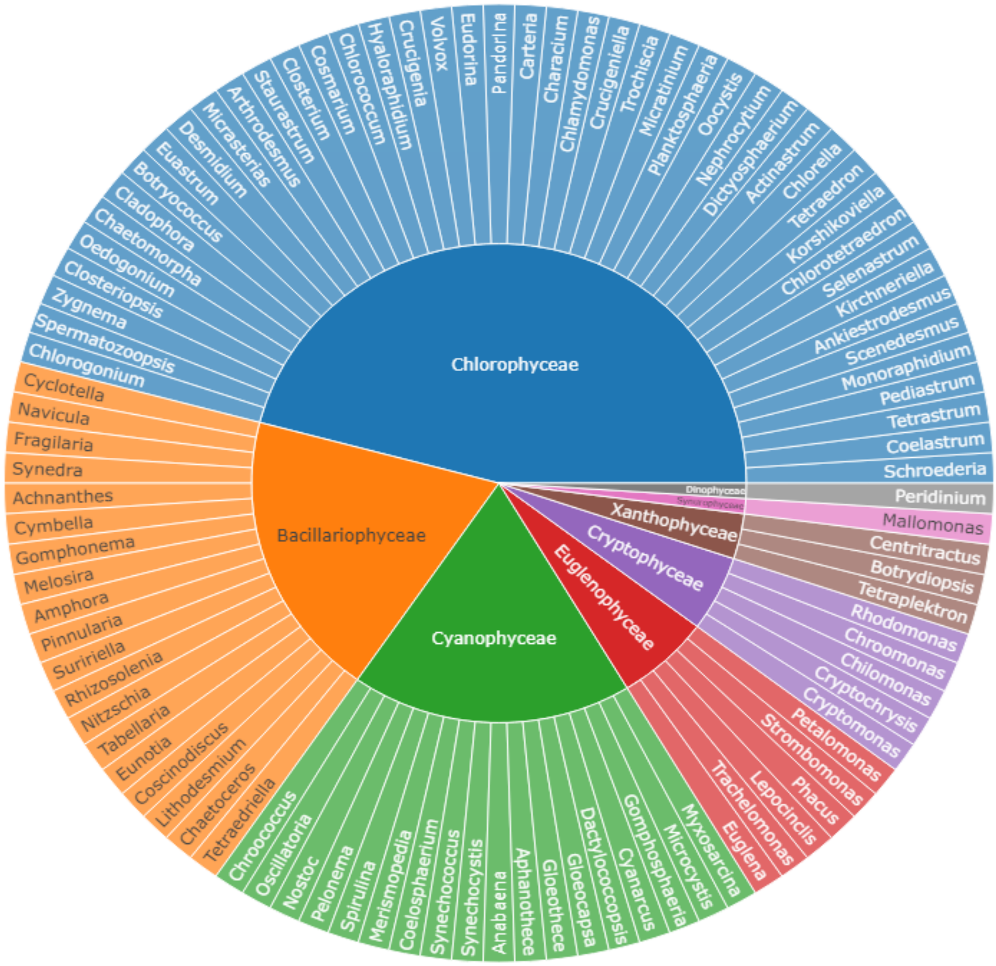
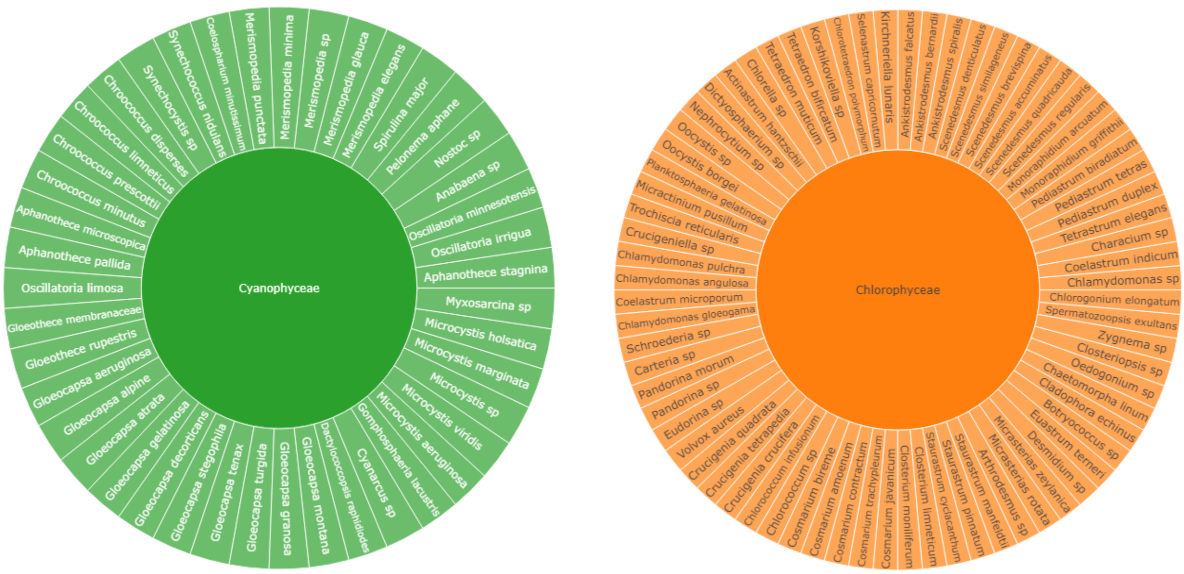


Fig. 3. Total phytoplankton genera found in the studied lake



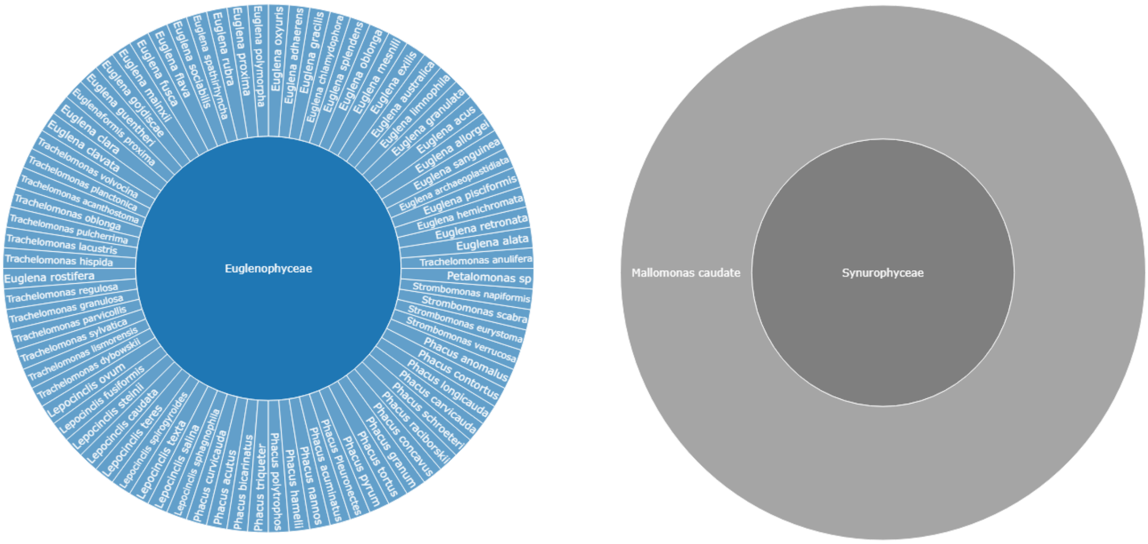


Fig. 4a. Total phytoplankton species found in the studied lake (cont.)

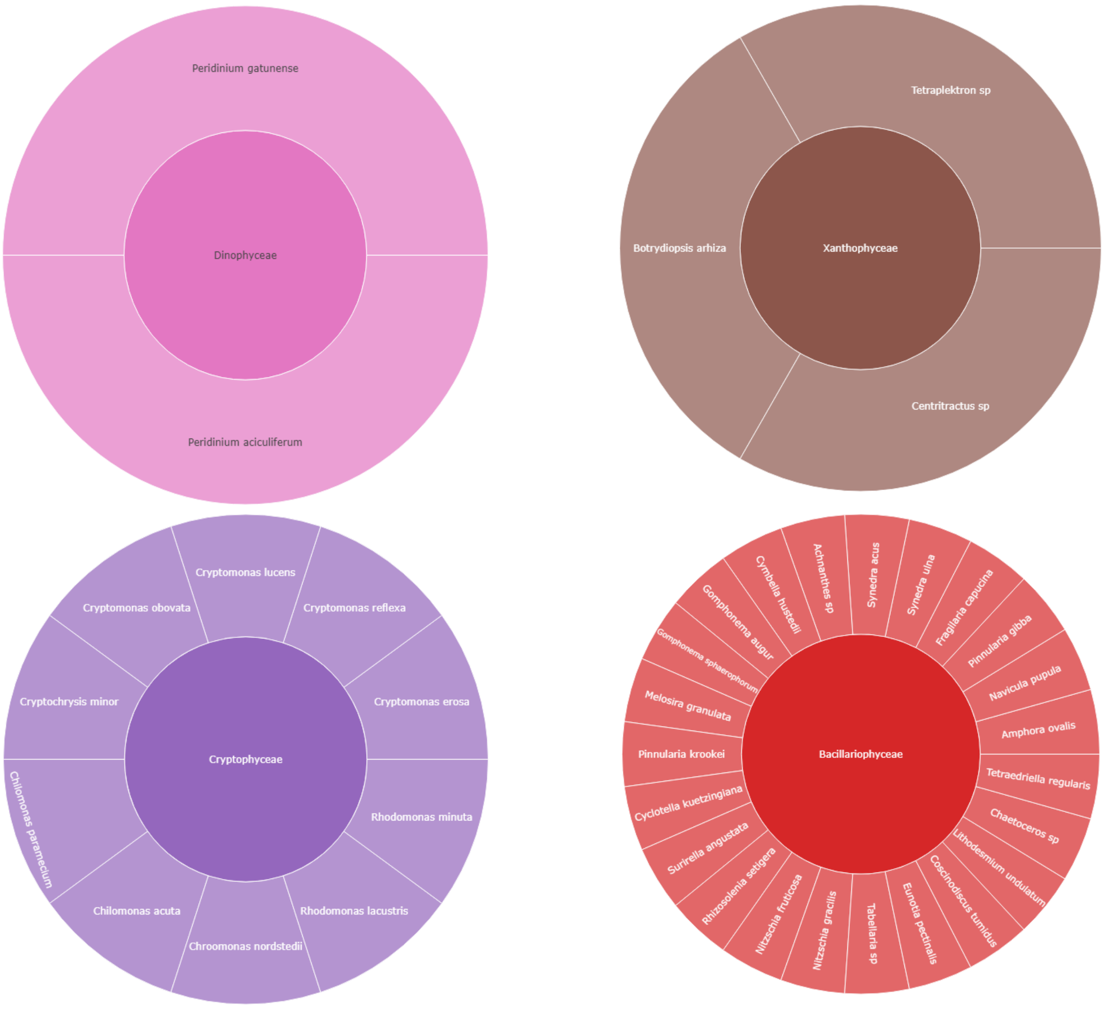


Fig. 4b. Total phytoplankton species found in the studied lake

The highest value for above-average cell density was observed for Cyanophyceae in August, whereas the class Cyanophyceae appeared to be more prevalent in July (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Chlorophyceae in March, as well as the class Chlorophyceae appeared to be more prevalent in March (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Bacillariophyceae in June, also the class Bacillariophyceae appeared to be more prevalent in June (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Euglenophyceae in May, whereas the class Euglenophyceae appeared to be more prevalent in April (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Cryptophyceae in December, also the class Cryptophyceae appeared to be more prevalent in December (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Dinophyceae in January, whereas the class Dinophyceae appeared to be more prevalent in February (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Synurophyceae in February, also the class Synurophyceae appeared to be more prevalent in February (Fig. 6 and Fig. 7). The highest value for above-average cell density was observed for Xanthophyceae in March, whereas the class Xanthophyceae appeared to be more prevalent in August (Fig. 6 and Fig. 7).

Comparable to the present study, it was found that the phytoplankton biodiversity in the two perennial lakes of Coimbatore, Tamil Nadu, India, varied seasonally, with the lowest population density occurring from September to November 2012 to the highest value observed from March to May 2013 [4]. Conversely, the total phytoplankton density was 163.53×10^4 ind/l, according to limnological notes on Ramsagar, Dinajpur, Bangladesh [15]. Similarly, it was found that euglenoid algae predominated in the phytoplankton flora of Lake Ashura [1]. However, physio-chemical conditions and the plankton population of two fishponds in Khulna showed that Cyanophyceae and Euglenophyceae were abundant in April and May. Moreover, Bacillariophyceae showed the highest values in September and October [31]. The highest density of Cyanophyceae occurred in July at 52.85×10^6 ind/l in the seasonal variation of Dharma Sagar water quality in Comilla [32]. In the Karkamis Dam Lake in Sanliurfa, Turkey, Cyanophyta species were typically observed during the spring and summer but in much smaller numbers during the fall and winter.

Likewise, most members of Chlorophyta were detected throughout the summer months. Species diversity of Bacillariophyta was most significant in spring, followed by summer, and lowest in winter and fall [33]. Similar results were observed for Euglenophyta throughout the summer in the spatial and temporal distribution of phytoplankton in Turkey [33], as well as in the Balikli dam reservoir in Turkey, where Euglenophyta was represented by 7 species and made up 12.72% of all taxa in the summer (May) [34]. This seemed to be consistent with the results of this investigation. A variety of taxa, primarily those belonging to the Dinophyceae and Cryptophyceae, composed the winter communities observed during the polar night and the early spring (17 January - 16 April and 15 November - 13 December, respectively) [23]. During the spring, synurophytes frequently predominated the phytoplankton biomass, although other studies had shown that their maximum concentrations occurred at temperatures below 12 °C [35]. The highest diversity of phytoplankton occurred during the pre-and post-monsoon months at all sites studied in the seasonal variation and species composition of the Ganga river and its tributary in the Garhwal Region of Uttarakhand, India. While Bacillariophyceae were most frequently observed in the pre-monsoon and winter months in several studied sites, Chlorophyceae showed the greatest diversity of phytoplanktons during summer. Depending on the studied sites, Cyanophyceae were more frequently observed during the summer, pre-monsoon, and post-monsoon seasons. However, Xanthophyceae and Euglenophyceae members were seldom found [36]. The analysis of fresh records of *Vaucheria* species (Xanthophyceae) with related *Proales werneckii* (Rotifera) from North America, however, revealed that Xanthophyceae were discovered between September and January [37,38].

Chlorophyceae, Bacillariophyceae, Euglenophyceae, Cryptophyceae, and Dinophyceae exhibited similar seasonal trends in the water bodies surrounding the Dhaka export processing zone (DEPZ), Savar, Dhaka, Bangladesh, except for Cyanophyceae, whose density was highest in summer. Phytoplankton density was also found to change with the seasons and between different study locations [21]. In October, carbon sequestration capability in an urban river was highest for the Cyanophyceae and Chlorophyceae communities, whereas the class Bacillariophyceae was constant throughout the year [39]. In terms of diatom distribution, the maximum and lowest values were recorded in November 2007 and March 2007, respectively. In September 2007, the most significant quantity of dinoflagellates and euglenophytes was observed. January 2007 was the month in which the greatest number of cyanophytes were recorded [39]. However, the analysis of phytoplankton composition with a focus on Cyanobacteria and their toxins as an indicator of the ecological status of Lake Vaya (Bulgaria) revealed a trend of phytoplankton abundance (numbers, biovolume) and structure changes. In spring, chlorophytes predominated in both portions of the lake, while cyanobacteria dominated during July (Summer) and September (Autumn). In July and September, the eastern diatom species that dominated in May and June were better represented in the west, whereas their eastern biovolume dropped. Euglenophytes, diatoms, and chlorophytes were abundant and varied depending on the eastern and western parts of the lake in June [40].

3.3 Diversity Index

Shannon Diversity Index (H) : 1.51, Shannon Equitability Index (E_H): 0.73, Simpson's Diversity Index (D): 0.28, Dominance Index $(1 - D)$: 0.72, and Simpson's Reciprocal Index $(1/D)$: 3.54 were the values for the genus numbers (Fig. 8). And Shannon Diversity Index (H): 1.52, Shannon Equitability Index (E_H) : 0.73, and Simpson's Diversity Index (D) : 0.25, Dominance Index $(1 - D)$: 0.75, Simpson's Reciprocal Index $(1/D)$: 3.94 were the values for the species numbers (Fig. 8). The Shannon diversity value was 1.51 on a scale from 1 to 4. According to the Shannon formula, the diversity level was low (< 2 = poor diversified; 2-3 = moderately diversified; and >3 = highly diversified). Simpson diversity index was 0.25 when the data were observed and calculated, with a range of 0 to 1. Thus, the diversity was poor and lowest during the studied period (0= poor diversified; 0.5= moderately diversified; and 0.8 -0.9 = highly diversified).

Indexes of diversity for Cyanophyceae were calculated as follows: Shannon diversity Index (H) = 1.33, the Shannon Equitability Index (E_H) = 0.96, the Simpson's Diversity Index (D) = 0.25, and the Dominance Index $(1 - D)$ = 0.76. The Chlorophyceae's diversity index values were as follows: Shannon Diversity Index (H) = 1.33, the Shannon Equitability Index (E_H) = 0.96, Simpson's Diversity Index (D) = 0.24, and the Dominance Index $(1 - D)$ = 0.76. For the Bacillariophyceae, the following numbers were provided for the diversity index: the Shannon Diversity Index (H) = 1.35, the Shannon Equitability Index (E_H) = 0.97, Simpson's Diversity Index (D) = 0.21, and the Dominance Index $(1 - D)$ = 0.79. Indexes of diversity for Euglenophyceae were reported as follows: Shannon Diversity Index (H) = 1.23; Shannon Equitability Index (E_H) = 0.88; Simpson's Diversity Index (D) = 0.32; and Dominance Index $(1 - D)$ = 0.68. The Shannon Diversity Index (H) for the Cryptophyceae = 1.33, the Shannon Equitability Index (E_H) = 0.96, Simpson's Diversity Index (D) = 0.20, and the Dominance Diversity Index $(1 - D)$ = 0.80. For the Dinophyceae, the following numbers were provided for the diversity index: Shannon Diversity Index (H) = 1.20, Shannon Equitability Index (E_H) = 0.87, Simpson's Diversity Index (D) = 0.29, and the Dominance Index $(1 - D)$ = 0.71. The findings for the diversity indexes of Synurophyceae were as follows: Shannon Diversity Index (H) = 1.23; Shannon's Equitability Index (E_H) = 0.89; Simpson's Diversity Index (D) = 0.07; and Dominance Index $(1 - D)$ = 0.93. The following diversity index values were provided for the Xanthophyceae: Shannon Diversity Index (H) = 1.27, the Shannon Equitability Index (E_H) = 0.91, Simpson's Diversity Index (D) = 0.13, and Dominance Index $(1 - D)$ = 0.87. Bacillariophyceae showed the greatest Shannon-Wiener Index values (H = 1.35), while Dinophyceae showed the lowest values (H = 1.20). Bacillariophyceae reported the most evenness (0.97), whereas Dinophyceae reported the least (0.87). Overall, the results showed a higher and more consistent level of phytoplankton evenness.

Algal flora of the water bodies in Dhaka Export Processing Zone (DEPZ), Savar, Dhaka, Bangladesh, showed similar indices variability ranges [21]. The study of certain estuaries in Ratnagiri district, Maharashtra, India, revealed a relative range of (1.279–1.681). The Shannon diversity index was associated with the number of species and their abundance, and the diversity was measured by the Shannon index (H), which combined species richness and evenness [3]. However, it was found that Euglenophyta had the highest Shannon-Wiener Index values (1.53). In contrast, Cyanophyta had the lowest values

(1.46) in a study of the effects of physico-chemical parameters on the composition and abundance of phytoplankton in the Ajiwa Reservoir in Katsina State, Northwestern Nigeria. The study's chosen water body showed a Shannon-Weiner diversity index ranging from 1.46 to 1.53. As a result, this body of water fluctuated between being mildly and severely polluted. The most uniform distributions were found in the Euglenophyta (0.93 and 0.86, respectively), whereas the least uniform was found in the Cyanophyta. Also, species were evenly abundant throughout the survey [41].

Nearly identical variations in phytoplankton quantity and structure as a measure of water quality were found in the Teera Drain of the Burullus Lagoon on the southern Mediterranean coast of Egypt [6]. However, the high diversity of the phytoplankton assemblage might be the result of favorable ecological conditions for its growth, according to Simpson's diversity index (D) (0.93) in the research of phytoplankton assemblage concerning water quality in the Turag River of Bangladesh [7]. In the distribution of phytoplankton diversity and abundance in the Mahakam Delta, East Kalimantan, the maximum Shannon-Wiener index values ranged from 2.09 to 1.15, indicating a moderately stable community. Additionally, its ST4 value of 0.9 was classified as an unstable community. Conversely, the Simpson (dominance) index ranged from 0.18 to 0.48. The index ranged from 0-1, and the value was less than 0.5, indicating moderate dominance [42]. In a study of phytoplankton distribution and its relationship to the physico-chemical environment in a Turkish coastal lagoon, the annual mean values of the diversity index and evenness of Bacillariophyceae were calculated to be 2.21 and 0.83, respectively, while the values for Dinophyceae were 0.40 and 0.37 [39]. The Shannon diversity (2.25±0.15; 3.08±0.37) and Richness No (22.28±2.15; 31.14±2.24) in the studied ponds were slightly higher than those in the current studied lake, according to a comparison of physico-chemical parameters and the diversity of phytoplankton species in two perennial ponds in Tamil Nadu's Sattur region [43].

3.4 Correlation between Different Classes According to PCA Cells

There were four dimensions to the scree plot (Fig. 9a). The eigenvalues for each dimension were 4.056839e+00, 2.401320e+00, 1.541841e+00, and 2.100430e-31. The four dimensions were 5.071048e+01, 3.001651e+01, 1.927301e+01, and 2.625537e-30 in terms of variance. The cumulative percentages of variance for each dimension were 50.71048, 80.72699, 100.00000, and 100.00000 (Fig. 9; Table 2).

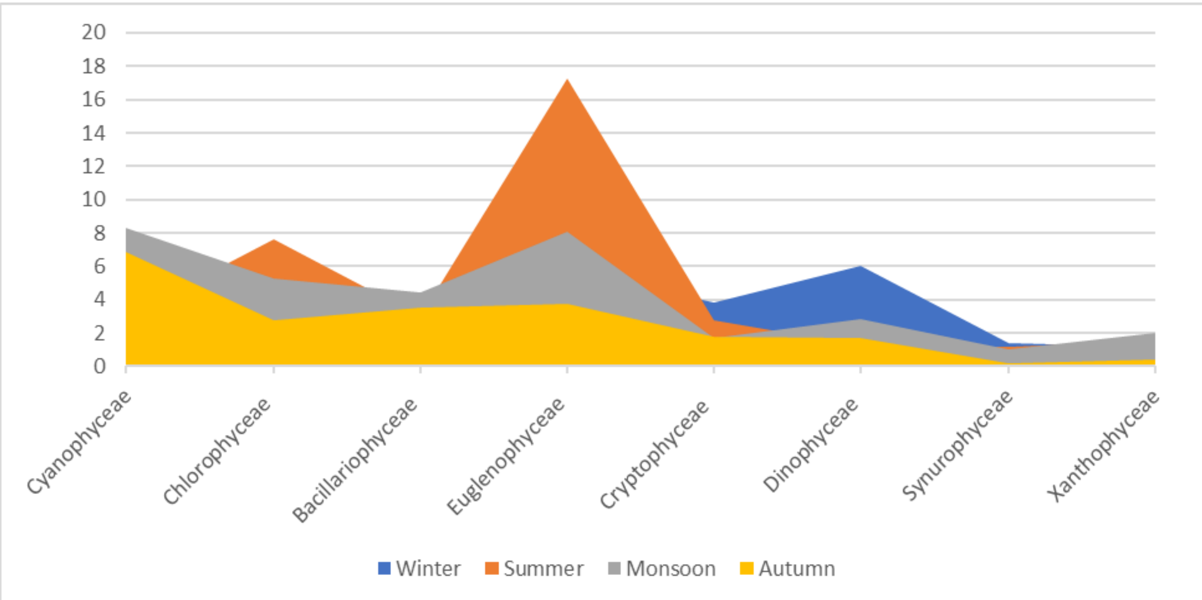


Fig. 5. Distribution of different phytoplankton groups during the four seasons studied

Fig. 6. The average cell density of phytoplankton classes during the studied months

The first two pcs of the dataset represented the most variation in standard deviation. Additionally, from cumulative proportion, the first two PCs expressed 80.73% of the total variation in the sample (Table 2). Similarly, in evaluating a phytoplankton risk matrix in drinking water supplies, the PCA accounted for 84.7% of the variability [44]. The first axis, in contrast, accounted for 30.5% of the total variance in a large tropical lake [5]. The PCA explained 73.18%, 77.61%, and 65.39% of the total variance in assessing surface water quality in the Fuji River basin, Japan [7].

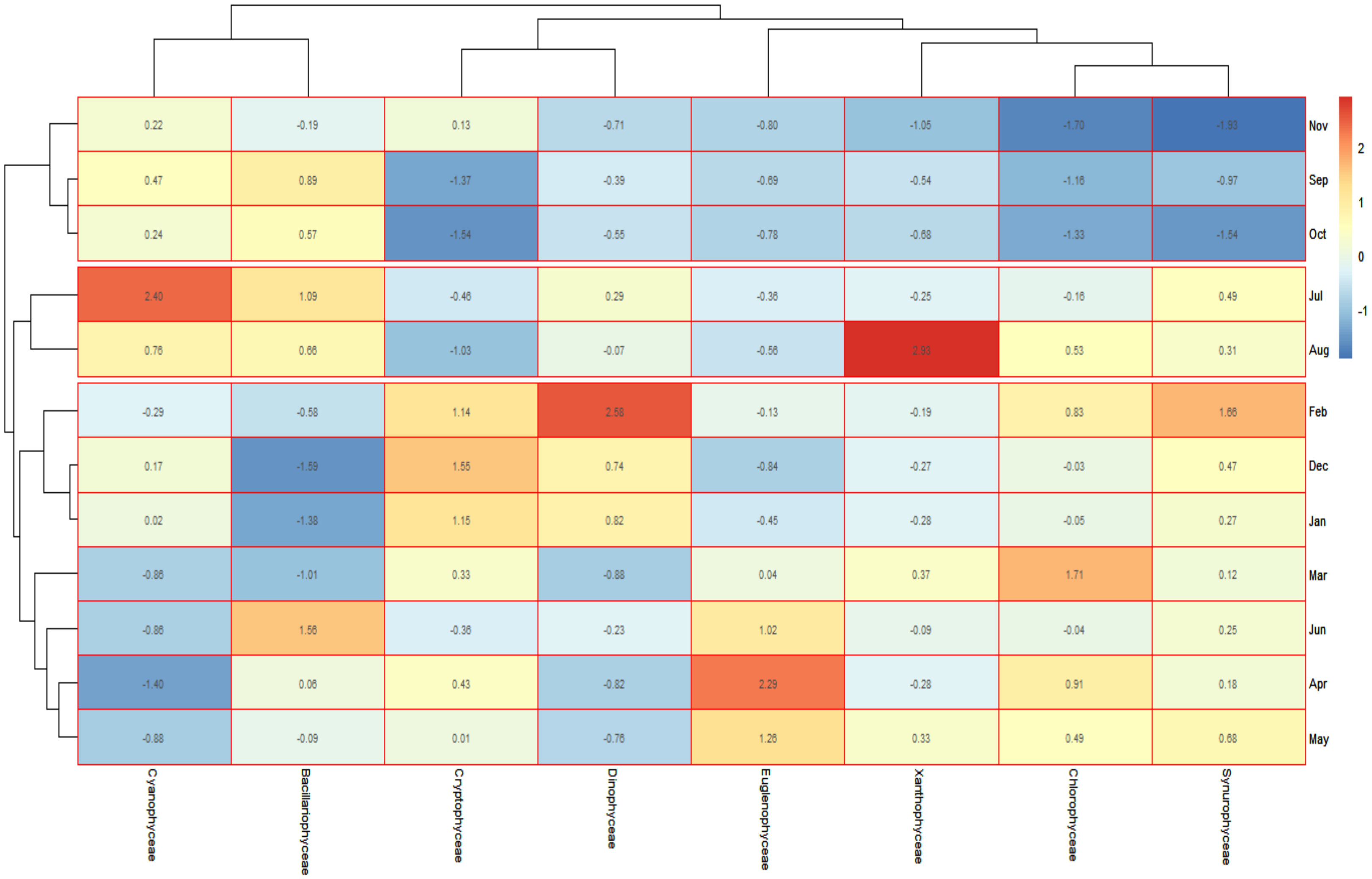


Fig. 7. Heatmap for phytoplankton classes during the studied period

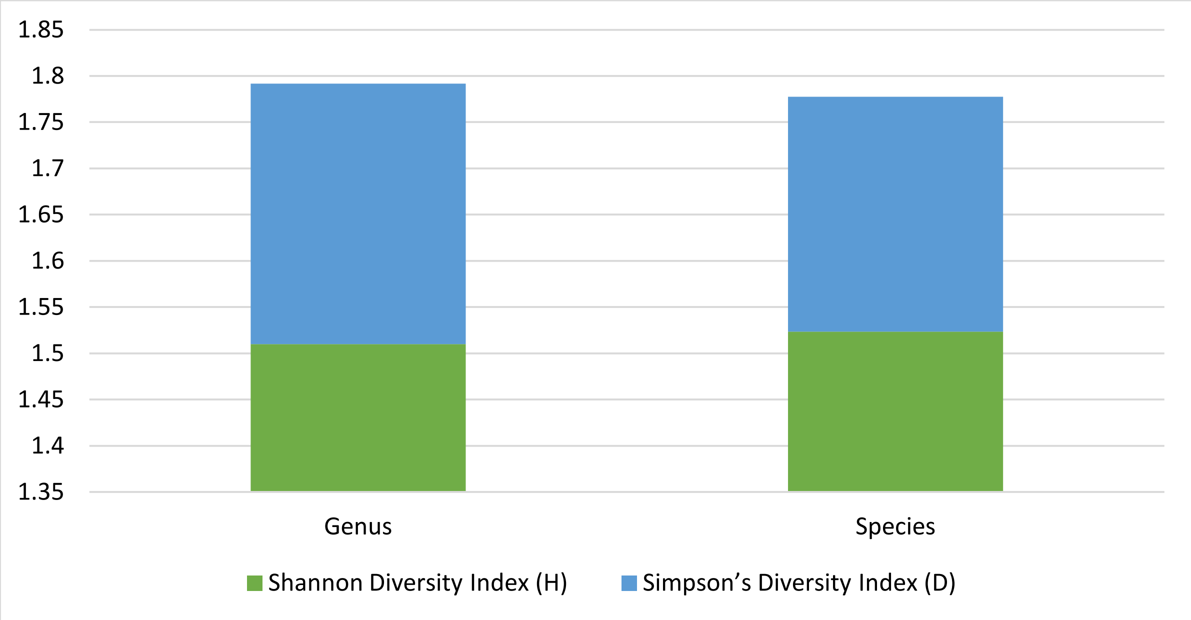


Fig. 8. Shannon diversity and Simpson's Diversity indices for the studied lake

Table 2. Importance of components

Principle components	Standard deviation	Proportion of Variance	Cumulative Proportion
PC1	2.0142	0.5071	0.5071
PC2	1.5496	0.3002	0.8073
PC3	1.2417	0.1927	1.0000
PC4	4.583e-16	0.000e+00	1.000e+00

Table 3. Calculation of each component's data

Class	PC1	PC2	PC3	PC4
Cyanophyceae	0.34	0.17	-0.53	0.7
Chlorophyceae	-0.46	-0.21	-0.07	0.32
Bacillariophyceae	0.33	-0.4	-0.32	-0.17
Euglenophyceae	-0.32	-0.46	0.18	0.47
Cryptophyceae	-0.42	0.36	0.07	0.16
Dinophyceae	-0.19	0.51	-0.38	-0.09
Synurophyceae	-0.44	0.02	-0.35	-0.26
Xanthophyceae	-0.21	-0.38	-0.54	-0.23

Chlorophyceae, Euglenophyceae, Cryptophyceae, Dinophyceae Synurophyceae, and Xanthophyceae showed negative contribution to PC1, while Cyanophyceae and Bacillariophyceae showed a positive contribution. In contrast to the positive contributions of Dinophyceae and Synurophyceae to PC2, Bacillariophyceae showed negative contributions (Table 3). According to the graph (Fig. 9), the items were shown as either row names or points. A series of arrows represented the variables. The scores were expressed as data points or sample identifiers. Each variable's score was defined as a deviation from its average. The variable vectors were shown as arrows (Fig. 9).

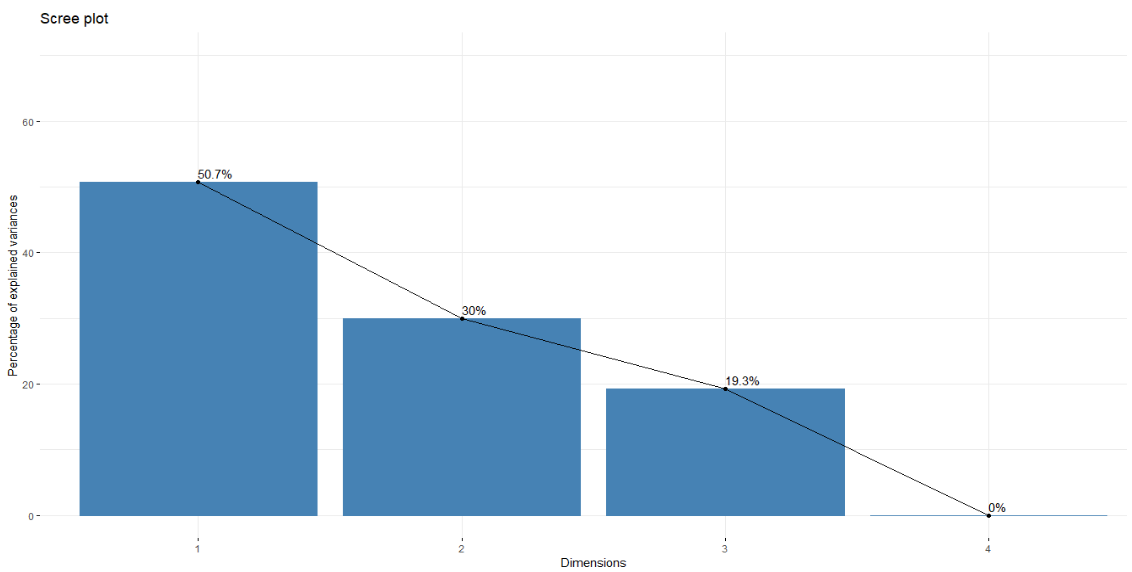
The separation between phytoplankton phyla was represented on the PCA by elongated vectors that pointed in the direction and had a certain amplitude [44]. The primary goal of the principal component analysis was to identify groups of study variables that adequately explained the underlying patterns in a given matrix [45]. Linear combinations of the original variables were transformed into new, independent indicators using this statistical technique called principal components [7,46]. To be statistically significant, an eigenvalue must be greater than 1 [45,47].

While Cyanophyceae exhibited a positive correlation with Bacillariophyceae and Dinophyceae, it showed a slightly negative correlation with other groups. Although it exhibited a negative correlation with certain other groups, Chlorophyceae exhibited a positive correlation with Euglenophyceae, Cryptophyceae, Dinophyceae, Synurophyceae, and Xanthophyceae. Cryptophyceae showed a slightly strong positive relation with Chlorophyceae, Euglenophyceae, Dinophyceae, and Synurophyceae, whereas it showed a negative correlation with Cyanophyceae, Bacillariophyceae, and Xanthophyceae (Fig. 9).

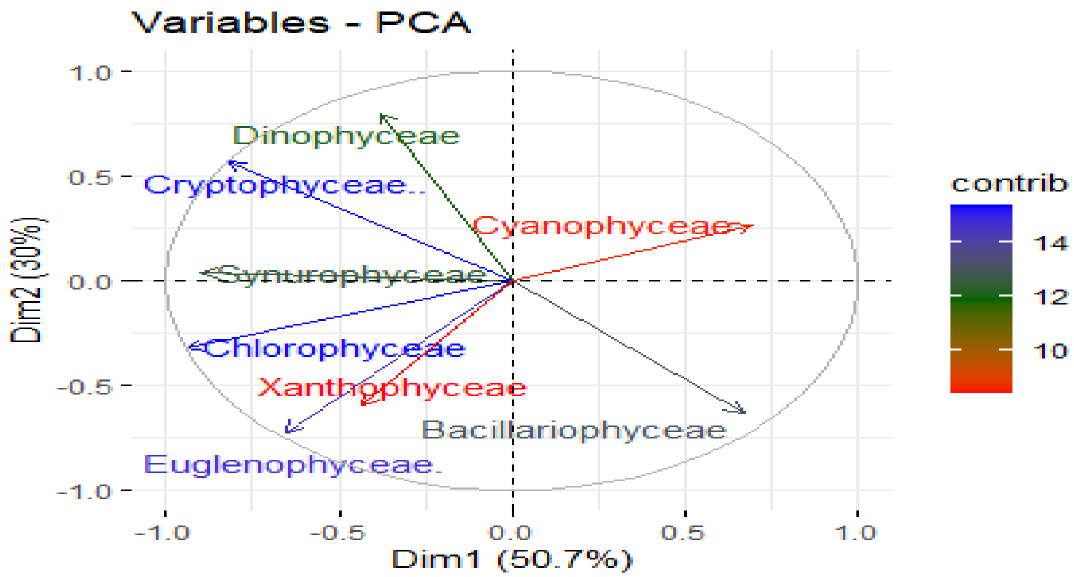
Bacillariophyceae showed a substantial positive correlation with Chlorophyceae in a study of the seasonal change of microalgae concerning the physico-chemical parameters of Karagam Lake in India. Similarly, it displayed a moderately positive connection with Cyanophyceae and Euglenophyceae [48]. In contrast, the importance of phytoplankton composition in the study of primary production in a large tropical lake revealed an inverse correlation between phytoplankton [5]. The distribution characteristics of the phytoplankton and their link to the bacterioplankton in Dianchi Lake, though, showed a similar positive correlation between the families Bacillariophyceae and Cyanophyceae as well as Chlorophyceae and Cryptophyceae [19]. It was found that three kinds of phytoplankton, including euglenoids, green algae, and diatoms, were well associated while studying the spatiotemporal effect of physicochemical factors on phytoplankton assemblage in a coastal brackish lagoon in the Caspian Sea in Iran [49]. Similarities were most noticeable in the most abundant group of phytoplankton, the Cyanophyceae [32,50,51]. At Santa Olalla, cyanobacteria were the dominant phytoplankton. Although the dominant cyanobacterial community was diversified, the species composition shifted with time. In addition, the proportion of cells from various species to total cyanobacteria varied substantially [52]. Compared to rivers, lakes had a higher biomass of cyanobacteria [53].

3.5 Dominant Phytoplankton and Their Densities in different Months

During the month of December, *Oscillatoria* (9.1×10^5 ind/l), *Carteria* (8.1×10^5 ind/l), *Monoraphidium* (6.03×10^5 ind/l), and *Trachlelomonas* (5.5×10^5 ind/l) were the most abundant phytoplankton in this lake. In the month of January, the most common blooms were *Monoraphidium* (8.6×10^5 ind/l), *Carteria* (7.03×10^5 ind/l), *Closterium* (6.3×10^5 ind/l), and *Scenedesmus* (5.81×10^5 ind/l). Species such as *Actinastrum* (66.5×10^5 ind/l), *Scenedesmus* (12.9×10^5 ind/l), *Monoraphidium* (9.54×10^5 ind/l), and *Trachlelomonas* (8.16×10^5 ind/l) dominated the environment in February. March was



(a)



(b)

Fig. 9. Principal component analysis (PCA) of phytoplankton cell densities observed monthly in the surface water of the studied lake from December 2021 to November 2022

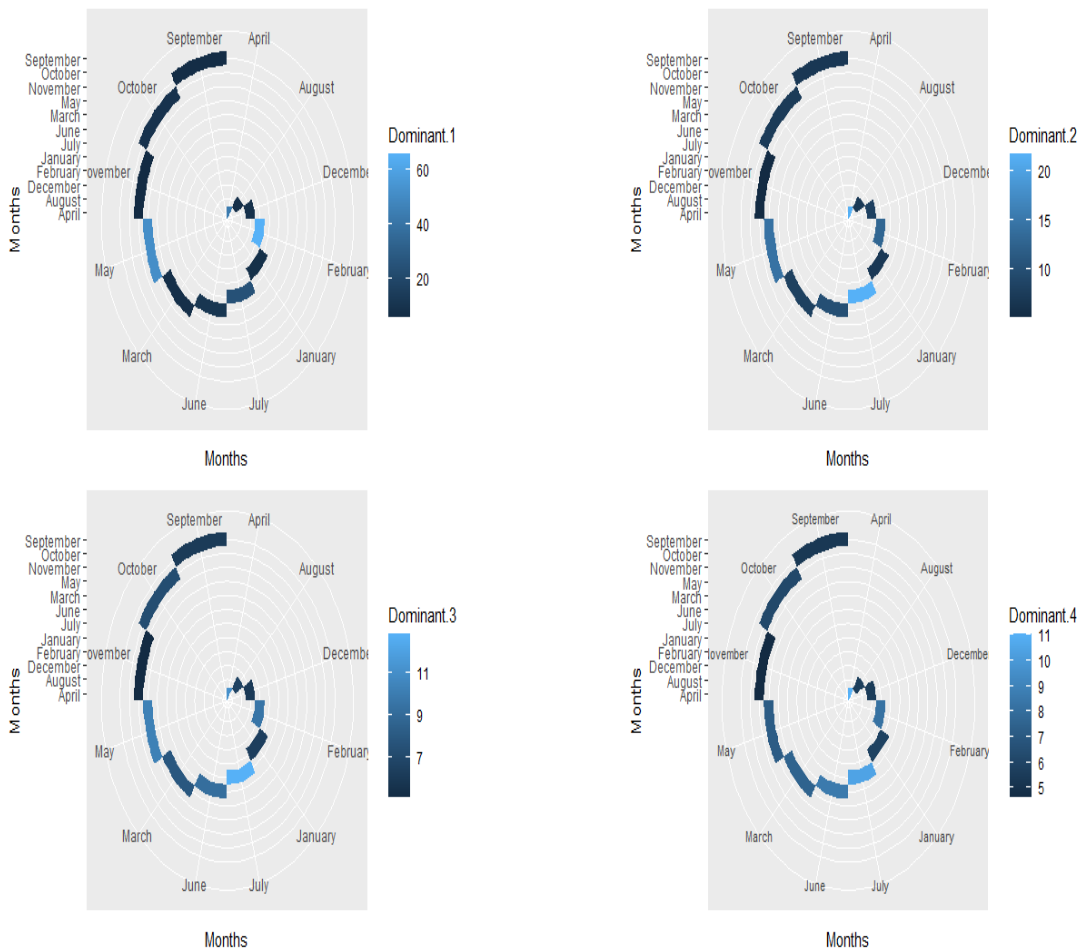


Fig. 10. Concentrations of dominant phytoplankton

dominated by *Cosmarium* (8.29×10^5 ind/l), *Carteria* (8.17×10^5 ind/l), *Monoraphidium* (7.83×10^5 ind/l), and *Euglena* (7.45×10^5 ind/l). In April, the most common species were *Trachelomonas* (43.15×10^5 ind/l), *Monoraphidium* (21.5×10^5 ind/l), *Actinastrum* (11.05×10^5 ind/l), and *Scenedesmus* (11×10^5 ind/l). *Trachelomonas* (51.27×10^5 ind/l), *Scenedesmus* (14.39×10^5 ind/l), *Actinastrum* (10.2×10^5 ind/l), and *Phacus* (7.13×10^5 ind/l) were abundant in May.

During the month of June, *Oscillatoria* (11.5×10^5 ind/l), *Trachlelomonas* (10.07×10^5 ind/l), *Pediastrum* (9.13×10^5 ind/l), and *Monoraphidium* (8.55×10^5 ind/l) were the most common. In July, the most common species were *Euglena* (24.78×10^5 ind/l), *Actinastrum* (21.65×10^5 ind/l), *Scenedesmus* (12.79×10^5 ind/l), and *Trachelomonas* (10.4×10^5 ind/l). Actinastrum (8.4×10^5 ind/l), *Monoraphidium* (7.09×10^5 ind/l), *Scenedesmus* (6.53×10^5 ind/l), and *Trachlelomonas* (5.6×10^5 ind/l) predominated in August. The month of September was dominated by *Oscillatoria* (7.25×10^5 ind/l), *Trachlelomonas* (6.91×10^5 ind/l), *Peridinium* (6.06×10^5 ind/l), and *Scenedesmus* (5.29×10^5 ind/l). In October, *Oscillatoria* (9.76×10^5 ind/l), *Pinnularia* (7.35×10^5 ind/l), *Euglena* (7.2×10^5 ind/l), and *Carteria* (6.15×10^5 ind/l) took precedence. In the month of November, the most common species were *Nostoc* (6.21×10^5 ind/l), *Phacus* (5.19×10^5 ind/l), *Pinnularia* (5.05×10^5 ind/l), and *Scenedesmus* (4.61×10^5 ind/l) (Fig. 10). *Trachelomonas* was found to be the second-longest taxon. *Peridinium* and *Scenedesmus* were the most common species in lake Bogakain, Bandarban, Bangladesh [24]. *Actinastrum* and *Scenedesmus* showed lower values in Lake Ashura, Dinajpur, Bangladesh (2.97×10^3 ind/l), while *Scenedesmus* exhibited lower values in Ramsagar (1.48×10^4 ind/l) [1,15]. Relative abundances of *Oscillatoria*, *Actinastrum*, *Scenedesmus*, *Trachelomonas*, *Euglena*, *Phacus*, *Pinnularia*, and *Synedra* were observed in the limnological research of lake Ashura, Dinajpur, Bangladesh [1]. *Scenedesmus* and *Oscillatoria* were found to grow excessively, indicating that the water bodies were being enriched with nutrients, according to a study on the effects of physico-chemical parameters on the composition and abundance of phytoplankton in the Ajiwa Reservoir in Katsina State, northwestern Nigeria [41]. Additionally, it was discovered that the phytoplankton biodiversity in the two perennial lakes of Coimbatore, Tamil Nadu, India, was dominated by *Oscillatoria*, *Scenedesmus*, *Pediastrum*, *Pinnularia*, and *Euglena* [4]. Similarly, *Scenedesmus*, *Pediastrum*, *Oscillatoria*, *Microcystis*, *Synedra*, *Euglena*, *Phacus*, *Trachelomonas,* and *Peridinium* dominated the species composition and relative dominance investigation of reservoir phytoplankton in Sri Lanka [27].

4. CONCLUSION

The lakes play a crucial role in maintaining biodiversity. Cell dispersion patterns were used in this study of the JP lake to demonstrate seasonal changes and monthly differences in the algal flora composition. The algal diversity in the studied lake was poor according to the diversity indexes. The principal component analysis demonstrated the close relationship between Chlorophyceae and Euglenophyceae. However, Chlorophyceae and Euglenophyceae were discovered to be prominent in the studied site. Thus, the present research revealed comprehensive information regarding the diversity of algal flora in the JP lake on the Jahangirnagar University campus.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Alfasane A, Gani A., Islam S, Khondker M. Limnology of lake Ashura, Dinajpur, Bangladesh. Bangladesh J Bot. 2012; 41(1):43–48.
2. Anny MF, Ara I. Plankton population and physico-chemical properties of a lake of Jahangirnagar University campus, Bangladesh at various lunar rhythms. Jahangirnagar University J. Biol. Sci. 2015; 4(2):31–36.
3. Dhumal SN, Sabale AB. Phytoplankton diversity, density and photosynthetic pigments with respect to hydrology of some estuaries from Ratnagiri district of Maharashtra (India). J. int. acad. res. multidiscip. 2014;393(2):219.
Available: www.jiarm.com

4. Manickam N, Bhavan P, Santhanam P, Muralisankar T, et al. Phytoplankton biodiversity in the two perennial lakes of Coimbatore, Tamil Nadu, India. Acta Ecologica Sinica. 2020;40(1):81–89. DOI: 10.1016/j.chnaes.2019.05.014
5. Darchambeau F, Sarmento H, Descy JP. Primary production in a tropical large lake: The role of phytoplankton composition. Sci. Total Environ. 2014;473–474:178–188. DOI: 10.1016/j.scitotenv.2013.12.036
6. El- Kassas H, Gharib S. Phytoplankton abundance and structure as indicator of water quality in the drainage system of the Burullus Lagoon, southern Mediterranean coast, Egypt. Environ Monit Assess. 2016; 188(9). DOI: 10.1007/s10661-016-5525-7
7. Shrestha S, Kazama F. Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. Environ Model Softw. 2007;22(4):464–475. DOI: 10.1016/j.envsoft.2006.02.001
8. Khatun M, Alam AKMR. Phytoplankton assemblage with relation to water quality in turag river of Bangladesh. Casp. J. Environ. Sci. 2020;18(1):31–45. DOI: 10.22124/cjes.2020.3977
9. Zaman L, Khondker M, Nabi Md. A comparative limnology of three ponds in Jahangirnagar University campus Physical and chemical aspects. Bangladesh J Bot. 1993;22:81–87.
10. Islam A, Khondker M. Euglenophyta of Bangladesh. I. Genus Trachelomonas Ehr. Internationale Revue der gesamten Hydrobiologie und Hydrographie. 1981;66: 109–125.
11. Islam AKMN, Begum ZT. Studies on the phytoplankton of the Dacca district. Order: Chlorococcales. J. Asiat. Soc. Pak. 1970; 15(3):227–271.
12. Islam A, Haroon AK, Khondker M. Limnological studies of the River Buriganga. 1. physical and chemical aspects. Dhaka Univ. stud., Part B Sci. 1974:99–111.
13. Khan Md, Hossain AMMM, Huda ME, Islam M, Elahi S. Physico-chemical and biological aspects of monsoon waters of Ashulia for economic and aesthetic applications: Preliminary studies. Bangladesh J Sci Ind Res. 2007;42. DOI: 10.3329/bjsir.v42i4.747
14. Alfasane M, et al. Egeria densa planchón (Hydrocharitaceae): A new angiospermic record for Bangladesh. Bangladesh J Plant Taxon. 2010;17:209–213.
15. Khondker M, Alfasane M, Gani MA, Islam Md. Limnological notes on Ramsagar, Dinajpur, Bangladesh. Bangladesh J Bot. 2012;41(1):119–121.
16. Haroun Rashid. Geography of Bangladesh. University Press; 1991.
17. Zach. Shannon Diversity Index: Definition & Example – Statology. Statology; 2021. Available:https://www.statology.org/shannon-diversity-index/ Access on 28 March 2023
18. Zach. Simpson's Diversity Index: Definition & Examples - Statology. Statology.;2021. Available:https://www.statology.org/shannon-diversity-index/ Access on 28 March 2023
19. Zhang Y, Zuo J, Salimova A, Li A, Li L, Li D. Phytoplankton distribution characteristics and its relationship with bacterioplankton in Dianchi Lake. Environ. Sci. Pollut. Res. 2020;27(32):40592–40603. DOI: 10.1007/s11356-020-10033-6
20. Alam AKM, Hossain A, Hoque S, Aziz A. Phytoplankton seasonality of some freshwater wetlands of greater Dhaka district in relation to water chemistry. Jahangirnagar Univ. J. Biol. Sci. 2004; 27:241–249.
21. Jolly SN, Islam RBA, Bhuiyan M, Almujaddade A. Algal flora of the water bodies around Dhaka Export Processing Zone (DEPZ), Savar, Dhaka, Bangladesh. IOSR-JPBS. 2020;15:1–14. DOI: 10.9790/3008-1501020114.
22. Donald WO, Carla KOO, Nataliya R, Thomas F. Xanthophyte, eustigmatophyte, and raphidophyte algae in freshwater algae of North America: Ecology and classification. Elsevier Inc. 2015; 485–536. DOI: 10.1016/B978-0-12-385876-4.00011-6
23. Kubiszyn AM, Wiktor JM, Griffiths C, Kristiansen S, Gabrielsen TM. The annual planktonic protist community structure in an ice-free high arctic fjord (Adventfjorden, West Spitsbergen). J Mar Syst. 2017;169: 61–72. DOI: 10.1016/j.jmarsys.2017.01.013.
24. Khondker M, Alfasane M, Islam Md, Bhuiyan MA, Gani MA. Limnology of lake Bogakain. Bangladesh J. Bot. 2010;39(2): 153–159.
25. Gadhia M, Ujjania NC, Ansari E. Phytoplankton diversity and water quality

assessment of ONGC pond, Hazira. IJRES. 2015;1(1):1–5.
Available:www.arcjournals.org

26. Stoyneva-Gärtner, M. Algological studies of Bulgarian coastal wetlands. I. Species composition of the phytoplankton of Durankulak and Shabla-Ezeretz lakes. Ann. Univ. Sof. 2000;91:27–48.

27. Silva E, Rott E, Thumpela I, Athukorala N, Silva ENS. Species Composition and relative dominance of reservoir phytoplankton in Sri Lanka: Indicators of environmental quality. Int. J. Biol. Eng. 2013;4:92-102.
Available: www.cafetinnova.org.

28. Cardoso S, Roland F, Loverde-Oliveira S, Huszar V. Phytoplankton abundance, biomass and diversity within and between Pantanal wetland habitats. Limnologica. 2012;42(3):235–241.
DOI: 10.1016/j.limno.2012.01.002

29. Zhu H, Liu X, Cheng S. Phytoplankton community structure and water quality assessment in an ecological restoration area of Baiyangdian Lake, China. Int. J. Environ. 2021;18(3):1529–1536.
DOI: 10.1007/s13762-020-02907-6

30. Cianelli D, D'Alelio D, Uttieri M, Sarno D, Zingone A, Zambianchi E, Ribera d'Alcala M. Disentangling physical and biological drivers of phytoplankton dynamics in a coastal system. Scientific Reports. 2017;7(1).
DOI: 10.1038/s41598-017-15880-x

31. Chowdhury A, Mamun A. Physio-chemical conditions and plankton population of two fishponds in Khulna. Univ. J. zool., Rajshahi Univ. 1970;25:41–44.
DOI: 10.3329/ujzru.v25i0.325.

32. Bhuiyan MA, Khondker M. Seasonal variation of water quality of Dharma Sagar of Comilla city. Bangladesh J. Bot. 2017; 46:971-978.

33. Sönmez F, Kutlu B, Sesli A. Spatial and temporal distribution of phytoplankton in Karkamis Dam lake (Sanliurfa/Turkey). Fresenius Environ Bull. 2017;26:6234–6245.
Available:www.algaebase.org.

34. Kolayli S, Şahin B. Species composition and diversity of epipelic algae in Balikli Dam Reservoir, Turkey. Turk J Botany. 2009;34:441-448.
DOI: 10.3906/bot-0912-290

35. Siver PA. Synurophyte algae. in freshwater algae of North America: Ecology and classification, Elsevier Inc. 2015:607–651.
DOI: 10.1016/B978-0-12-385876-4.00014-1

36. Negi R. Seasonal Variation And Species composition of phytoplankton in Ganga river and its Tributary at Garhwal Region Uttrakhand. Int. J. Zool. Res; 2007.
Available:https://www.researchgate.net/publication/271208831.

37. Verb R, M Vis, Ott D, Wallace R. New records of vaucheria species (xanthophyceae) with associated proales werneckii (rotifera) from North America. Cryptogam Algol. 1999;20(2):67–73.
DOI: 10.1016/S0181-1568(99)80007-5

38. Yang J, Wang F, Lv J, Liu Q, Nan F, Liu X, Xu L, Xie S, Feng J. The spatiotemporal contribution of the phytoplankton community and environmental variables to the carbon sequestration potential in an urban river. Environ. 2020;27(5):4814–4829.
DOI: 10.1007/s11356-019-07109-3

39. Colak Sabanci F. Phytoplankton distribution and its relationship to the physico-chemical environment in a coastal lagoon. Ekoloji. 2014;23(90):61–72.
DOI: 10.5053/ekoloji.2014.908

40. Teneva I, Belkinova D, Mladenov R, Stoyanov P, Moten D, Basheva D, Kazakov S, Dzhambazov B. Phytoplankton composition with an emphasis of cyanobacteria and their toxins as an indicator for the ecological status of Lake Vaya (Bulgaria) – part of the Via Pontica migration route. Biodivers. Data J. 2020;8.
DOI: 10.3897/BDJ.8.e57507

41. Usman LU, Namadi S, Nafiu SA. Effects of physico-chemical parameters on the composition and abundance of phytoplankton in Ajiwa Reservoir Katsina State, North Western Nigeria. BAJOPAS. 2018;10(2):16.
DOI: 10.4314/bajopas.v10i2.3

42. Effendi H, Kawaroe M, Lestari D, Salim M, Permadi Tri. Distribution of phytoplankton diversity and abundance in Mahakam Delta, East Kalimantan. Procedia Environ Sci. 2016;33:496–504.
DOI: 10.1016/j.proenv.2016.03.102

43. Rajagopal T, Archunan G. Comparison of physico-chemical parameters and phytoplankton species diversity of two perennial ponds in Sattur area, Tamil Nadu. J Environ Biol. 2010;31:787-794.
Available:https://www.researchgate.net/publication/223136191

44. Rose AK, Kinder JE, Fabbro L, Kinnear S. A phytoplankton risk matrix: combining health, treatment, and aesthetic considerations in drinking water supplies. Environ Syst Decis. 2019;39(2):163–182. DOI: 10.1007/s10669-018-9711-8
45. Dochin K, Kuneva V, Iliev I. Principal component analysis of the phytoplankton interactions with the environmental factors in two reservoirs in Bulgaria. Bulg. J. Agric. Sci. 2017;23(6):1037–1046.
46. Wu ML, Wang YS, Wang YT, Sun FL, Sun CC, Jiang ZY, Cheng H. Influence of environmental changes on phytoplankton pattern in Daya Bay, South China Sea. Revista De Biología Marina Y Oceanografía. 2014;49:323-337. DOI:10.4067/S0718-19572014000200011
47. Kim JO, Mueller CW. Factor Analysis: Statistical Methods and Practical Issues. Beverly Hills, CA: Sage; 1978.
48. Jyotsna N, Rangaiah G, Narasimha Rao G. Seasonal variation of microalgae in relation to the physico-chemical parameters of Karagam Lake, Srikakulam district, A.P. India. J. Algal Biomass Utln. 2014;5(4):68–73. Available:https://www.researchgate.net/publication/275346936
49. Jabbari M, Salahi M, Ghorbani R. Spatio-temporal influence of physicochemical parameters on phytoplankton assemblage in coastal brackish lagoon: Gomishan Lagoon, Caspian Sea, Iran. Biodiversitas. 2018;19(6):2020–2027. DOI: 10.13057/biodiv/d190606
50. Dimitrova R., Nenova E, Uzunov B, Shishiniova M, Stoyneva M. Phytoplankton abundance and structural parameters of the critically endangered protected area Vaya Lake (Bulgaria). Biotechnol. 2014;28(5):871–877. DOI: 10.1080/13102818.2014.947718.
51. Sekadende B, Mbonde A, Shayo S, Lyimo T. Phytoplankton species diversity and abundance in satellite lakes of Lake Victoria basin (Tanzanian side). Tanzan. j. sci. 2005;30(1). DOI: 10.4314/tjs.v30i1.18390
52. López-Archilla AI, Moreira D, López-García P, Guerrero C. Phytoplankton diversity and cyanobacterial dominance in a hypereutrophic shallow lake with biologically produced alkaline pH. Extremophiles. 2004;8(2):109–115. DOI: 10.1007/s00792-003-0369-9
53. Zhu W, Wan L, Zhao L. Effect of nutrient level on phytoplankton community structure in different water bodies. J Environ Sci. 2010;22(1):32–39. DOI: 10.1016/S1001-0742(09)60071-1

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