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Seasonal Dynamics and Diversity of Phytoplankton in a Subtropical Freshwater pond in Ri-Bhoi District, Meghalaya, Northeast India

[1]Dhurjati Pathak, [2]Prabal Sarkar, [3]Anindita Bhattacharya[3] and [2]Golphina Ahmed

[1]Department of Zoology, Tangla College, Tangla - 784521 (India)
[2]Department of Zoology, University of Science & Technology, Meghalaya - 793101 (India)
[3]Independent Researcher, Guwahati - 781028 (India)
Corresponding: abhattacharya14@gmail.com

Abstract

Phytoplankton communities form the foundation of aquatic food webs and are widely used as indicators of ecological conditions in freshwater ecosystems. The present study investigates the diversity and seasonal abundance of phytoplankton in a freshwater pond located within the campus of the University of Science and Technology Meghalaya (USTM), Northeast India. Phytoplankton samples were collected seasonally and identified up to the genus level. A total of 32 genera belonging to three major algal groups, *i.e.*, Chlorophyta, Bacillariophyta, and Cyanophyta, were recorded during the study period. Chlorophyta represented the dominant group with 20 genera (62.5%), followed by Bacillariophyta (7 genera, 21.88%) and Cyanophyta (5 genera, 15.62%). Seasonal analysis showed that total phytoplankton abundance varied from 1015 u.L^{-1} during post-monsoon to 1879 u.L^{-1} during winter, with intermediate values recorded during monsoon (1382 u.L^{-1}) and pre-monsoon (1274 u.L^{-1}). Chlorophyta contributed the largest share of the phytoplankton community across all seasons, accounting for 61.6–68.5% of the total abundance, while Bacillariophyta and Cyanophyta contributed 16.6-19.0% and 14.0-19.8%, respectively. Genera such as Scenedesmus, Spirogyra, Pediastrum, and Cosmarium exhibited relatively higher abundance among Chlorophyta, whereas Navicula and Pinnularia were dominant among Bacillariophyta. Cyanophyta were mainly represented by Microcystis and Oscillatoria. The dominance of Chlorophyta and the higher phytoplankton abundance during winter suggest favourable environmental conditions, including improved light penetration and nutrient availability. The findings provide baseline information on phytoplankton diversity and seasonal dynamics in small freshwater ecosystems of Northeast India.

Key words : Phytoplankton diversity, seasonal dynamics, Chlorophyta, Bacillariophyta, Cyanophyta, freshwater pond, Northeast India.

Phytoplankton are microscopic photosynthetic organisms that play a fundamental role in freshwater ecosystems by contributing to primary productivity and forming the base of aquatic food webs[13,16]. They constitute one of the most significant groups of primary producers, contributing substantially to global primary production and regulating key biogeochemical cycles, particularly through the uptake of silica, carbon, nitrogen, and phosphorus in aquatic systems[19]. Owing to their rapid response to environmental fluctuations and disturbance gradients, phytoplankton are widely recognized as reliable bioindicators of water quality and pollution[24,32,34].

Freshwater ponds are among the most productive aquatic ecosystems and often support diverse phytoplankton assemblages. They frequently exhibit higher biodiversity than other freshwater habitats, such as lakes and rivers, harbor rare and endangered taxa, and function as important refugia within anthropogenically modified landscapes[6]. In tropical and subtropical regions, phytoplankton communities are typically dominated by members of Chlorophyta, Bacillariophyta, and Cyanophyta. Despite their broad cosmopolitan distribution, the composition and distribution of phytoplankton are strongly influenced by trophic status, particularly along the eutrophication-oligotrophication gradient[20].

Northeast India is endowed with abundant freshwater resources, including rivers, wetlands, lakes, and ponds, which support rich aquatic biodiversity. However, small freshwater bodies, such as campus ponds, remain comparatively understudied with respect to planktonic diversity and ecological dynamics. The University of Science and Technology Meghalaya (USTM) campus encompasses freshwater ponds that sustain a variety of aquatic organisms and provide valuable natural systems for ecological research. In this context, the present study aims to document the diversity and seasonal abundance of phytoplankton in a campus pond at USTM and to assess the seasonal dynamics of major phytoplankton groups.

Study Area :

The study was conducted in a freshwater pond (26°05’57"N 91°50’36"E) located within the campus of the University of Science and Technology Meghalaya (USTM) in Ri-Bhoi district, Meghalaya, Northeast India (Fig. 1). The region experiences a humid subtropical climate characterized by heavy monsoon rainfall and moderate temperature variations throughout the year. The pond receives water mainly from precipitation.

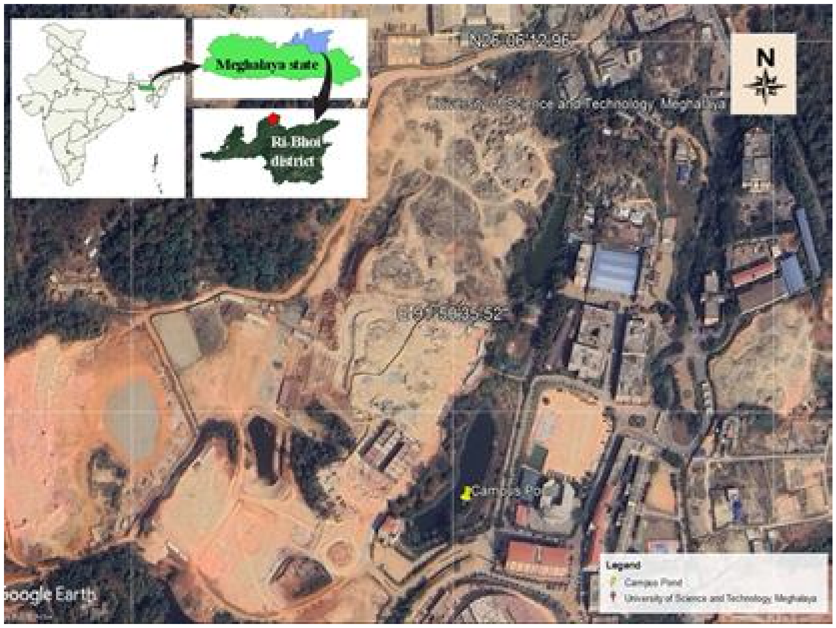

Fig. 1. Map of USTM campus in Ri-Bhoi district of Meghalaya, Northeast India, where the present study was conducted.

Sampling :

Plankton samples were collected from the pond at regular monthly intervals during the study period, *i.e.*, from December 2023 to November 2024, covering all four seasons- Winter (December to February), Pre-Monsoon (March to May), Monsoon (June to September), and Retreating Monsoon (October to November)[4]. Phytoplankton samples were filtered through a standard plankton net (25 µm mesh size Nylobolt) and preserved in Lugol's iodine solution for laboratory examination.

Identification and Enumeration :

Phytoplankton identification and counting were performed using a binocular light microscope (Labomed Vision 2000) at the required magnifications of 10X initially, followed by 40X. Phytoplankton were identified up to the genus level using standard taxonomic keys[1,3,5,7-12,21,31,33,35].

The quantitative analysis of phytoplankton ($u.L^{-1}$) was conducted by extracting 1 ml of homogenized preserved samples using a wide-mouthed graduated pipette, which was then transferred to a Sedgwick Rafter cell for microscopic examination.

The total phytoplankton count per liter of water was determined using the following formula[28,29]:

$$\text{Phytoplankton units/Litre, } N = \frac{(\mathbf{n} \times \mathbf{v})}{V}$$

where, N = Number of plankton counted in 1ml concentrate under S-R cell.
v = Total volume of concentrate in ml.

V = Total volume of water filtered for sample in litres

Data analysis :

MS Excel software, MEGA, and the Bio-Diversity Pro program were used to compute the plankton abundance and diversity. The following formula was used to calculate the relative abundance of each phytoplankton species[18,36].

$$RA = \frac{\text{Number of samples of a specific phytoplankton species X 100}}{\text{Total number of samples}}$$

Distribution of Phytoplankton :

A total of 32 phytoplankton genera belonging to three major algal groups were recorded during the study period (Table-1).

Table-1. Distribution and relative abundance of phytoplankton in the USTM campus pond

Sl No.	Groups	Genera	Relative Abundance
1	Chlorophyta	*Chlamydomonas*	3.48
2		*Closterium*	3.95
3		*Coleastrum*	2.56
4		*Cosmarium*	4.20
5		*Desmidium*	2.36
6		*Docidium*	2.13
7		*Euastrum*	2.27
8		*Eudorina*	2.95
9		*Hydrodictyon*	2.56
10		*Netrium*	2.05
11		*Oedogonium*	3.75
12		*Pandorina*	3.15
13		*Pediastrum*	4.58
14		*Rhizoclonium*	3.53
15		*Scenedesmus*	5.39
16		*Sirogonium*	2.02
17		*Spirogyra*	4.97
18		*Staurastrum*	2.83
19		*Staurodesmus*	2.76
20		*Xanthidium*	2.56
21	Bacillariophyta	*Diatoma*	2.97
22		*Frustulia*	1.69
23		*Navicula*	3.64
24		*Pinnularia*	3.24
25		*Rhopalodia*	2.14
26		*Surirella*	2.31
27		*Tabellaria*	1.95
28	Cyanophyta	*Anabaena*	3.73
29		*Microcystis*	4.20
30		*Nostoc*	2.90
31		*Oscillatoria*	3.93
32		*Spirulina*	3.26

Chlorophyta represented the largest group with 20 genera (62.5%), followed by Bacillariophyta with 7 genera (21.88%) and Cyanophyta with 5 genera (15.62%) (Fig. 2). The chi-square test revealed a statistically significant difference in the distribution of genera across the three phytoplankton groups ($\chi^2 = 12.43$, df = 2, $p < 0.01$), suggesting that the observed prevalence of Chlorophyta is not

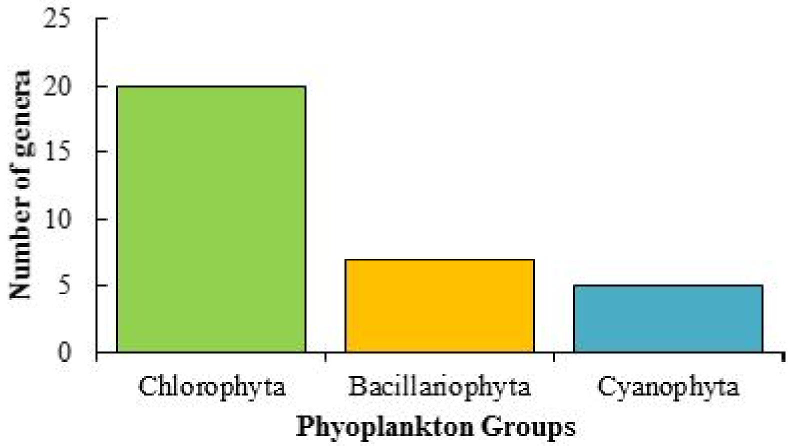

Fig. 2. Distribution of phytoplankton groups with respect to genera

a result of random variation. This implies a preferential ecological advantage for Chlorophyta within the pond environment, likely influenced by favourable physicochemical conditions that support higher taxonomic richness in comparison to Bacillariophyta and Cyanophyta.

Phytoplankton abundance :

The overall relative abundance of zooplankton in the campus pond was dominated by Chlorophyta, representing the highest proportion (64.04%), followed by Cyanophyta (18.02%) and Bacillariophyta (17.95%) (Fig. 3). The chi-square test demonstrated a highly significant difference in the distribution of phytoplankton groups (χ^2 = 2355.63, df=2, $p<0.001$), suggesting that the predominance of Chlorophyta is not a result of random variation but rather indicates a strong ecological preference influenced by the existing environmental conditions of the pond.

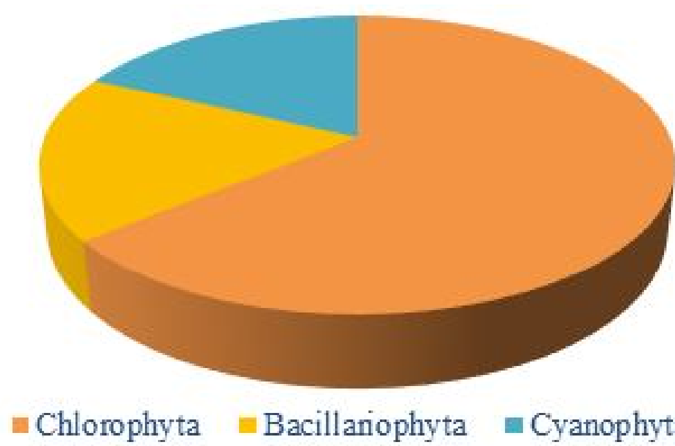

Fig. 3. Relative abundance of the major groups of phytoplankton

There were marked seasonal variations in the abundance of phytoplankton groups. The highest total phytoplankton abundance was recorded during winter (1879 u.L^{-1}), followed by monsoon (1382 u.L^{-1}), pre-monsoon (1274 u.L^{-1}), and post-monsoon (1015 u.L^{-1}) (Fig. 4). The chi-square test of independence demonstrated a highly significant correlation between phytoplankton groups and seasons ($\chi^2 = 54.06$, df=6, $p<0.001$), indicating that the distribution of phytoplankton groups exhibited distinct seasonal variation, attaining its highest level in winter and progressively declining through monsoon, pre-monsoon, and post-monsoon, suggesting that winter conditions were most favourable for phytoplankton growth in the pond.

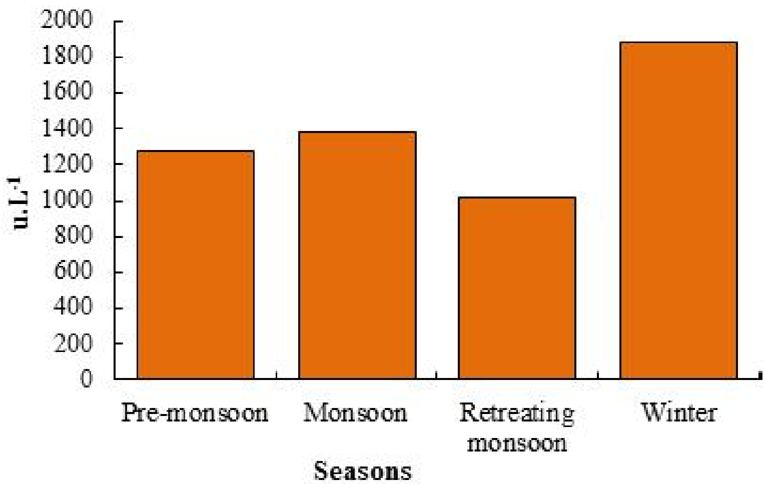

Fig. 4. Overall seasonal variation in zooplankton abundance

Among the three phytoplankton groups, Chlorophyta consistently dominated across all seasons, with abundances ranging from 629 u.L^{-1} during post-monsoon to 1157 u.L^{-1} during winter. Chlorophyta recorded values of 821 u.L^{-1} during pre-monsoon and 947 u.L^{-1} during monsoon, indicating its strong contribution to overall phytoplankton productivity in the pond ecosystem. Similarly, Bacillariophyta showed comparatively moderate abundance, varying between 193 u.L^{-1} during post-monsoon and 350 u.L^{-1} during winter. The group recorded 211 u.L^{-1} during pre-monsoon and 242 u.L^{-1} during monsoon, reflecting its consistent presence throughout the study period. Again, Cyanophyta also displayed notable seasonal variation. The abundance ranged from 193 u.L^{-1} during the monsoon and post-monsoon to 372 u.L^{-1} during winter, while 242 u.L^{-1} was recorded during the pre-monsoon (Fig. 5). The coefficient of variation indicated a moderate level of seasonal variability in phytoplankton abundance across all groups. Cyanophyta displayed the highest degree of variability (29.52%), indicating a greater seasonal fluctuation, whereas Chlorophyta (24.72%) and Bacillariophyta (24.62%) exhibited relatively comparable and moderate levels of variation, suggesting more stable seasonal distribution patterns.

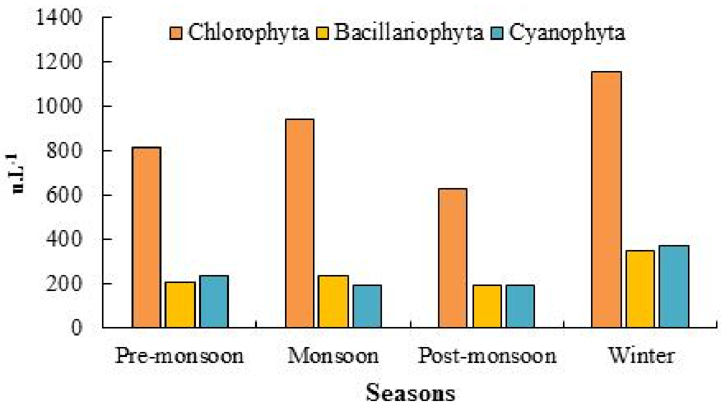

Fig. 5. Seasonal variation of phytoplankton abundance of each group in terms of u.L^{-1}

The proportional composition of phytoplankton groups also varied across seasons, with Chlorophyta dominating the community by contributing 64.4% during pre-monsoon, 68.5% during monsoon, 62.0% during post-monsoon, and 61.6% during winter. Again, Bacillariophyta represented a moderate proportion of the phytoplankton assemblage, contributing 16.6% during pre-monsoon, 17.5% during monsoon, 19.0% during post-monsoon, and 18.6% during winter. Similarly, Cyanophyta contributed 19.0% of the total phytoplankton during pre-monsoon, decreased to 14.0% during monsoon, and increased again to 19.0% during post-monsoon and 19.8% during winter (Fig. 6). The chi-square test indicated a highly significant difference in the composition of phytoplankton groups (χ^2 = 42.13, df=2, $p<0.001$), suggesting that the dominance of Chlorophyta is statistically significant and not attributable to random variation, while Bacillariophyta and Cyanophyta showed moderate and seasonally fluctuating contributions, indicating a relatively stable community structure with minor seasonal shifts.

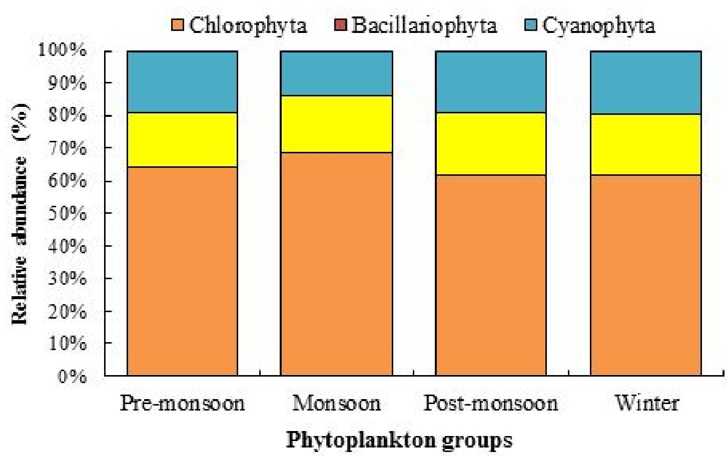

Fig. 6. Seasonal variation in relative abundance of phytoplankton groups

Among Chlorophyta, Scenedesmus exhibited the highest abundance with values ranging from 53 $u.L^{-1}$ during the retreating monsoon to 98 u.L during winter. Similarly, Spirogyra showed relatively high abundance, reaching 90 $u.L^{-1}$ in winter. Other genera such as Pediastrum and Cosmarium also demonstrated increased abundance during winter. Within Bacillariophyta, Navicula and Pinnularia were the most abundant genera, with maximum abundance recorded during winter. Cyanophyta showed moderate abundance, with Microcystis reaching 87 $u.L^{-1}$ during winter and Oscillatoria showing similar seasonal trends. The results demonstrate that Chlorophyta dominated the phytoplankton community throughout the year, with peak abundance during winter, while Bacillariophyta and Cyanophyta contributed comparatively smaller yet significant proportions to the overall community structure.

Phytoplankton Diversity :

The comprehensive evaluation of diversity indices indicated a moderate level of phytoplankton diversity, characterized by a relatively high degree of evenness throughout the seasons. The Shannon-Wiener index (H′) exhibited values ranging from 0.84 to 0.93, while Simpson's diversity index (1-D) fluctuated between 0.48 and 0.55, signifying a moderate degree of species heterogeneity accompanied by notable dominance. Pielou's evenness index (J′) values, which ranged from 0.76 to 0.85 (Table-2), further imply a fairly uniform distribution of phytoplankton groups, despite the persistent dominance of Chlorophyta. Lower diversity and evenness during the monsoon may be attributed to environmental disturbances, including increased turbidity and nutrient influx, whereas higher values during the post-monsoon and winter seasons suggest enhanced ecological stability and a more balanced community structure.

The study has revealed that the phytoplankton community in the USTM campus pond is primarily composed of Chlorophyta, which leads in both diversity and abundance, followed by Bacillariophyta and Cyanophyta. The predominance of Chlorophyta (62.5% of total genera and approximately 64% relative abundance) is a characteristic feature of many freshwater ecosystems and has been widely reported in ponds and lakes of tropical and subtropical regions[22]. The pond ecosystem offers favourable environmental conditions, including sufficient light penetration, moderate nutrient levels, and relatively stable physico-chemical parameters, all of which are conducive to the growth of green algae[30,36]. A similar prevalence of Chlorophyta was observed in freshwater environments characterized by mesotrophic to moderately eutrophic conditions,

Table-2. Seasonal Variation in Phytoplankton Diversity Indices Season

Season	Shannon–Wiener Index (H′)	Simpson's Index(1 - D)	Pielou's Evenness (J′)
Pre-monsoon	0.90	0.52	0.82
Monsoon	0.84	0.48	0.76
Post-monsoon	0.93	0.54	0.85
Winter	0.93	0.55	0.85

where green algae flourish due to their ability to adapt to varying ecological circumstances[18].

The relatively lower representation of Bacillariophyta and Cyanophyta indicates that while these groups are essential components of the phytoplankton community, the environmental conditions may not consistently favour their growth. Diatoms (Bacillariophyta), which make up about 18-22% of the community, are generally found in well-oxygenated waters with available silica, and their moderate presence reflects balanced ecological conditions within the pond[26]. Cyanophyta, representing roughly 15-19%, are frequently associated with nutrient enrichment, particularly phosphorus, and their moderate abundance implies that the pond may be undergoing mild nutrient enrichment without severe eutrophication[23].

Seasonal fluctuations in phytoplankton abundance were significant, with the highest levels observed in winter and the lowest during the post-monsoon period. This seasonal pattern aligns with findings from tropical and subtropical freshwater ecosystems, where winter conditions often enhance phytoplankton growth due to improved water clarity, decreased turbidity, and better light penetration[2,15,36]. Conversely, the monsoon season generally brings about high turbidity and flushing effects, which can hinder phytoplankton growth despite an increase in nutrient availability[23]. The comparatively lower abundance noted during the post-monsoon period may be linked to dilution effects and ecological instability that follow heavy rainfall events.

The dominance of Chlorophyta throughout all seasons further highlights its ecological resilience. Genera such as Scenedesmus, Spirogyra, Pediastrum, and Cosmarium exhibited greater abundance, especially in winter, demonstrating their adaptability to seasonal changes and their significance as primary producers in the pond ecosystem[14]. These genera are widely acknowledged as indicators of productive freshwater systems and are typically associated with nutrient-rich habitats[21]. The steady presence of Bacillariophyta genera like Navicula and Pinnularia were also prominent components of the phytoplankton community. Their increased abundance during winter may be related to favourable temperature conditions and adequate silica availability[17,25], which further indicates stable ecological conditions, as these taxa are known to be sensitive to variations in water quality and are frequently utilized as bioindicators[26].

Cyanophyta displayed significant seasonal variations, with increased abundance during the winter and post-monsoon phases. Genera such as Microcystis and Oscillatoria are recognized for their ability to thrive under favourable temperature and nutrient conditions, potentially signaling the onset of eutrophic conditions when present in high densities[23,27]. Nevertheless, in this study, their moderate abundance indicates that the pond ecosystem remains in a balanced trophic state, without the occurrence of severe algal blooms.

The seasonal composition of phytoplankton further emphasizes the stability of the community structure. While minor variations were noted in the relative proportions of various groups, Chlorophyta consistently held a dominant position throughout all seasons. This stability indicates that the pond ecosystem is relatively resilient to seasonal environmental changes and sustains a balanced ecological state. Similar findings were documented in small freshwater bodies where phytoplankton communities displayed seasonal fluctuations in abundance yet maintain overall compositional stability[23,36].

The moderate values of the Shannon-Wiener index (H2 = 0.84-0.93) and Simpson's index (1-D = 0.48-0.55) suggest a moderately diverse phytoplankton community exhibiting some level of dominance, which aligns with mesotrophic freshwater conditions[36]. The relatively high evenness (J′ =0.76-0.85) indicates a fairly uniform distribution of phytoplankton groups, despite the dominance of Chlorophyta, which reflects ecological stability throughout the seasons[23]. Seasonal fluctuations in diversity, characterized by lower values during the monsoon and higher values in the post-monsoon and winter, can be attributed to variations in light availability, nutrient dynamics, and hydrological conditions[23,36].

Overall, the findings suggest that the USTM campus pond fosters a diverse and productive phytoplankton community, characterized by distinct seasonal dynamics shaped by environmental factors such as temperature, light availability, and nutrient concentration. The predominance of Chlorophyta, along with moderate contributions from Bacillariophyta and Cyanophyta, implies that the pond is likely in a mesotrophic state, supporting a stable and balanced aquatic ecosystem. Such small freshwater bodies are vital for preserving local biodiversity and function as significant natural laboratories for ecological research, especially in landscapes affected by human activity.

The present investigation documented a total of 32 phytoplankton genera belonging to three major algal groups from a freshwater pond within the USTM campus, Northeast India. This pond supports a diverse and seasonally fluctuating phytoplankton community primarily characterized by Chlorophyta. The abundance of phytoplankton showed distinct seasonal variation, peaking in winter, which suggests advantageous ecological conditions. Overall, the pond serves as a stable, moderately productive (mesotrophic) ecosystem that holds considerable ecological significance for freshwater biodiversity.

References :

1. Anand, N. (1998). *Indian freshwater microalgae*. Bishen Singh Mahendra Pal Singh.
2. Behrenfeld, M.J. (2010). *Ecology, 91*(4): 977–989. https://doi.org/10.1890/09-1207.1
3. Bellinger, E.G. and D.C. Sigee, (2010). Freshwater algae identification and use as bioindicators. Wiley-Blackwell.
4. Borthakur, M. (1986). *The Northeast Geographer*, *18*(1–2): 22-27.
5. Brook, A.J. (1959). *Journal of Ecology, 47*(2): 429-445.
6. Davies, B., J. Biggs, P. Williams, M. Whitfield, P. Nicolet, D. Sear, S. Bray, and S. Maund, (2008). *Agriculture, Ecosystems and Environment, 125:* 1-8.
7. Desikachary, T. V. (1985). *Cyanophyta*. Indian Council of Agricultural Research.
8. Dillard, G.E. (1989). *Freshwater algae*

of the southeastern United States. Western Kentucky University.

9. Gandhi, H.P. (1998). *Freshwater diatoms of central Gujarat: With a review and some others*. Shiva Offset Press.
10. Islam, A. K. M.N. and A.K.Y. Haroon, (1980). *Internationale Revue der gesamten Hydrobiologie, 65*(4): 551–604.
11. John, D.M., B.A. Whitton, and A.J. Brook (2002). *The freshwater algal flora of the British Isles: An identification guide to freshwater and terrestrial algae*. Cambridge University Press.
12. Kimor, B. and U. Pollingher, (1965). *The plankton algae of Lake Tiberias.* Ministry of Agriculture, Department of Fisheries, Sea Fisheries Research Station.
13. Kumar, E.G., K.V. Thanzeeha, K. Sasikala, P.G. Kumar, K.K. Sivadasan, and A.V.A. Jaleel, (2018). *Phykos, 48*(2): 13-16.
14. Lanza, W.G., V.C. Hernández, D. Achá, and X. Lazzaro, (2024). *Journal of Great Lakes Research, 50*(2): Article 102294. https://doi.org/10.1016/j.jglr.2024.102294
15. Mignot, A., R. Ferrari, and H. Claustre, (2018). *Nature Communications, 9:* 190. https://doi.org/10.1038/s41467-017-02143-6
16. Mooij, W.M., S. Hülsmann, L.N. De Senerpont Domis, B.A. Nolet, P.L.E. Bodelier, P.C.M. Boers, L.M.D. Pires, H.J. Gons, B.W. Ibelings, R. Noordhuis, R. Portielje, K. Wolfstein, and E.H.R.R. Lammens, (2005). *Aquatic Ecology, 39*(4): 381–400.
17. Moore, J.W. (1974). *Journal of Ecology, 62*(3): 809–819.
18. Odum, E.P. (1971). *Fundamentals of ecology* (3rd ed.). Saunders.
19. Plus, M., I. Auby, D. Maurer, G. Trut, Y. Del Amo, F. Dumas, and B. Thouvenin, (2015). *Estuarine, Coastal and Shelf Science, 165:* 52-60.
20. Pomati, F., B. Matthews, J. Jokela, A. Schildknecht, and B. W. Ibelings, (2012). *Oikos, 121*(8): 1317–1327. https://doi.org/10.1111/j.1600-0706.2011.20055.
21. Prescott, G.W. (1982). *Algae of the Western Great Lakes area* (Revised ed.). Otto Koeltz Science Publishers.
22. Rajagopal, T., A. Thangamani, and G. Archunan, (2010). *Journal of Environmental Biology, 31*(5): 787–794.
23. Reynolds, C. S. (2006). *The ecology of phytoplankton*. Cambridge University Press.
24. Ribeiro, K.F., L. Duarte and L.O. Crossetti (2018). *Hydrobiologia, 820:* 23-48. https://doi.org/10.1007/s10750-018-3669-x
25. Round, F.E. (1991). *Journal of Applied Phycology, 3:* 129–145.
26. Round, F.E., R.M. Crawford, and D.G. Mann, (1990). *The diatoms: Biology and morphology of the genera*. Cambridge University Press.
27. Sahabuddin, A. Sahrijanna, and H.S. Suwoyo, (2019). *International Journal of Environment, Agriculture and Biotechnology, 4*(6):
28. Santhanam, P., A. Begum and P. Pachiappan (2019). *Basic and applied phytoplankton biology*. Springer. https://doi.org/10.1007/978-981-10-7938-2
29. Sarojini, Y. and V. V. S. S. Sarma, (2001).

Indian Journal of Marine Sciences, 30: 65-69.

30. Shoman, N. Yu. and A.I. Akimov, (2022). *Marine Biological Journal, 7*(3): 103–106. https://doi.org/10.21072/MBJ.2022.07.3.09
31. Stansbery, D.H. (1971). *The distribution of algae by division, classes, and order*. Ohio State University.
32. Stomp, M., J. Huisman, G. G. Mittelbach, E. Litchman, and C.A. Klausmeier, (2011). *Ecology, 92*(11): 2096-2107. https://doi.org/10.1890/10-1023.1
33. Vinyard, W.C. (1975). *A key to the genera of marine planktonic diatoms of the Pacific coast of North America.*
34. Wang, T., H. Zhang, L. Zhao, F. Zhang, and H. Huang, (2017). *International Journal of Environmental Research and Public Health, 14*(1): 95. https://doi.org/10.3390/ijerph14010095
35. Weber, C.I. (1971). *A guide to the common diatoms at water pollution surveillance system: Analytical quality control.* U.S. Environmental Protection Agency.
36. Wetzel, R.G. (2001). *Limnology: Lake and river ecosystems* (3rd ed.). Academic Press.