

## Community Structure with Diversity indices of Periphytic and Phytoplanktonic Algal Assemblages in Three Water Bodies of the Campus of Jahangirnagar University, Bangladesh

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### Abstract

This study compared periphyton and phytoplankton communities in three water bodies named Padma Pukur, Transport Lake and Auditorium Pond of Jahangirnagar University, Bangladesh from April to December 2022. To find out the periphyton (attached algae), five dominant free-floating hydrophytes named as *Salvinia minima*, *Nelumbo nucifera*, *Nymphaea pubescens*, *Pistia stratiotes* and *Eichhornia crassipes* were collected to which they (periphyton) were attached. Samples were analyzed for alpha diversity using Shannon ( $H'$ ), Simpson's dominance ( $1-D$ ), Margalef richness ( $d$ ) and Pielou's evenness ( $J'$ ), along with some of water quality parameters (water temperature, sechhi transparency, pH, DO, TDS, alkalinity and conductivity). Water was alkaline with optimum range of DO (3.03-9.8 mg/l) and conductivity (70.8-380  $\mu\text{S}/\text{cm}$ ) that is suitable for aquatic lives. Periphyton maintained higher and more stable diversity (mean  $H' \approx 2.9$ ;  $1-D \approx 0.91$ ;  $d \approx 4.5$ ;  $J' \approx 1.0$ ) compared to phytoplankton (mean  $H' \approx 1.8$ ;  $1-D \approx 0.70$ ;  $d \approx 3.5$ ;  $J' \approx 0.7$ ). Bacillariophyceae dominated the periphyton community while phytoplankton showed shifts and bloom-driven declines, with extreme density in Auditorium Pond reducing evenness to 0.16. Jaccard similarity between communities was low ( $<20\%$ ), confirming distinct assemblages. Correlation to water quality analyses revealed that periphyton diversity was promoted by water clarity and dissolved oxygen, while phytoplankton richness was positively linked to temperature and pH but declined under high conductivity. These results highlight the complementary roles of periphyton and phytoplankton in sustaining fresh water biodiversity under variable conditions.

**Keywords:** *Periphyton, phytoplankton, diversity indices, correlation, water quality.*

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### Introduction

In Bangladesh, wetlands cover nearly one-third of the land area and play a central role in food production, fisheries, and ecological balance (Waliuzzaman et al., 2012). Studies on periphytic (attached) algae are more rare than that on phytoplankton from both phycological and ecological aspects. Periphyton, a

complex mixture of algae attached to submerged surfaces, is equally significant as it can contribute up to 80% of primary production in shallow systems and also serve as an ecological indicator (Moss, 1968; Persson et al., 1977; Edmonson, 1992).

Phytoplankton are the main primary producers, responsible for carbon fixation and nutrient transfer in aquatic food webs (Stevenson et al., 1996). Their composition and abundance fluctuate seasonally, often reflecting changes in nutrient levels, pH, and temperature, which makes them effective bioindicators of water quality (Patrick, 1972; Wunsam et al., 2002).

The lakes on Jahangirnagar University campus support diverse algal communities but are increasingly influenced by human activities such as pisciculture and habitat alteration (Islam & Haroon, 1975; Khondker et al., 1995). The present study was undertaken in 2022 to investigate the diversity, community structure and variation of periphyton and phytoplankton in three selected water bodies of Jahangirnagar University with reference to their relationship of water quality.

## Materials and Methods

### Description of Study Area

Jahangirnagar University is situated about 32 kilometers from Capital Dhaka on Western side of the National Highway near Savar. The place is located at height of 11.89m above the mean sea level. The relative geographical position is 90°13' N and 23° 51' E (Fig. 1).

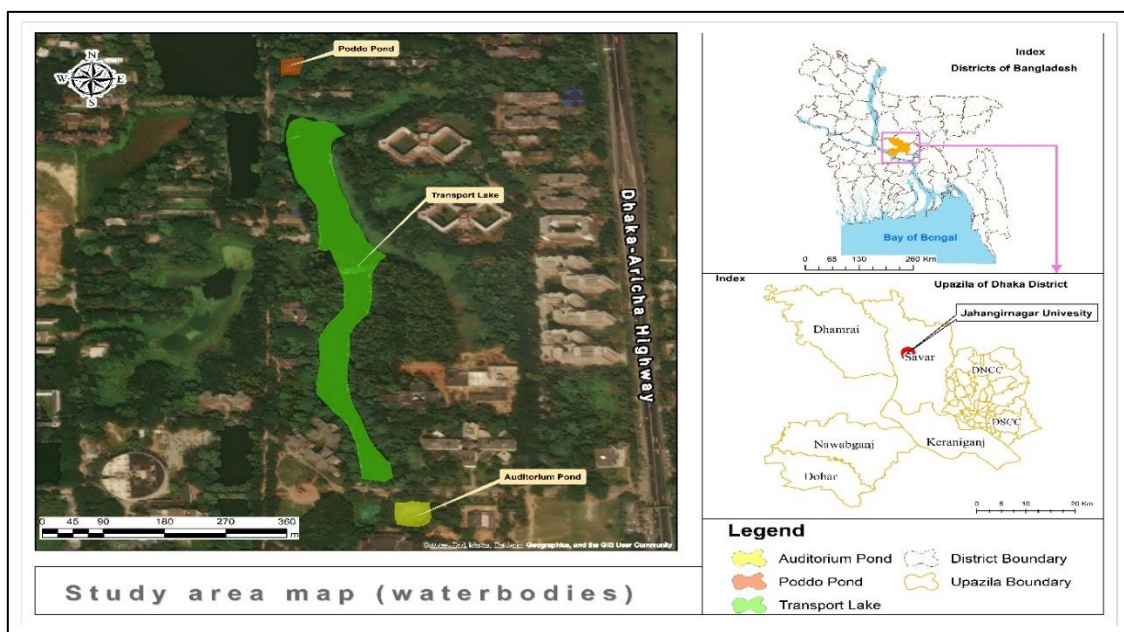


Figure 1. Map Showing the Sampling Sites

The study was conducted in 2022 at three water bodies of Jahangirnagar University named as Padma Pukur, Transport Lake and Auditorium Pond (rain water and ground water seepage are the main sources of nutrition), from April to December.

Table 1. Environmental Details of Study Areas

| No. | Name        | Dominated macrophyte    | Pisciculture practices |
|-----|-------------|-------------------------|------------------------|
| 01  | Padma Pukur | <i>Nelumbo nucifera</i> | None                   |



|    |                 |                             |                                                                                          |
|----|-----------------|-----------------------------|------------------------------------------------------------------------------------------|
| 02 | Transport lake  | <i>Nymphaea pubescens</i>   | Semi-intensive pisciculture with management of both inorganic and organic fertilization. |
| 03 | Auditorium pond | <i>Eiccbornia crassipes</i> | None                                                                                     |

## Sample Collection

Periphyton samples were collected from submerged macrophytes (*Salvinia minima*, *Nelumbo nucifera*, *Nymphaea pubescens*, *Pistia stratiotes* and *Eiccbornia crassipes*) while phytoplankton samples were obtained using a Schindler's sampler at 50 cm depth. Water temperature, Secchi depth, pH, conductivity, total dissolved solids (TDS), dissolved oxygen, alkalinity, and DO were measured following standard limnological methods (Murphy & Riley, 1962; Wetzel & Likens, 1979). Algal samples were concentrated by sedimentation and preserved with Lugol's iodine.

Enumeration of phytoplankton was done under a compound microscope (Nikon, Japan) at a magnification of 400× with the help of the Hilbert Bacteria Counting Cell (Single round, Hawksly, UK). Taxonomic identification was carried out using standard monographs and keys (Smith, 1950; Prescott, 1982; Islam & Khondker, 1981). Diversity indices including Shannon-Wiener ( $H'$ ), Simpson's dominance index ( $D$ ), Margalef's richness ( $DMg$ ), and Evenness ( $J'$ ) were calculated. The Jaccard index was applied to compare periphyton and phytoplankton communities among three different water bodies and Pearson's correlation analysis (SPSS v. 16.0) was used to examine relationships between algal indices and environmental variables.

## Phytoplankton Density (PD)

$$\text{Density/l} = [\text{units}/3.015\mu\text{l} \times \{(10000 \div 3.015)\} \times (50 \div 9.7)] \div 100 \quad (1)$$

where,

Units/3.015  $\mu\text{l}$  = sum of the counts in triplicate of the phytoplankton individuals for each sample made by Hawksleys Counting Chamber, 3.015  $\mu\text{l}$  = vol. of the Hawksleys Chamber ( $1.005 \times 3$  in  $\mu\text{l}$ ).

10000 = 10 ml sub-sample of phytoplankton concentrate as obtained after passing of sample water through plankton net, in  $\mu\text{l}$ .

50 = Volumes of phytoplankton concentrate, in ml obtained after filtering 100 liters of sample water through plankton net.

9.7 = Actual vol. of phytoplankton concentrates obtained as a sub-sample fixed with 0.3 ml Lugol's solution ( $9.7 + 0.3$ ) finally making a volume of 10 ml as supplied to us for counting.

100 = Amounts of sample water passed through plankton net in liters.

## Diversity Indices

$$\text{Shannon-Wiener Index } (H') = -\sum(p_i \times \ln(p_i)) \quad (2)$$

where,

$p_i$  = the proportion of individuals belonging to the  $i$ -th species;



Here, higher values indicate greater diversity (usually falls between 1.5-3.5).

$$\text{Simpson's Index (1-D)} = \sum (p_i^2) \quad (3)$$

where,

$p_i$  = the proportion of individuals belonging to the  $i$ -th species.

(Range: 0-1, where 0 is the infinite diversity)

$$\text{Margalef's Richness (d)} = (S-1)/\ln(N) \quad (4)$$

where,

$S$  = the species richness and

$N$  = the total number of individuals.

$$\text{Pielou's Evenness Index (J')} = H'/\ln(S) \quad (5)$$

where:

$H'$  = the Shannon Diversity Index

$S$  = the total number of species

$\ln(S)$  = the natural logarithm of  $S$

$$\text{Jaccard Similarity index, } J(A, B) = |A \cap B| / |A \cup B| \quad (6)$$

(number of observations in both sets) / (number in either set)

If two datasets share the exact same members, their Jaccard Similarity Index will be 1. Conversely, if they have no members in common, their similarity will be 0.

## Results and Discussion

### Water Quality Parameters of the Studied Sites

The present study revealed marked the variation in environmental conditions, diversity and structure among periphyton and phytoplankton communities across the water bodies. Environmental variables showed clear differences from April to December, 2022.

Water temperature (WT) ranged from 19.9 °C (December) to 31.9°C (April) in Padma Pukur, On the other hand, water temperature varied between 21.1°C to 31.9 °C (mean 26.5 °C) of Transport Lake. In Auditorium Pond, the water temperature of periphyton sample ranged from 20.8 to 30.1 °C (mean 25.5 °C) and for phytoplankton sample, WT averaged 26 °C. Water temperature was consistently higher in April and declined in December, a seasonal pattern also reported for other tropical lakes (Hannan, 1979; Dwivedi & Pandey, 2002). In April, the mean water temperature of Lake Ashura was  $30.0 \pm 0.45^\circ\text{C}$  (Alfasane et al., 2012), close to the findings of the present investigation.



In Padma Pukur, secchi depth declined from 60.7 cm (April) to 39 cm (December) and mean variation was 50-59 cm. In Transport Lake, secchi depth ranged highest in April (74 cm) and mean variation was 55-60 cm. In Auditorium Pond, the secchi depth was the lowest among the three sites (35 to 56.9 cm) in case of periphyton sample and for phytoplankton sample it averaged 48.5 cm. In the present study, April showed the highest secchi transparency for all of the studied water bodies. The range of secchi disc transparency is almost similar to other aquatic habitats of Bangladesh (Khondker and Abed 2013, Turag River: 20 cm to 50 cm; Ameen et al., 1986, Fish Pond, Raipur: 58-76 cm) but the range of Secchi disc transparency (8.89-53.34 cm) is low in Chandbil baor of Meherpur, Bangladesh (Kabir and Naser 2011). The range of transparency of three lakes of Jahangirnagar University lakes was 22-87 cm (Rahman et al., 2015). The range of transparency of three lakes of Jahangirnagar University lakes was 22-87 cm (Rahman et al., 2015).

In case of conductivity, it ranged from 70.8  $\mu\text{S}/\text{cm}$  in (April) to 81.5  $\mu\text{S}/\text{cm}$  (December) in Padma Pukur while markedly higher ranged from 140 -380  $\mu\text{S}/\text{cm}$  in Transport Lake. Conductivity varied from 116 to 275  $\mu\text{S}/\text{cm}$  in the Auditorium Pond. The outside range of conductivity between 150 and 500  $\mu\text{S}/\text{cm}$  of fresh waters could indicate the unsuitability for some species of fish or macro-invertebrates (APHA, 1992). According to APHA, among all the study site of this research, water of the Padma Pukur is more suitable for aquatic lives. The mean conductivity was 81.66  $\mu\text{S}/\text{cm}$  which was lower than 1294  $\mu\text{S}/\text{cm}$  reported earlier by Islam et al., (2014) in the Hakaluki Haor. Alam (2017) reported the average EC was 64.5  $\mu\text{S}/\text{cm}$ , 88.5  $\mu\text{S}/\text{cm}$  and 74.25  $\mu\text{S}/\text{cm}$  during pre-monsoon, monsoon and post-monsoon seasons, respectively from the wetland at National Monument of Bangladesh.

Dissolved oxygen decreased from 6.43 mg/L in April to 3.03 mg/L in December in the first site, the mean of the DO was 7.8 mg/L in the second site and varied between 3.4 to 9.8 mg/ for the third site (Fig. 2). In Auditorium Pond, DO values were comparatively elevated, averaging 8 mg/L. Chowdhury and Mazumder (1981) carried out limnological research on Kaptai Lake and found quit similar DO (6.25 mg/l) of the present research. Islam and Saha (1975) detected DO of Ramna Lake ranged from 3.51-4.59 mg/l, Islam and Mendes (1976) observed dissolved oxygen ranged from and 4.48-9.83 mg/l in Sher-e-Bangla Nagar Jheel. In contrast, Khondker and Parveen (1993) reported very low DO concentration (0.18 mg/l) for Dhanmondi Lake.

The mean of TDS ranged 39-60 mg/l, 95-78 mg/l and 65-77 mg/l for the three studied sites, respectively. The variation of TDS value (28-142 mg/l) detected by Alam et al., 2017 in the wetland at National Monuments of Bangladesh was higher than the present study.

Alkalinity ranged between 0.2-23 meq/l, 0.2-78 meq/l and 0.2-72 meq/l in the present studied site, respectively. The total alkalinity range was higher (43-92 meq/l) in three lakes of Jahangirnagar University campus (Rahman et al., 2015) than the present result. The range of alkalinity was 51.3 to 85.5 mg in the chandbil baor of Meherpur district in Bangladesh (Kabir and Naser 2011) that is also higher than that of the present study. The alkalinity greater than 100 meq/l was indicated highly productive water by Alikunhi (1957). The water of the present study seemed unproductive in nature.

The mean pH was 8.9 and 6.8 in both sample of Padma Pukur, while 9.5 and 3.9 in transport lake and 9.2 and 7.2 in Auditorium Pond. Almost all study area contained alkaline water. In winter, the water was acidic. The optimum pH range has been reported as 6.8 - 9.0 for aquatic life (Trevedi and Raj 1992) while WHO (1984) reported that the water is best between 6.5 to 8.5 pH ranging. The mean pH of Dhanmondi lake was 7.5 (Khondker and Parveen, 1992) which is nearly close to that of recorded pH of present investigation. In another study, Islam et al., (2015) pointed out the ranges of pH were from 7.14-8.87, 7.30-8.83 and 7.12 -8.76 in Ramna, Crescent and Hatirjheel lakes, respectively.



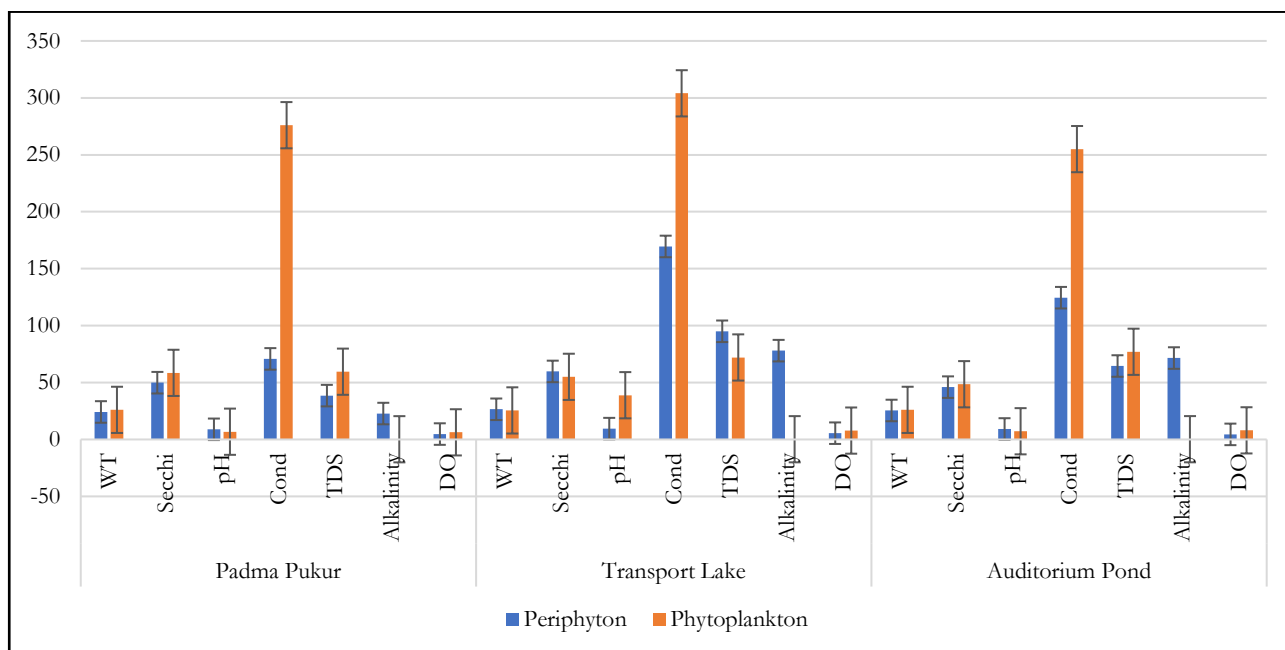


**Figure 2. Limnological Parameters of Water Recorded in Periphyton and Phytoplankton Sampling Stations (Padma Pukur, Transport Lake and Auditorium Pond) from April to December in 2022**

## Community Composition

### Periphyton

In the present study, a total of 60 genera of periphyton were recorded across the three study sites. In Padma Pukur, April assemblages were dominated by Zygnematophyceae (35%), followed by Bacillariophyceae (30%) and Chlorophyceae (25%). Minor groups included Xanthophyceae and Tribophyceae (5% each). In December, Zygnematophyceae remained significant (26%), while Cyanophyceae (18%), Bacillariophyceae (17%), Euglenophyceae (13%) and Chlorophyceae (9%) were also noteworthy. Minor groups such as Dinophyceae, Trebouxiophyceae, Coleochaetophyceae (4% each) contributed further diversity (Fig. 3).

On the other hand, periphyton showed a strong dominance of Bacillariophyceae in Transport Lake. In April, Bacillariophyceae comprised 42%, followed by Chlorophyceae (21%), Euglenophyceae (9%) and Trebouxiophyceae (8%) in Transport Lake. Others contributed 4% each. In December, Bacillariophyceae increased further (59%), with Chlorophyceae (11%) as a major group. Dinophyceae contributed 6%. Similarly, in Auditorium Pond, April communities were led by Bacillariophyceae (37%), followed by Cyanophyceae (21%), Euglenophyceae (16%), and Chlorophyceae (11%). Zygnematophyceae, Xanthophyceae and Dinophyceae each contributed 5%. In December, Bacillariophyceae (67%) remained dominant, followed by Zygnematophyceae (9%). Euglenophyceae, Chrysophyceae and Xanthophyceae contributed 5% each (Fig. 3). According to Gurumayum and Goswami, 2013, among the periphyton population, Bacillariophyceae dominated during winter (57.1%), monsoon (69%) and post monsoon (96.1%) seasons in Thoubal river that is similar to the present investigation. In this study Bacillariophyceae dominated April and December month in Transport Lake and Auditorium Pond.



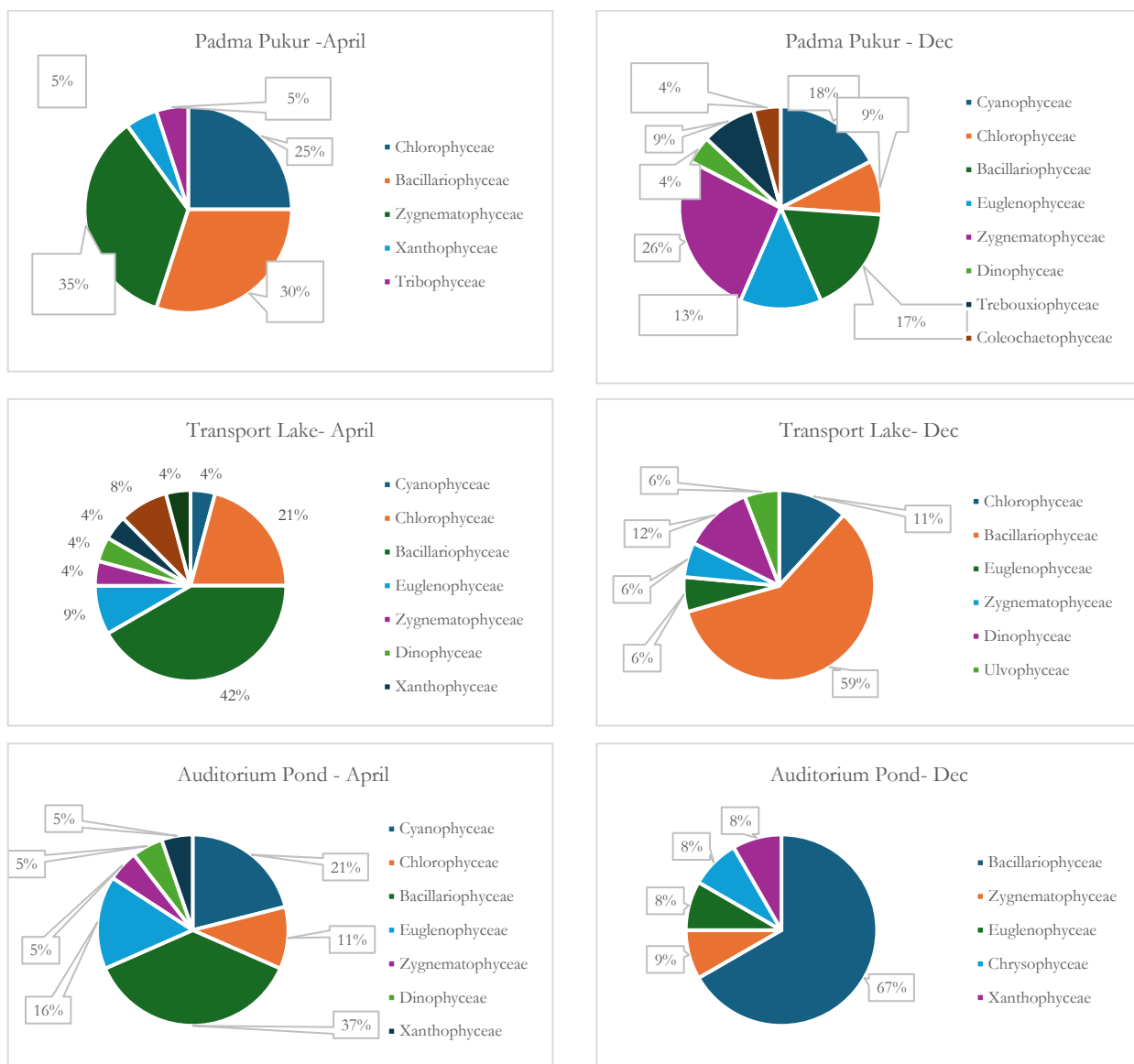


**Figure 3. Class-Level Composition of Periphytic Algae in Padma Pukur, Transport Lake and Auditorium Pond during April and December 2022**

Dominance of diatoms corroborated with findings of Fritsch (1945) suggested that, Bacillariophyceae dominance is favored by the secretion of mucilage by them and their quality to withstand changes of light intensity, temperature and other adverse conditions. Sukumaran et al. (1996) in a lentic habitat in Bangalore, Kawosa (2001) in rural lake of Kashmir; Singh et al., (2003) in a man-made lake, India found same result (Bacillariophyceae dominance) in their research.

### Number of Species

A total number of 122 different species were identified attached to five different free-floating hydrophytes (*Salvinia minima*, *Nelumbo nucifera*, *Nymphaea pubescens*, *Pistia stratiotes* and *Eichhornia crassipes*) from the study area (Table 2). The present investigation observed macrophyte *Salvinia minima* harbored the algae of Chlorophyceae, Bacillariophyceae and Zygnemmatophyceae; algae belonging to Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae attached to *Nelumbo nucifera*; phytoplankton of Cyanophyceae, Chlorophyceae and Bacillariophyceae were found to be more in association with *Pistia*



*stratiotes* and *Nymphaea pubescens*. Cyanophyceae, Bacillariophyceae and Euglenophyceae algae were available on the roots of *Eichhornia crassipes*. In 2023, Yunandar *et al.*, investigated that the free-floating hydrophytes species *Eichhornia crassipes* and *Salvinia molesta* in Negara River of Indonesia provide shelter for the periphyton of Chrysophyta.

**Table 2. List of Periphytic Algae Found Attached to Particular Hydrophytes**

| No. | Name of periphyton                  | Shelter providing hydrophytes |                         |                           |                          |                             |
|-----|-------------------------------------|-------------------------------|-------------------------|---------------------------|--------------------------|-----------------------------|
|     |                                     | <i>Salvinia minima</i>        | <i>Nelumbo nucifera</i> | <i>Nymphaea pubescens</i> | <i>Pistia stratiotes</i> | <i>Eichhornia crassipes</i> |
| 01  | <i>Ankistrodesmus falcatus</i>      | +                             | -                       | -                         | -                        | -                           |
| 02  | <i>Chlorococcum infusionum</i>      | +                             | -                       | +                         | -                        | -                           |
| 03  | <i>Oedogonium franklinianum</i>     | +                             | -                       | -                         | -                        | -                           |
| 04  | <i>Planktosphaeria gelatinosa</i>   | +                             | +                       | -                         | -                        | -                           |
| 05  | <i>Amphora commutata</i>            | +                             | +                       | -                         | -                        | -                           |
| 06  | <i>Amphora ovalis</i>               | +                             | -                       | -                         | -                        | -                           |
| 07  | <i>Cymbella gracilis</i>            | +                             | -                       | +                         | -                        | -                           |
| 08  | <i>Cymbella stuxbergii</i>          | +                             | -                       | -                         | -                        | -                           |
| 09  | <i>Cymbella turgidula</i>           | +                             | -                       | +                         | -                        | -                           |
| 10  | <i>Cymbella ventricose</i>          | +                             | -                       | -                         | -                        | -                           |
| 11  | <i>Gomphonema affine</i>            | +                             | -                       | -                         | -                        | +                           |
| 12  | <i>Gomphonema beleveticum</i>       | +                             | -                       | -                         | -                        | -                           |
| 13  | <i>Gomphonema longiceps</i>         | +                             | +                       | -                         | -                        | -                           |
| 14  | <i>Gomphonema subtile</i>           | +                             | -                       | -                         | -                        | -                           |
| 15  | <i>Gomphonema olivaceum</i>         | -                             | -                       | -                         | +                        | -                           |
| 16  | <i>Gomphonema gracile</i>           | -                             | -                       | -                         | -                        | +                           |
| 17  | <i>Gomphonema lanceolatum</i>       | -                             | -                       | +                         | -                        | +                           |
| 18  | <i>Gomphonema minutum</i>           | -                             | -                       | -                         | -                        | +                           |
| 19  | <i>Navicula bacillum</i>            | +                             | -                       | -                         | -                        | -                           |
| 20  | <i>Navicula radiosa</i>             | +                             | -                       | -                         | -                        | +                           |
| 21  | <i>Navicula americana</i>           | +                             | -                       | +                         | -                        | -                           |
| 22  | <i>Navicula lanceolata</i>          | -                             | -                       | -                         | -                        | +                           |
| 23  | <i>Navicula mutica</i>              | -                             | -                       | -                         | -                        | +                           |
| 24  | <i>Navicula phyllepta</i>           | -                             | -                       | -                         | -                        | +                           |
| 25  | <i>Navicula pupula</i>              | -                             | -                       | -                         | -                        | +                           |
| 26  | <i>Nitzschia gracilis</i>           | +                             | -                       | -                         | -                        | +                           |
| 27  | <i>Nitzschia sigma</i>              | -                             | -                       | +                         | -                        | +                           |
| 28  | <i>Nitzschia fruticosa</i>          | -                             | +                       | -                         | -                        | -                           |
| 29  | <i>Nitzschia palea</i>              | +                             | -                       | -                         | +                        | -                           |
| 30  | <i>Nitzschia linearis</i>           | -                             | -                       | -                         | -                        | +                           |
| 31  | <i>Pinnularia brevicostata</i>      | +                             | -                       | -                         | -                        | +                           |
| 32  | <i>Pinnularia major</i>             | +                             | +                       | -                         | -                        | -                           |
| 33  | <i>Pinnularia microstauron</i>      | -                             | -                       | -                         | -                        | -                           |
| 34  | <i>Pinnularia stauoptera</i>        | +                             | -                       | -                         | +                        | -                           |
| 35  | <i>Pinnularia stauoptera</i>        | +                             | +                       | -                         | -                        | -                           |
| 36  | <i>Pinnularia viridis</i>           | +                             | -                       | -                         | -                        | -                           |
| 37  | <i>Pinnularia brounii</i>           | -                             | -                       | -                         | +                        | -                           |
| 38  | <i>Pinnularia neomajor</i>          | -                             | -                       | +                         | -                        | +                           |
| 39  | <i>Pinnularia acrosphaeria</i>      | -                             | -                       | -                         | -                        | +                           |
| 40  | <i>Pinnularia gibba</i>             | -                             | -                       | -                         | -                        | +                           |
| 41  | <i>Actinotaenium pseudoconnatum</i> | +                             | -                       | -                         | -                        | -                           |
| 42  | <i>Actinotaenium turgidum</i>       | +                             | -                       | -                         | -                        | -                           |
| 43  | <i>Arthrodesmus apiculatus</i>      | +                             | -                       | -                         | -                        | -                           |
| 44  | <i>Actinotaenium diploporum</i>     | -                             | +                       | -                         | -                        | -                           |
| 45  | <i>Aphanothece microscopica</i>     | -                             | +                       | -                         | -                        | -                           |



|     |                                                |   |   |   |   |   |
|-----|------------------------------------------------|---|---|---|---|---|
| 46  | <i>Gleocapsa magma</i>                         | - | + | - | - | - |
| 47  | <i>Gleocapsa monata</i>                        | - | + | - | - | - |
| 48  | <i>Oscillatoria princeps</i>                   | - | + | + |   | - |
| 49  | <i>Oscillatoria amphibia</i>                   | - | - | + | + | - |
| 50  | <i>Oscillatoria limosa</i>                     | - | - | + | + | - |
| 51  | <i>Phormidium autumnale</i>                    | - | + | - | - | - |
| 52  | <i>Phormidium bulgaricum</i>                   | - | + | - | - | - |
| 53  | <i>Phormidium chlorinum</i>                    | - | - | + | - | - |
| 54  | <i>Phormidium teergerstinum</i>                | - | - | + | - | - |
| 55  | <i>Kirchneriella irregularis</i>               | - | + | - | + | - |
| 56  | <i>Euglena viridis</i>                         | - | + | - | - | - |
| 57  | <i>Euglena hemisphaerica</i>                   | - | - | - | + | - |
| 58  | <i>Euglena clara</i>                           | - | - | - | - | + |
| 59  | <i>Phacus orbicularis</i>                      | - | + | - | - | - |
| 60  | <i>Phacus circulatus</i>                       | - | - |   | + | - |
| 61  | <i>Trachelomonas allia</i>                     | - | + | - | - | - |
| 62  | <i>Trachelomonas cervicula</i>                 | - | - | - | - | + |
| 63  | <i>Trachelomonas hispida</i>                   | - | - | - | - | + |
| 64  | <i>Trachelomonas hispida</i>                   | - | - | - | - | + |
| 65  | <i>Trachelomonas volvocina</i>                 | - | - | - | - | + |
| 66  | <i>Closterium closterioides</i>                | - | + | - | - | - |
| 67  | <i>Closterium lunula</i>                       | - | + | - | - | - |
| 68  | <i>Closterium rostratum</i>                    | - | - | - | - | + |
| 69  | <i>Closterium ebrenbergii</i>                  | - | - | - | + | - |
| 70  | <i>Closterium pseudolunula</i>                 | - | - | - | - | + |
| 71  | <i>Closterium leibleinii</i>                   | - | - | - | + | - |
| 72  | <i>Cosmarium lundelli</i>                      | - | + | - | - | - |
| 73  | <i>Cosmarium obsoletum</i>                     | - | + | - | - | - |
| 74  | <i>Cosmarium pachydermum</i>                   | - | + | - | - | - |
| 75  | <i>Cosmarium pardails</i>                      | - | + | - | - | - |
| 76  | <i>Cosmarium taxichondriiforme</i>             | - | + | - | - | - |
| 77  | <i>Euastrum didelta</i> var. <i>bengalicum</i> | - | + | - | - | - |
| 78  | <i>Pleurotaenium trabecula</i>                 | - | + | - | - | - |
| 79  | <i>Staurastrum furcatum</i>                    | - | + | - | - | - |
| 80  | <i>Staurastrum disputatum</i>                  | - | + | - | - | - |
| 81  | <i>Staurastrum pinnatum</i>                    | - | + | - | - | - |
| 82  | <i>Staurastrum polymorphum</i>                 | - | + | - | - | - |
| 83  | <i>Staurastrum rectangulare</i>                | - | + | - | - | - |
| 84  | <i>Peridiniella catenata</i>                   | - | + | - | - | - |
| 85  | <i>Coccomyxa confluens</i>                     | - | + | - | - | - |
| 86  | <i>Desmococcus vulgaris</i>                    | - | + | - | - | - |
| 87  | <i>Chaetosphaeridium</i>                       | - | + | - | - | - |
| 88  | <i>Apocalathium malmogiense</i>                | - | - | - | - | - |
| 89  | <i>Ophiocytium capitatum</i>                   | - | - | - | - | - |
| 90  | <i>Chlorella vulgaris</i>                      | - | - | - | + | - |
| 91  | <i>Dictyosphaerium pulchellum</i>              | - | - | - | + | - |
| 92  | <i>Mallomonas caudata</i>                      | - | - | - | + | - |
| 93  | <i>Borodiniella polytetrax</i>                 | - | - | - | + | - |
| 94  | <i>Gonium pectoral</i>                         | - | - | - | + | - |
| 95  | <i>Pediastrum duplex</i>                       | - | - | + | + | - |
| 96  | <i>Scenedesmus armatus</i>                     | - | - | - | + | - |
| 97  | <i>Eunotia bilunaris</i>                       | - | - | + | + | - |
| 98  | <i>Eunotia monodon</i>                         | - | - | + | + | - |
| 99  | <i>Eunotia pectinalis</i>                      | - | - | + | - | - |
| 100 | <i>Fragilaria intermedia</i>                   | - | - | - | + | - |
| 101 | <i>Fragilaria capucina</i>                     | - | - | + | - | - |
| 102 | <i>Fragilaria crotonensis</i>                  | - | - | + | - | - |



|     |                                        |   |   |   |   |   |
|-----|----------------------------------------|---|---|---|---|---|
| 103 | <i>Frustulia rhomboides</i>            | - | - | - | + | - |
| 104 | <i>Melosira granulata</i>              | - | - | - | + | - |
| 105 | <i>Rhoicosphenioa abbreviate</i>       | - | - | - | + | - |
| 106 | <i>Stauroneis schroederi</i>           | - | - | - | + | - |
| 107 | <i>Synedra ulna</i>                    | - | - | - | + | - |
| 108 | <i>Synedra ulna</i>                    | - | - | - | + | - |
| 109 | <i>Synedra ulna</i> var. <i>Danica</i> | - | - | - | + | - |
| 110 | <i>Synedra ulna</i>                    | - | - | - | + | - |
| 112 | <i>Spirulina major</i>                 | - | - | + | - | - |
| 113 | <i>Carteria globosa</i>                | - | - | + | - | - |
| 114 | <i>Merismopedia trolleri</i>           | - | - | + | - | - |
| 115 | <i>Borodiniella polytetrax</i>         | - | - | + | - | - |
| 116 | <i>Cyclotella comta</i>                | - | - | + | - | - |
| 117 | <i>Gonyaulax spinifera</i>             | - | - | + | - | - |
| 118 | <i>Cladosphora echinus</i>             | - | - | + | - | - |
| 119 | <i>Gonyaulax spinifera</i>             | - | - | + | - | - |
| 120 | <i>Cladosphora echinus</i>             | - | - | + | - | - |
| 121 | <i>Merismopedia trolleri</i>           | - | - | + | - | - |
| 122 | <i>Lepocynclis acuta</i>               | - | - | - | - | + |
| 123 | <i>Lepocyncli cymbiformis</i>          | - | - | - | - | + |
| 124 | <i>Gonyaulax spinifera</i>             | - | - | - | - | + |
| 125 | <i>Diademsis confervacea</i>           | - | - | - | - | + |
| 126 | <i>Diatoma hyemalis</i>                | - | - | - | - | + |

## Phytoplankton

A total of 44 phytoplankton genera were identified from the three study sites in the present investigation. In Padma Pukur, phytoplankton was dominated in April by Cyanophyceae (68%), with Euglenophyceae contributing 14%, Cryptophyceae 9%, Xanthophyceae 5% and Bacillariophyceae 4%. However, in December, Bacillariophyceae dominated (60%), followed by Cryptophyceae (20%), and Cyanophyceae and Dinophyceae each 10% (Fig. 4). Studies by Ali et al., (1985a) in a pond and Hossain et al., (1998) in Basukhali-Salimpur-Kola Barnal beel reported that, Cyanophyceae was the most dominant, followed by Chlorophyceae and Bacillariophyceae whereas, Bacillariophyceae (54.45%) was dominant in winter reported by Alam (2017) in a wetland of Bangladesh, that is similar to Padma Pukur of the present research.

Likewise, phytoplankton in April was dominated by Bacillariophyceae (31%), followed by Euglenophyceae (23%), Chlorophyceae (15%) and Cryptophyceae (15%) in Transport Lake (Fig.4). Cyanophyceae and Dinophyceae each contributed 8%. In December, Euglenophyceae were also most abundant (37%), followed by Bacillariophyceae (27%), Cryptophyceae (18%), Chlorophyceae (9%), and Dinophyceae (9%). According to Alam (2017) in post monsoon, the dominant phytoplankton in the wetland was Bacillariophyceae (54.45%), followed by Chlorophyceae (21.96%), Cyanophyceae (19.64%), and Euglenophyceae (3.95%) resembles the present investigation. The occurrence of high population of Euglenophyceae in organically enriched pond was reported by Ameen et al., (1986). In winter, water bodies contain less water and they become enriched by nutrients provide suitable environment for the Euglenophycean algae.

On the contrary, in Auditorium Pond, phytoplankton was dominated by Chlorophyceae (53%), followed by Euglenophyceae and Cryptophyceae (each 12%) and Bacillariophyceae (11%) in April. Cyanophyceae and Dinophyceae each contributed 6%. In December, Chlorophyceae (50%) remained dominant, followed by Euglenophyceae (25%) and Bacillariophyceae (15%) while Cyanophyceae and Dinophyceae contributed 5% each (Fig. 4). Chlorophyceae dominated phytoplankton community during summer season was also reported by Ahmed et al., (1997) in kaptai lake.





**Figure 4. Class-Level Composition of Phytoplankton Communities in Padma Pukur, Transport Lake and Auditorium Pond during April and December 2022**

### Alpha Diversity

The diversity indices of phytoplankton and periphyton across the three lakes during April and December are presented in Table 1. In Padma Pukur, periphyton in April recorded richness ( $S = 20$ ) and Shannon diversity ( $H' = 2.77$ ), with high evenness ( $J' = 0.93$ ). Phytoplankton, in contrast, showed higher richness ( $S = 22$ ) but lower diversity ( $H' = 2.18$ ) and reduced evenness ( $J' = 0.71$ ). In December, periphyton richness increased ( $S = 23$ ) with moderate diversity ( $H' = 2.84$ ) and high evenness ( $J' = 0.99$ ), whereas phytoplankton richness dropped ( $S = 10$ ) and diversity remained low ( $H' = 1.82$ ;  $J' = 0.79$ ).

Periphyton showed relatively high richness ( $S = 24$ ) and diversity ( $H' = 4.01$ ;  $J' = 1.26$ ) in April, indicating a well-distributed community In Transport Lake. Phytoplankton, however, exhibited lower richness ( $S = 13$ ) and diversity ( $H' = 2.21$ ;  $J' = 0.86$ ). By December, periphyton richness decreased ( $S = 17$ ) with  $H' = 2.76$  and  $J' = 0.97$ , while phytoplankton also declined ( $S = 11$ ;  $H' = 1.75$ ;  $J' = 0.73$ ). In Auditorium Pond, high richness ( $S = 19$ ) and balanced diversity ( $H' = 2.88$ ;  $J' = 0.98$ ) were recorded in the periphyton in April. Phytoplankton, however, displayed extremely high density ( $PD = 844.9 \times 10^4$  ind/L), resulting in



very low Shannon diversity ( $H' = 0.45$ ) and evenness ( $J' = 0.16$ ). By December, periphyton richness declined ( $S = 12$ ) but maintained moderate diversity ( $H' = 2.34$ ;  $J' = 0.94$ ). Phytoplankton improved in diversity ( $S = 20$ ;  $H' = 2.59$ ;  $J' = 0.86$ ) though still remained lower than periphyton.

**Table 3. Diversity Indices of Phytoplankton and Periphyton Communities in Three Lakes (Padma Pukur, Transport Lake, and Auditorium Pond) during April and December. Indices Include Species Richness (S), Population Density (PD,  $\times 10^4$  ind/L), Shannon Diversity ( $H'$ ), Simpson's Index (1-D), Margalef's Index (d) and Pielou's Evenness ( $J'$ )**

| Lake            | Month    | Community     | S  | PD ( $\times 10^4$ ind/L) | $H'$ | 1-D  | d    | $J'$ |
|-----------------|----------|---------------|----|---------------------------|------|------|------|------|
| Padma Pukur     | April    | Periphyton    | 20 | 63.75                     | 2.77 | 0.93 | 4.57 | 0.93 |
|                 |          | Phytoplankton | 22 | 177.65                    | 2.18 | 0.79 | 4.05 | 0.71 |
|                 | December | Periphyton    | 23 | 36.98                     | 2.84 | 0.93 | 6.09 | 0.9  |
|                 |          | Phytoplankton | 10 | 19.13                     | 1.82 | 0.77 | 3.05 | 0.79 |
| Transport Lake  | April    | Periphyton    | 24 | 51.85                     | 4.01 | 0.84 | 5.83 | 1.26 |
|                 |          | Phytoplankton | 13 | 34                        | 2.21 | 0.86 | 3.4  | 0.86 |
|                 | December | Periphyton    | 17 | 39.53                     | 2.76 | 0.93 | 4.35 | 0.97 |
|                 |          | Phytoplankton | 11 | 17                        | 1.75 | 0.71 | 3.53 | 0.73 |
| Auditorium Pond | April    | Periphyton    | 19 | 103.7                     | 2.88 | 0.94 | 3.88 | 0.98 |
|                 |          | Phytoplankton | 17 | 844.9                     | 0.45 | 0.14 | 2.37 | 0.16 |
|                 | December | Periphyton    | 12 | 79.05                     | 2.34 | 0.89 | 2.52 | 0.94 |
|                 |          | Phytoplankton | 20 | 70.975                    | 2.59 | 0.91 | 4.46 | 0.86 |

### Common and Distinct Genera

In the month of April, in Padma Pukur, only one genus (*Closterium*) was common, while periphyton supported 19 exclusive genera (e.g., *Navicula*, *Pinnularia*, *Cymbella*, *Oedogonium*, *Ankistrodesmus*) and phytoplankton supported 21 exclusive genera (e.g., *Oscillatoria*, *Scenedesmus*, *Synedra*, *Pandorina*, *Trachelomonas*). The similarity was very low (Jaccard index = 0.024, 2.4%). By December, five genera were shared (*Oscillatoria*, *Nitzschia*, *Euglena*, *Phacus*, *Trachelomonas*), while periphyton retained 18 exclusive genera and phytoplankton five, giving a higher similarity (0.179, 17.9%).

In Transport Lake, six genera were shared in April (*Oscillatoria*, *Navicula*, *Pinnularia*, *Closterium*, *Euglena*, *Phacus*), while periphyton contained 18 exclusive genera and phytoplankton seven. The Jaccard index was 0.194 (19.4%). In December, three genera (*Navicula*, *Cyclotella*, *Lepocinclis*) were shared, periphyton had 14 exclusive genera, and phytoplankton eight, with a similarity of 0.120 (12.0%).

Three genera were shared in April (*Closterium*, *Navicula*, *Euglena*) in the Auditorium Pond. While periphyton contained nine exclusive genera (e.g., *Fragilaria*, *Frustulia*, *Synedra*, *Mallomonas*) and phytoplankton 17 exclusive genera (e.g., *Merismopedia*, *Scenedesmus*, *Chlorella*, *Cyclotella*, *Strombomonas*). The Jaccard index was 0.161 (16.1%). In December, the same three genera remained shared, with periphyton again having nine exclusive genera and phytoplankton 17 exclusive genera. The similarity index declined slightly (0.103, 10.3%). On average, Padma Pukur showed the lowest similarity between periphytic and phytoplankton genera (Jaccard index = 0.087), while Transport Lake showed the highest (0.161), followed by Auditorium Pond (0.133) (Table 2).



**Table 4. Comparison of Shared and Unique Genera of Periphyton and Phytoplankton Communities in Three Lakes (Padma Pukur, Transport Lake, and Auditorium Pond) during April and December**

| Lake        | Month    | Shared Genera | Periphyton | Phytoplankton | Jaccard Index |
|-------------|----------|---------------|------------|---------------|---------------|
| Padma Pukur | April    | 1             | 19         | 21            | 0.024 (2.4%)  |
|             | December | 5             | 18         | 5             | 0.179 (17.9%) |
| Transport   | April    | 6             | 18         | 7             | 0.194(19.4%)  |
|             | December | 3             | 14         | 8             | 0.120 (12.0%) |
| Auditorium  | April    | 5             | 14         | 12            | 0.161(16.1%)  |
|             | December | 3             | 9          | 17            | 0.103 (10.3%) |

### Correlations Between Diversity Indices and Environmental Parameters (Periphyton)

The correlation analysis (Figure 4) showed that species richness (S) was very strongly correlated with Margalef's index ( $r = 0.99$ ). Richness also had positive correlations with Secchi depth ( $r = 0.55$ ), Shannon diversity ( $r = 0.52$ ), dissolved oxygen ( $r = 0.53$ ), and Margalef ( $r = 0.99$ ), while showing weak negative correlations with pH ( $r = -0.22$ ), conductivity ( $r = -0.27$ ), TDS ( $r = -0.18$ ), alkalinity ( $r = -0.60$ ), and water temperature ( $r = -0.28$ ). Shannon diversity ( $H'$ ) was strongly correlated with Secchi depth ( $r = 1.00$ ), dissolved oxygen ( $r = 1.00$ ), pH ( $r = 0.71$ ), conductivity ( $r = 0.68$ ), TDS ( $r = 0.75$ ), and evenness ( $r = 0.89$ ).

Simpson's index showed strong negative correlations with Shannon ( $r = -0.83$ ), Margalef ( $r = -0.09$ ), evenness ( $r = -0.99$ ), water temperature ( $r = -0.97$ ), Secchi depth ( $r = -0.82$ ), pH ( $r = -0.98$ ), conductivity ( $r = -0.97$ ), TDS ( $r = -0.99$ ), alkalinity ( $r = -0.82$ ), and dissolved oxygen ( $r = -0.83$ ). Evenness was positively correlated with Shannon ( $r = 0.89$ ), water temperature ( $r = 0.93$ ), Secchi depth ( $r = 0.88$ ), pH ( $r = 0.95$ ), conductivity ( $r = 0.94$ ), TDS ( $r = 0.97$ ), and alkalinity ( $r = 0.75$ ). Water temperature was positively correlated with pH ( $r = 1.00$ ), conductivity ( $r = 1.00$ ), TDS ( $r = 0.99$ ), and alkalinity ( $r = 0.94$ ). Secchi depth correlated with Shannon ( $r = 1.00$ ), dissolved oxygen ( $r = 1.00$ ), pH ( $r = 0.70$ ), and conductivity ( $r = 0.66$ ). pH was highly correlated with conductivity ( $r = 1.00$ ), TDS ( $r = 1.00$ ), and alkalinity ( $r = 0.91$ ). Conductivity was similarly correlated with TDS ( $r = 1.00$ ) and alkalinity ( $r = 0.93$ ). TDS was also correlated with alkalinity ( $r = 0.90$ ). Alkalinity showed a weaker correlation with dissolved oxygen ( $r = 0.37$ ).

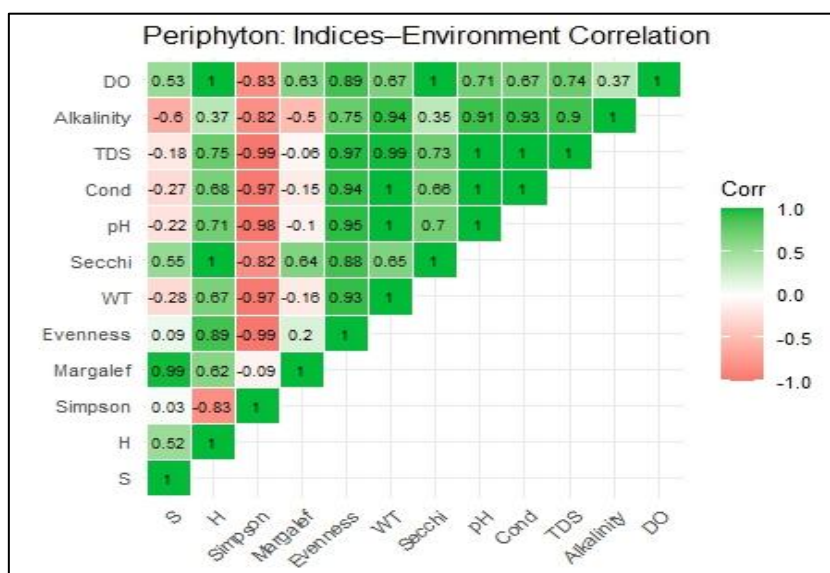


**Figure 4. Correlation Matrix Showing Relationships between Periphytic Diversity Indices and Environmental Variables**



## Correlations Between Diversity Indices and Environmental Parameters (Phytoplankton)

The correlation analysis of phytoplankton indices with environmental parameters (Figure 5) revealed positive links of species richness (S) with water temperature ( $r = 0.92$ ) and pH ( $r = 1.00$ ), while negative correlations were found with Shannon diversity ( $r = -0.77$ ), Simpson's index ( $r = -0.80$ ), evenness ( $r = -0.87$ ), conductivity ( $r = -1.00$ ), Secchi depth ( $r = -0.53$ ), and dissolved oxygen ( $r = -0.03$ ). Shannon diversity ( $H'$ ) was strongly correlated with Simpson ( $r = 1.00$ ), evenness ( $r = 0.98$ ), and Secchi depth ( $r = 0.95$ ). It showed negative correlations with species richness ( $r = -0.77$ ), pH ( $r = -1.00$ ), TDS ( $r = -0.75$ ), alkalinity ( $r = -0.76$ ), and dissolved oxygen ( $r = -0.62$ ). Simpson's index was highly correlated with Shannon diversity ( $r = 1.00$ ), evenness ( $r = 0.99$ ), and Secchi depth ( $r = 0.93$ ). Negative correlations were found with richness ( $r = -0.80$ ), pH ( $r = -1.00$ ), TDS ( $r = -0.71$ ), alkalinity ( $r = -0.72$ ), and dissolved oxygen ( $r = -0.57$ ). Margalef's index showed positive correlations with Shannon diversity ( $r = 0.80$ ), Simpson ( $r = 0.77$ ), and Secchi depth ( $r = 0.95$ ). It was negatively correlated with pH ( $r = -1.00$ ), TDS ( $r = -1.00$ ), alkalinity ( $r = -1.00$ ), and dissolved oxygen ( $r = -0.96$ ).

Evenness was positively correlated with Shannon ( $r = 0.98$ ), Simpson ( $r = 0.99$ ), conductivity ( $r = 0.90$ ), and Secchi depth ( $r = 0.88$ ). It was negatively correlated with richness ( $r = -0.87$ ), pH ( $r = -1.00$ ), TDS ( $r = -0.61$ ), alkalinity ( $r = -0.62$ ), and dissolved oxygen ( $r = -0.46$ ). Water temperature was positively correlated with richness ( $r = 0.92$ ), but negatively with conductivity ( $r = -0.90$ ), alkalinity ( $r = -0.23$ ), and dissolved oxygen ( $r = -0.41$ ). Secchi depth correlated strongly with Shannon ( $r = 0.95$ ), Simpson ( $r = 0.93$ ), and Margalef ( $r = 0.95$ ), but negatively with richness ( $r = -0.53$ ), pH ( $r = -1.00$ ), TDS ( $r = -0.92$ ), alkalinity ( $r = -0.92$ ), and dissolved oxygen ( $r = -0.83$ ). pH showed perfect positive correlations with TDS ( $r = 1.00$ ), alkalinity ( $r = 1.00$ ), and dissolved oxygen ( $r = 1.00$ ), while being negatively correlated with Shannon ( $r = -1.00$ ), Simpson ( $r = -1.00$ ), Margalef ( $r = -1.00$ ), evenness ( $r = -1.00$ ), Secchi depth ( $r = -1.00$ ), and conductivity ( $r = -1.00$ ). TDS and alkalinity were highly correlated ( $r = 1.00$ ) and both were also strongly correlated with dissolved oxygen ( $r = 0.98$ ).

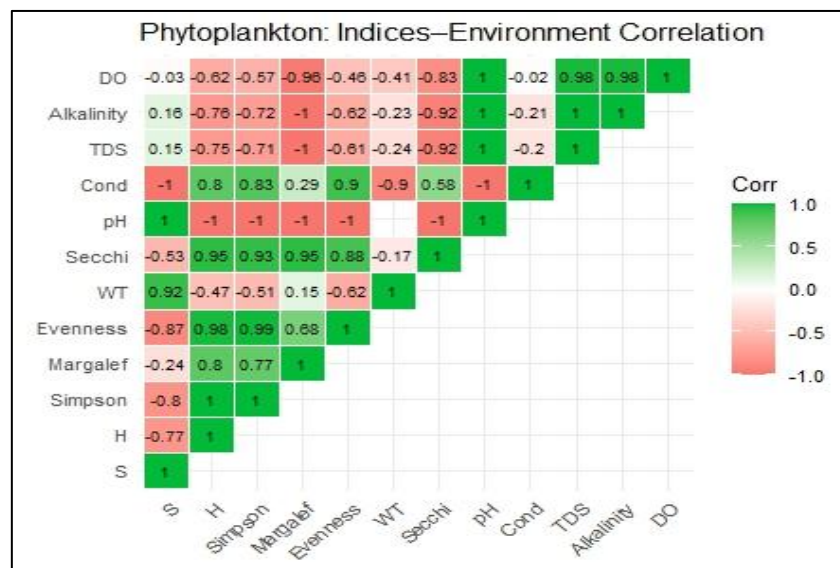


Figure 5. Correlation Matrix Showing Relationships between Phytoplankton Diversity Indices and Environmental Variables

The patterns of alpha diversity confirmed fluctuations between communities. Periphyton exhibited higher Shannon diversity and evenness than phytoplankton which formed well-balanced assemblages across lakes. This is in line with Moore (1980) and Begum & Hadi (1994), where benthic algae typically maintain richer, more evenly distributed communities compared with plankton. In Auditorium Pond, the



phytoplankton bloom in April ( $PD = 844.9 \times 10^4$  ind/L) caused very low Shannon diversity ( $H' = 0.45$ ), consistent with Moss (1973), who demonstrated that eutrophic blooms reduce diversity when a few taxa dominate.

### Dominant Phytoplankton

Periphyton was strongly dominated by Bacillariophyceae, especially in Transport Lake and Auditorium Pond, confirming the ecological preference of diatoms for benthic colonization (Grimes & Rushforth, 1983). However, in Padma Pukur, phytoplankton communities shifted from Cyanophyceae in April to Bacillariophyceae in December, while Auditorium Pond remained consistently dominated by Chlorophyceae, a group commonly reported as dominant in shallow, nutrient-rich ponds (Habib et al., 1991; Vyas & Kumar, 1968). The notable increase in Euglenophyceae in Auditorium Pond reflects their preference for organically enriched waters (Pringsheim, 1956). The analysis of shared and unique genera revealed very low similarity between periphytic and planktonic assemblages, with Jaccard indices ranging from 2.4% to 19.4%. This confirms that the two communities maintained largely distinct species pools, a pattern also noted by Moore (1980) in Great Bear Lake. Similar findings were reported by Sarwar & Zutshi (1988), who showed that attached algae on substrates develop independently of the plankton. This complementarity is ecologically important, as Vadeboncoeur et al. (2002) emphasized that benthic and pelagic producers together enhance overall lake biodiversity.

In the correlation analysis, periphyton diversity was positively associated with dissolved oxygen and water clarity. It refers that oxygen-rich and transparent habitats promote stable communities which is consistent with Hasan & Bhuiyan (2013). In contrast, phytoplankton richness increased with temperature and pH but declined with conductivity and oxygen which reflects stress conditions similar to those described by Jameel (1998). Positive links between water clarity and periphyton diversity align with Paramasivam & Kannan (2005), while the decline in phytoplankton evenness under high conductivity supports the conclusion of Vadeboncoeur et al. (2003) that nutrient enrichment favors dominance by a few taxa.

### Conclusion

The reason behind the scarcity of the studies on periphyton probably is for the difficulties in the assemblages of attached algae. In the present study periphyton showed higher and steadier diversity, while phytoplankton varied more with time and sometimes declined during blooms. Together, both groups support the overall biodiversity and ecological health of the lakes. More research should undertake to clarify the role of both types of algae in the geochemical cycling of N, C and P. Moreover, their responses to climate change and exposure anthropogenic pollutants using in situ approaches are now in crucial need. Furthermore, periphyton and phytoplankton studies may provide cumulative water quality degradation by human activities.

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