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The Spatio-temporal Variations of Phytoplankton Diversity of a Subtropical Sacred Lake of Meghalaya State, Northeast India

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ABSTRACT

The spatio-temporal variations of phytoplankton diversity of the 'de-mineralized' sacred Thadlaskein Lake of Meghalaya state of northeast India are monitored based on analyses of the littoral and limnetic assemblages. Our study reveals a total of 51 species, depicts notable desmid diversity, and records the speciose constellation of 49 species per sample. Phytoplankton indicates importance vis-a-vis net plankton abundance and exhibits quantitative dominance of Charophyta; Chlorophyta > Bacillariophyta > Dinozoa > Chrysophyta are sub-dominant groups, and Cyanobacteria and Euglenozoa record poor densities. *Closterium* spp., *Cosmarium* spp., *Scenedesmus* spp. and *Staurastrum* spp. are noteworthy taxa, and eleven species contribute notably to phytoplankton abundance. Our results depict high species diversity, lower dominance and high evenness. Individual abiotic factors exert the differential spatial influence on phytoplankton, and register the relative importance of the rainfall, transparency and total hardness, while the CCA registers the moderate cumulative influence of 10 abiotic factors on the littoral and limnetic assemblages. The spatial variations of various aspects of phytoplankton diversity and the influence of abiotic factors are hypothesized to the habitat heterogeneity amongst the two regions. The present study is a useful contribution to the phytoplankton diversity of India and that of the subtropical lacustrine environs of the country.

Keywords: Calcium poor, de-mineralized, phytoplankton assemblages, sacred lake, soft water

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Introduction

Thadlaskein or 'Pung Sajar Nangli', a man-made historical Lake of Meghalaya state of NEI, is named after the legacy of a young medieval Jaintia rebel leader named 'Sajar Nangli'. This sacred Lake is revered by the people of Raid Mukhla and is worshipped by the Niamtre community of Meghalaya. Our study on phytoplankton diversity of the sub-tropical Thadlaskein lake is important in view of the paucity of works based on the detailed analyses of the spatio-temporal variations of phytoplankton assemblages of India, and the sub-tropical lacustrine systems of north India (NI) in particular (Sharma and Sharma 2021a). Referring to NI, certain useful studies from its northwest region with a variable focus on temporal variations are from the lakes of Kashmir (Zutshi and Wanganeo 1984; Wanganeo and Wanganeo 1991; Baba and Pandit 2014; Ganai and Parveen 2014), Himachal Pradesh (Thakur et al. 2013; Gupta et al. 2018; Jindal et al. 2013, 2014a, 2014b) and Uttarakhand (Sharma and Singh 2018; Sharma and Tiwari 2018). The notable studies from lacustrine environs of northeast India (NEI) are, however, limited to the spatio-temporal analyses of phytoplankton diversity of the selected reservoirs of Mizoram (Sharma and Pachuau 2016) and Meghalaya (Sharma and Sharma 2021a, 2021b) states, while the works of Sharma (1995), Sharma and Lyngdoh (2003) and Sharma and Lyngskor (2003) dealt with the preliminary surveys from certain reservoirs of Meghalaya.

The present study on phytoplankton diversity of Thadlaskein Lake, based on analyses of the monthly littoral and limnetic net plankton collections, assumes national and regional limnology interest in light of the stated lacunae as well as a pioneering work on algal diversity of a sacred Lake of NEI. This study monitors the spatio-temporal variations of species composition, richness, community similarities, abundance, notable taxa, important species, species diversity, dominance, evenness, and the individual and cumulative influence of abiotic factors on phytoplankton assemblages. We compare our results with the studies from the Himalayan and sub-Himalayan sub-tropical lakes of India, and the floodplain lakes and the sub-tropical reservoirs of NEI.

Materials and Methods

Study Site

Thadlaskein Lake or 'Pung Sajar Nangli' (Lat. 25.4969° N, Long. 92.1730° E; area ~5 ha; max. depth 12 m) is located beside National Highway 6 by the side of Mukhla village and at a distance of about 10 km from the city of Jowai of West Jaintia Hills district of Meghalaya state of NEI (Figure 1, A-D).

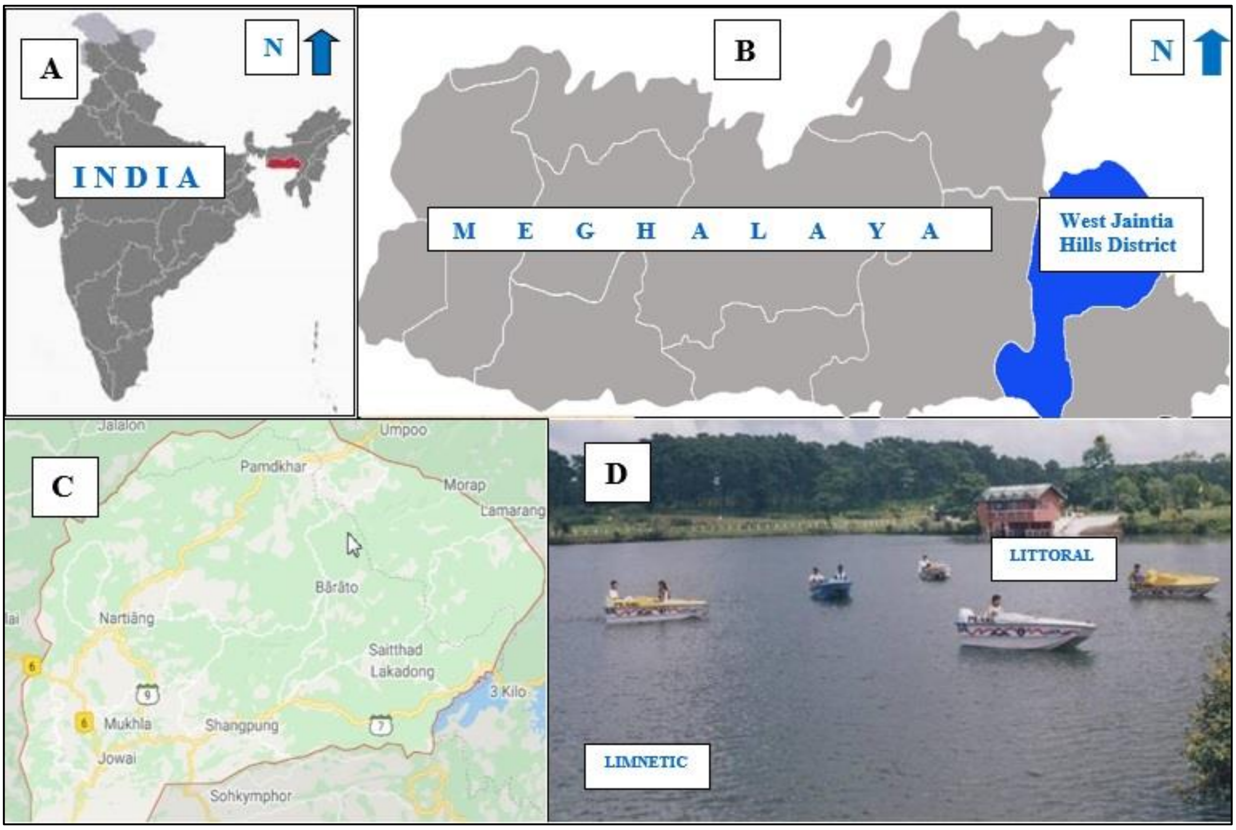

Figure 1. A-D: A, map of India showing Meghalaya state (red colour); B, District map of Meghalaya showing West Jaintia Hills district (blue colour); C, part map of West Jaintia Hills district showing the location of Mukhla village; D, Photograph of Thadlaskein Lake indicating the sampled Littoral and Limnetic regions

This lake is named after the legacy of a medieval young leader named Sajar Nangli - a rebel general of the Jaintia king who along with his clan dug this lake with the ends of their arrows to commemorate the great exodus of their clan. Thadlaskein Lake is fed by a perennial spring, indicates distinct growth of *Utricularia vulgaris* in the littoral region, and we categorize it as a small lake following Downing et al. (2008) and Céréghino et al. (2014).

Methodology

The present study is based on the limnological survey of Thadlaskein Lake undertaken during January–December 2016. Water samples as well as the qualitative and quantitative net plankton samples were collected at monthly intervals from the littoral and limnetic regions.

Physico-chemical Analysis: Water temperature, pH and specific conductivity were recorded with the field probes (Whatman), transparency was measured with a Secchi disc, dissolved oxygen was estimated by Winkler's method, and other abiotic factors namely total alkalinity, total hardness, calcium, magnesium, chloride, dissolved organic matter, total dissolved solids, phosphate, nitrate, sulphate and silicate were analyzed following APHA (1992). The rainfall data were obtained from the local meteorological station.

Sampling Procedure and Analyses: The qualitative net plankton samples were collected by towing a nylon bolt plankton net (#40 µm) and preserved in 5% formalin, and were screened with a Wild Stereoscopic binocular microscope. Phytoplankton was observed with a Leica stereoscopic microscope (DM 1000) and was identified following the works of Biswas (1949), Islam and Haroon (1980), Prescott (1982), Fitter and Manuel (1986), Anand (1998) and John et al. (2002). The community similarities were calculated to vide Sørensen's index and the hierarchical cluster analysis was computed vide SPSS (version 20). The quantitative net plankton samples were obtained by filtering 25 L of water each through the plankton net and were preserved in 5% formalin. The quantitative enumeration of phytoplankton assemblages was done by using a Sedgewick-Rafter counting cell and abundance was indicated as n/l (Woelkerling et al. 1976).

Data Analysis: Species diversity (Shannon-Weiner's index), dominance (Berger-Parker's index) and evenness (E_1 index) were calculated vide Ludwig and Reynolds (1988) and Magurran (1988). Two-way ANOVA was used to ascertain the significance of variations of the abiotic factors and phytoplankton. Pearson correlation coefficients, for the littoral and limnetic regions (r_1 and r_2, respectively), were calculated between abiotic factors and phytoplankton; p values (two-tailed) were calculated vide http://vassarstats.net/tabs.html and their significance were ascertained after Bonferroni corrections. The canonical correspondence analysis (XLSTAT 2015) was done to ascertain the cumulative influence of 10 abiotic parameters: water temperature, rainfall, transparency, specific conductivity, total alkalinity, total hardness, phosphate, nitrate, dissolved organic matter and total dissolved solids on the littoral and limnetic phytoplankton assemblages.

Results

The spatio-temporal variations of abiotic factors of Thadlaskein Lake are indicated in Table 1. This study records water temperature ranging between 12.0-24.5ºC, transparency between 47.0-120cm, pH between 6.38-6.95, specific conductivity between 20.0-29.5 µS/cm, dissolved oxygen between 6.1-8.6 mg/l, free carbon dioxide between 4.0-8.0 mg/l, total alkalinity between 19.0-29.0 mg/l, total hardness between 16.0-26.0 mg/l, calcium between 7.4-12.6 mg/l, magnesium between 3.3-9.8 mg/l, chloride between 20.5-39.0 mg/l, dissolved organic matter between 1.1-4.0 mg/l and total dissolved solids between 0.02-3.9 mg/l, while phosphate, nitrate, sulphate and silicate range between 0.210-0.547 mg/l, 0.007-0.089, 0.059-0.335 and 0.7-10.0 mg/l, respectively. Rainfall ranged between 12.0-1920.4 mm during the study. The significance of the spatio-temporal variations (vide ANOVA) of abiotic factors is indicated in Table 2.

Table 1. The spatio-temporal variations of abiotic factors

Regions→	**Littoral**		**Limnetic**	
Factors ↓	**Range**	**Mean ± S.D**	**Range**	**Mean ± S.D**
Water temperature (^{0}C)	12.0-22.5	18.8±3.6	16.5-24.5	18.7±3.7
Rainfall (mm)	12.0-1920.4	613.5±667.9	12.0-1920.4	613.5±667.9
Transparency (cm)	47.0-70.0	57.6±7.1	80-120	62.1±7.3
pH	6.38-6.85	6.62±0.17	6.40-6.95	6.67±0.15
Specific conductivity (µS/cm)	21.0-27.0	25.1±3.4	20.0-29.5	24.7±2.6
Dissolved oxygen (mg/l)	6.1-8.6	7.2±0.7	6.2-8.4	7.1±0.9
Free Carbon dioxide (mg/l)	4.0-8.0	6.7±1.2	4.0-9.0	6.0±1.3
Total Alkalinity (mg/l)	19.0-28.0	23.4±2.4	20.7-29.0	24.0±2.7
Total Hardness (mg/l)	16.0-25.0	19.5±4.8	16.9-26.0	21.2±2.2
Calcium (mg/l)	7.4-10.5	9.4±1.0	7.4-12.6	9.4±1.7
Magnesium (mg/l)	3.8-9.1	6.4±1.8	3.3-9.8	6.3±2.1
Chloride (mg/l)	20.5-36.5	33.1±5.0	23.0-39.0	32.7±5.1
Phosphate (mg/l)	0.278-0.547	0.413±0.082	0.210-0.478	0.349±0.091
Nitrate (mg/l)	0.010-0.041	0.018±0.008	0.007-0.089	0.021±0.022
Silicate (mg/l)	0.180-0.335	0.263±0.095	0.059-0.280	0.200±0.061
Sulphate (mg/l)	4.3-10.0	7.0±1.9	0.7-9.2	4.1±2.4
Dissolved organic matter (mg/l)	1.2-4.0	2.4±0.9	1.1-3.4	2.7±1.6
Total dissolved solids (mg/l)	1.0-2.6	1.7±0.5	0.2-3.9	1.3±1.8

Table 2. ANOVA indicating the spatio-temporal significance of abiotic factors

Parameters	Regions	Months
Water temperature	-	$F_{11,23}$=76.340, P=9.42E-09
Transparency	$F_{1,23}$ = 28.566, P = 0.0003	$F_{11,23}$ = 24.923, P = 3.48E-06
pH	-	-
Specific conductivity	-	$F_{11,23}$ = 5.133, P= 0.0057
Dissolved oxygen	-	-
Free Carbon dioxide	-	-
Total Alkalinity	-	$F_{11,23}$ = 3.783, P = 0.018
Total Hardness	-	$F_{11,23}$ = 7.116, P = 0.0015
Calcium	-	-
Magnesium	-	$F_{11,23}$ = 6.171, P = 0.0027
Chloride	-	$F_{11,23}$ = 4.379, P= 0.0107
Phosphate	$F_{1,23}$ = 43.466, P = 3.9E-05	$F_{11,23}$ = 27.915, P = 1.94E-06
Sulphate	-	-
Nitrate	-	-
Silicate	$F_{1,23}$ = 5.734, P = 0.035	-
Dissolved organic matter	-	$F_{11,23-}$= 6.324, P = 0.0024
Total dissolved solids	-	-

(-) insignificant variations

The littoral and limnetic phytoplankton assemblages (Table 3) reveal a total of 51 species. The monthly richness ranges between 34-44 and 37-49 species (Figure 2), records 71.4-94.5 and 67.5-94.7% community similarities, the hierarchical cluster analysis (Figures 3-4) indicates differences in the cluster groupings, and Charophyta richness varies between 19-26 and 19-25 species at the two regions, respectively.

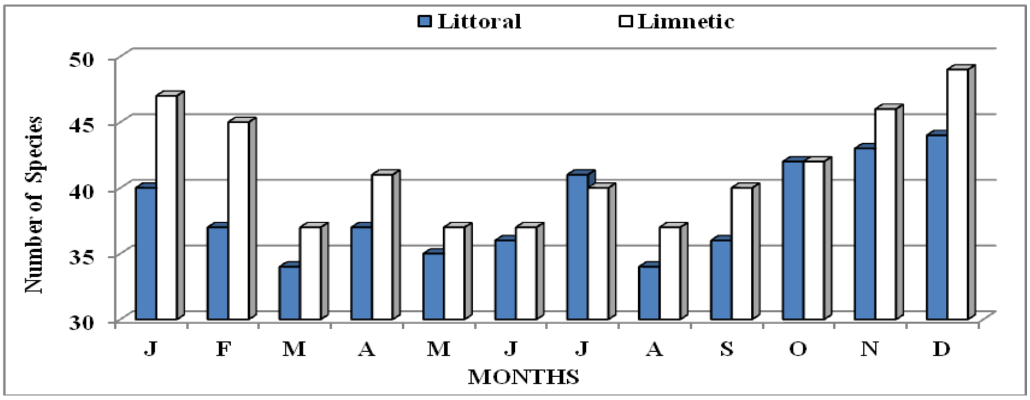

Figure 2. The spatio-temporal variations of phytoplankton richness

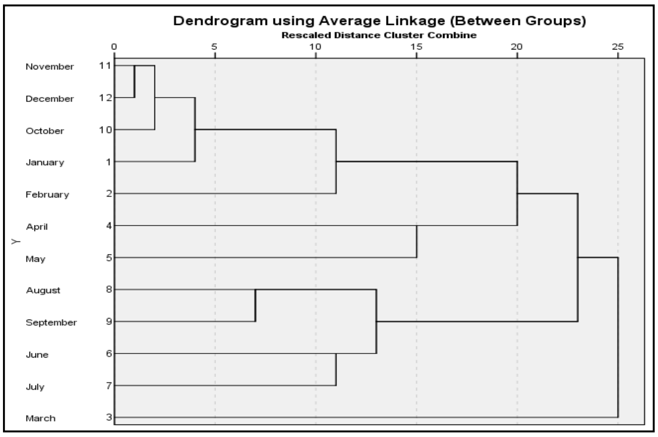

Figure 3. Hierarchical cluster analysis of phytoplankton assemblage (Littoral region)

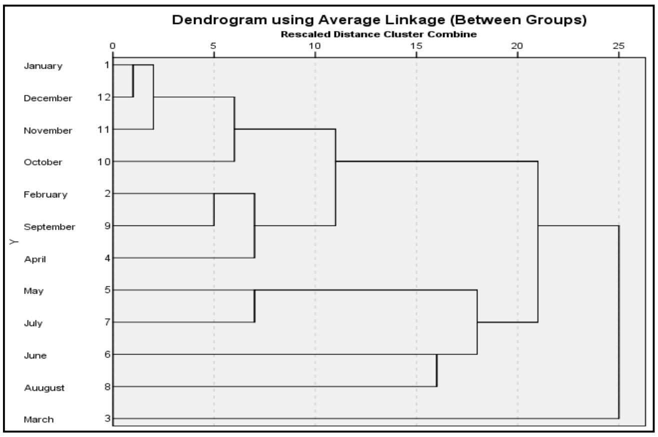

Figure 4. Hierarchical cluster analysis of phytoplankton assemblage (Limnetic region)

Table 3. The spatio-temporal variations of phytoplankton assemblages

Taxa ↓ Regions →	**Littoral region**	**Limnetic region**
Richness		
Phytoplankton (51 species) Community similarity (%)	34-44, 38±3 species 71.4-94.5	37-49, 42±4 species 67.5-94.7
Charophyta (27 species)	19-26, 22±2 species	19-25, 22±2 species
Abundance (n/l)		
Net Plankton	368-652 510±103	315-658 482±116
Phytoplankton Percentage of net phytoplankton	210-421 300±81 50.4-66.1 58.0±4.8	159-388 259±79 41.8-61.1 53.0±5.2
Charophyta Percentage of phytoplankton	94-192 136±38 40.1-55.6 45.4±4.3	70-190 122±39 39.2-52.1 46.5±3.3
Chlorophyta Percentage of phytoplankton	35-97 64±20 18.0-29.5 21.4±3.2	24-73 43±15 11.9-20.4 16.5±2.1
Bacillariophyta Percentage of phytoplankton	20-58 40±12 9.8-17.4 14.1±2.9	28-45 36±7 9.5-21.8 14.4±3.3
Dinozoa Percentage of phytoplankton	21-41 31±9 7.4-18.3 10.7±2.6	13-43 27±11 8.7-21.8 14.3±3.7
Chrysophyta Percentage of phytoplankton	7-44 23±13 7.4-11.3 7.1±2.7	8-48 21±12 5.0-13.4 7.5±2.4
Cynaobacteria	2-7 3±1	3-9 6±2
Euglenozoa	0-6 2±2	1-7 4±2
Diversity indices		
Species Diversity	2.986-3.366 3.169±0.122	3.045-3.503 3.319±0.138
Dominance	0.073-0.157 0.103±0.020	0.063-0.133 0.092±0.022
Evenness	0.827-0.912 0.870±0.026	0.830-0.950 0.893±0.038
Important taxa (n/l)		
Staurastrum spp.	17-64 39±13	12-61 35±14
Closterium spp.	17-53 34±14	17-55 33±13
Cosmarium spp.	9-37 22±9	7-38 21±9
Scenedesmus spp.	9-44 23±11	9-35 19±8
Important species (n/l)		
Ulothrix aequalis	10-39 27±9	6-29 13±6
Ceratium hirudinella	10-40 26±9	8-42 22±11
Dinobryon sociale	7-44 23±13	8-48 21±12
Navicula radiosa	8-40 23±11	8-27 16±7
Closterium acrosum	5-42 19±12	0-32 16±10
Scenedesmus acuminatus	8-41 18±10	6-32 15±8
Cosmarium granatum	3-25 18±9	5-35 16±9
Staurastrum arctiscon	6-34 16±9	6-36 17±11
Staurastrum freemani	2-24 15±8	4-24 13±6
Cosmarium decoratum	4-41 12±5	2-20 11±5
Spirogyra indica	10-21 13±3	4-12 8±3

Phytoplankton abundance (Table 3) ranges between 210-421 and 159-388 n/l; it comprises 50.4-66.1 and 41.8-61.1% of net plankton abundance at the littoral and limnetic regions and depicts a bimodal pattern of monthly density variations (Figure 5). Charophyta indicate abundance (Figure 6) varying between 84-192 and 79-190 n/l; Chlorophyta (Figure 7), and Bacillariophyta, Dinozoa and Chrysophyta abundance vary between 35-97 and 24-73 n/l, 20-58 and 28-45 n/l, 21-41 and 13-43n/l, and 7-44 and 8-48 n/l at the two regions (Figures 8-9). Cyanobacteria and Euglenozoa record poor abundance in Thadlaskein Lake (Table 3).

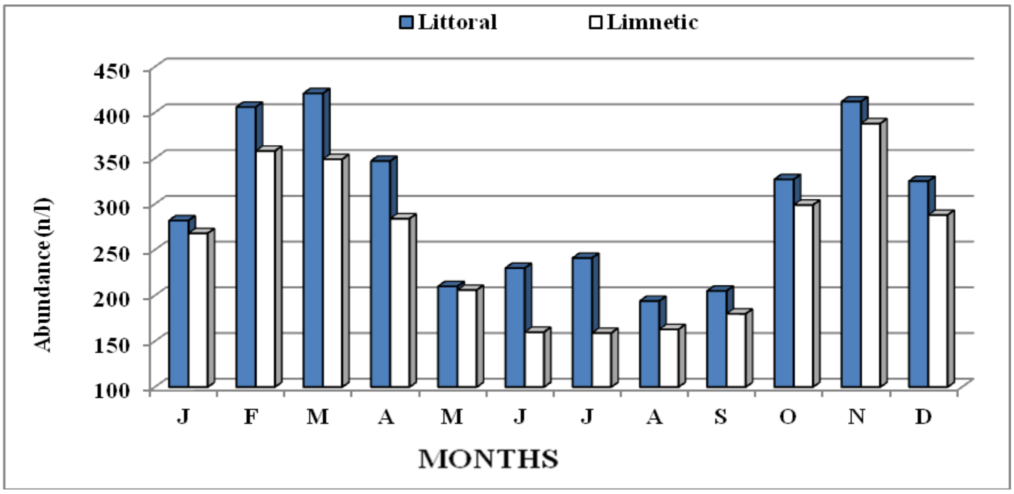

Figure 5. The spatio-temporal variations of phytoplankton abundance

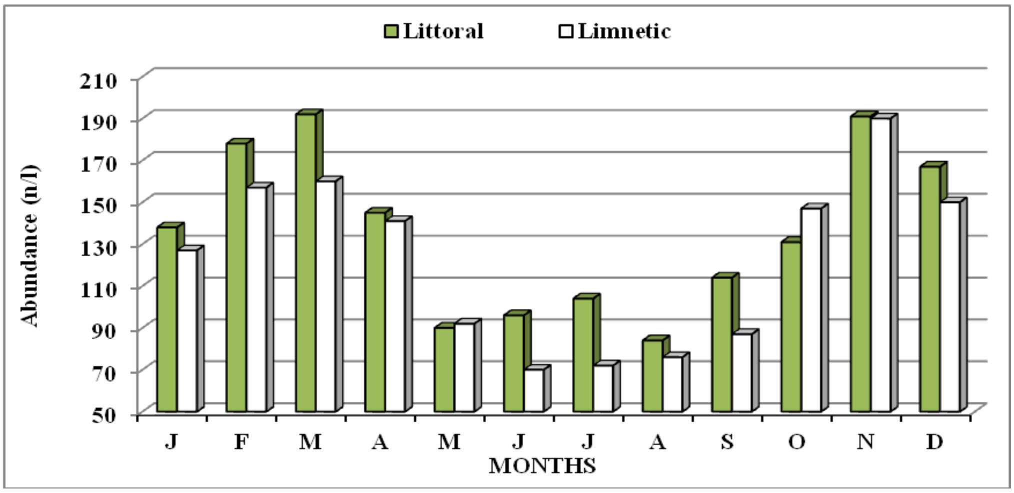

Figure 6. The spatio-temporal variations of Charophyta abundance

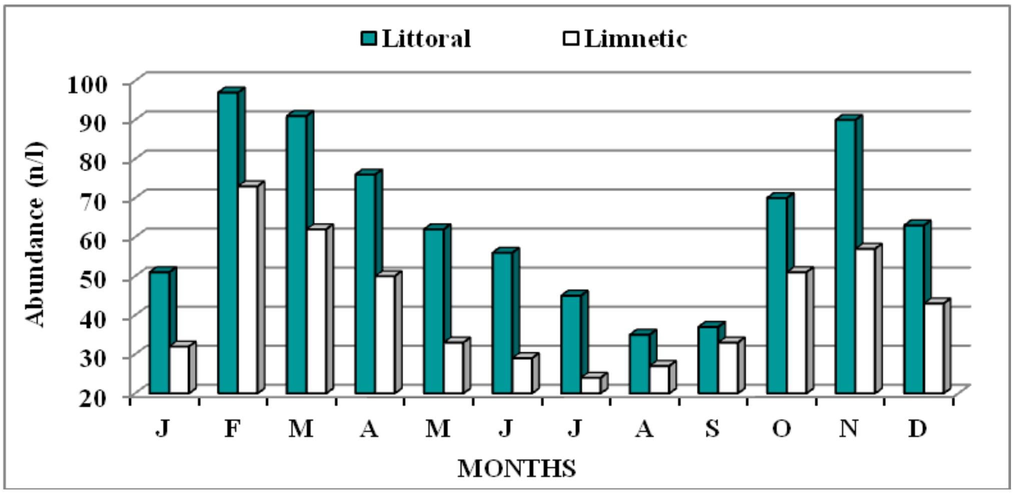

Figure 7. The spatio-temporal variations of Chlorophyta abundance

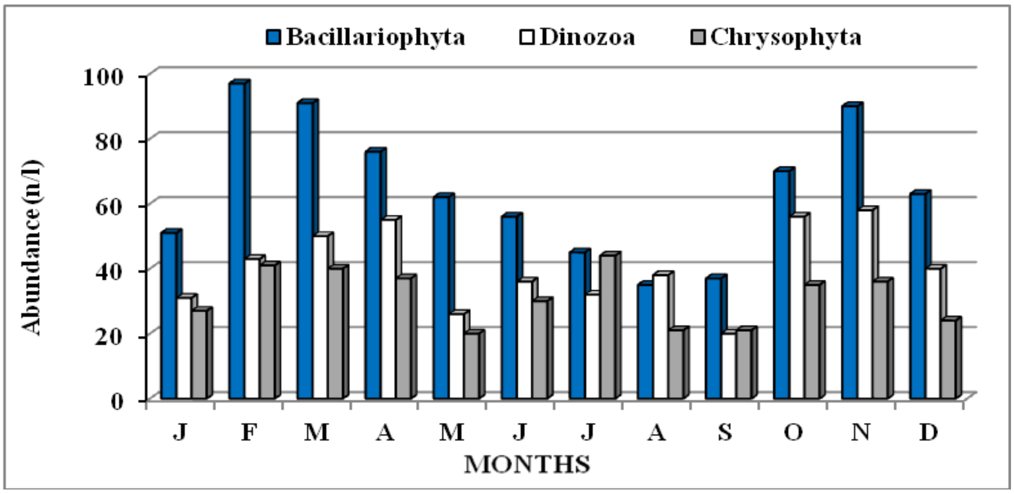

Figure 8. The spatio-temporal variations of the abundance of subdominant groups (Littoral)

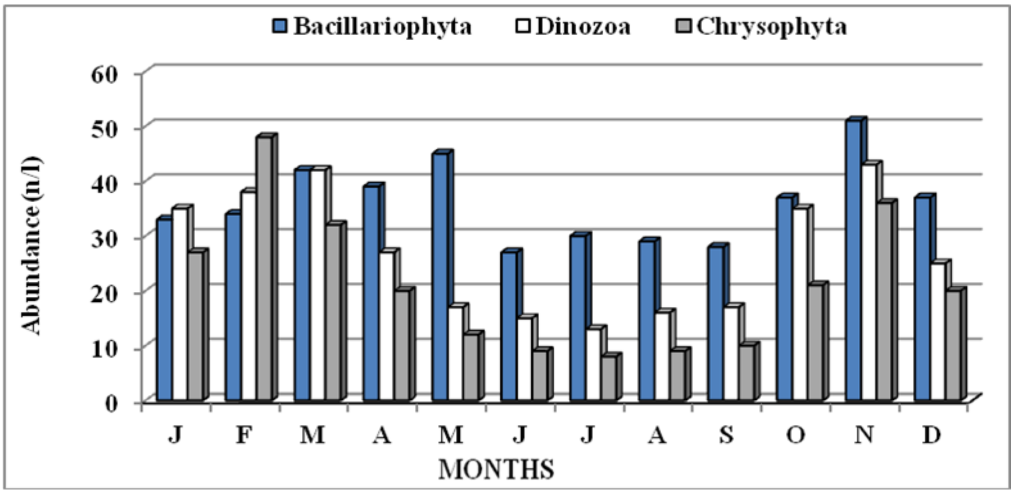

Figure 9. The spatio-temporal variations of the abundance of subdominant groups (Limnetic)

Staurastrum spp. (39±13, 35±14 n/l), *Closterium* spp. (34±14, 33±13 n/l), *Cosmarium* spp. (22±9, 21±9 n/l) and *Scenedesmus* spp. (23±11, 19±8 n/l) are notable (Table 3) taxa of the littoral and limnetic phytoplankton. *Ceratium hirudinella*, *Closterium acrosum*, *Cosmarium decoratum*, *C. granatum*, *Dinobryon sociale*, *Navicula radiosa*, *Scenedesmus acuminatus*, *Staurastrum arctiscon*, *S. freemani*, *Spirogyra indica* and *Ulothrix aequalis* are quantitatively notable species (Table 3). Phytoplankton species diversity (Figure 10), dominance and evenness range between 2.986-3.366 and 3.045-3.503, 0.073-0.157 and 0.063-0.133, and 0.827-0.912 and 0.830-0.950 at the two regions, respectively (Table 3). The spatio-temporal significance of phytoplankton assemblages and diversity indices (vide ANOVA) are indicated in Table 4.

Phytoplankton influence net plankton richness (r_1= 0.805, p = 0.005; r_2= 0.761, p = 0.0106) at the littoral and limnetic regions, respectively and Charophyta influence phytoplankton richness (r_1= 0.871, p = 0.001) at the littoral region. Phytoplankton influence net plankton abundance (r_1= 0.987, p < 0.0001; r_2= 0.965, p < 0.0001), and Charophyta (r_1= 0.919, p = 0.0002; r_2 = 0.985, p < 0.0001), Chlorophyta (r_1= 0.939, p <0.0001; r_2 = 0.910, p = 0.0003), Bacillariophyta (r_1= 0.693, p = 0.026; r_2= 0.701, p = 0.024) and Chrysophyta (r_1= 0.954, p < 0.0001; r_2= 0.914, p = 0.0002) influences phytoplankton abundance at the littoral and limnetic regions, while Dinozoa influences phytoplankton (r_2 = 0.953, p < 0.0001) at the limnetic region.

Eleven important species collectively influence phytoplankton abundance at the two regions (r_1= 0.981, p < 0.0001; r_2= 0.984, p < 0.0001); *Ceratium hirudinella* (r_1 = 0.810, p = 0.004; r_2 = 0.924, p = 0.0001), *Dinobryon sociale* (r_1 = 0.954, p < 0.0001; r_2 = 0.914, p = 0.0002), *Closterium acrosum* (r_1 = 0.892, p = 0.0005; r_2 = 0.926, p = 0.002), *Cosmarium granatum* (r_1 = 0.945, p < 0.0001; r_2 = 0.834, p < 0.0027), *Scenedesmus acuminatus* (r_1 = 0.869, p = 0.0011; r_2 = 0.852, p = 0.0011), *Staurastrum arctiscon* (r_1 = 0.753, p = 0.011; r_2 = 0.753, p = 0.0027), *S. freemani* (r_1 = 0.793, p = 0.006; r_2 = 0.709, p = 0.022), and *Navicula radiosa* (r_1 = 0.819, p = 0.004;

r_2 = 0.851, p = 0.002) influence phytoplankton abundance at both the regions.

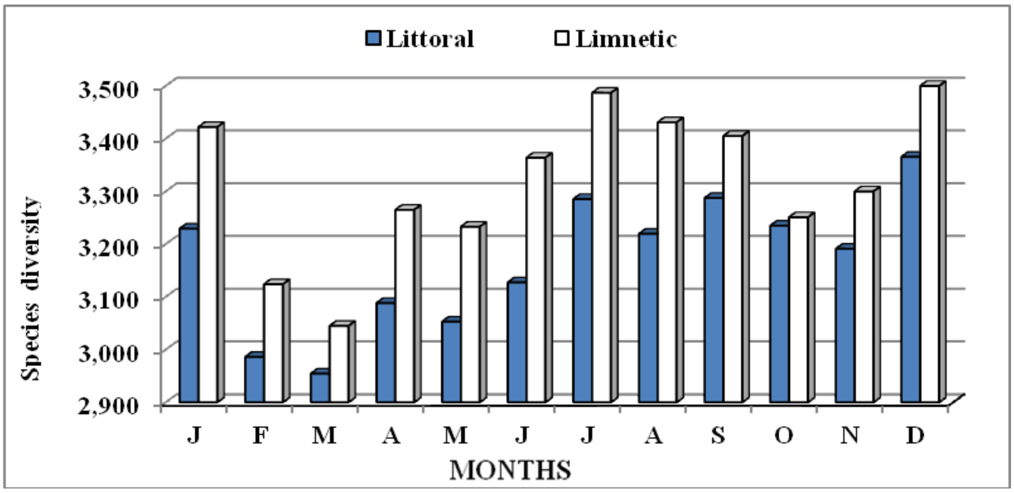

Figure 10. The spatio-temporal variations of phytoplankton species diversity

Table 4. ANOVA indicating the spatio-temporal significance of phytoplankton assemblages

Parameters↓	Regions	Months
Phytoplankton richness	$F_{1,23}$ = 18.285, P = 0.0013	$F_{11,23}$ = 8.056, P= 0.0008
Chlorophyta richness	-	$F_{11,23}$ = 6.088, P= 0.0028
Abundance		
Phytoplankton	$F_{1,23}$ = 18.287, P = 0.0013	$F_{11,23}$ = 48.887, P= 1E-07
Charophyta	$F_{1,23}$ = 9.562, P = 0.0102	$F_{11,23}$ = 25.536, P= 2.1E-06
Chlorophyta	$F_{1,23}$ = 76.394, P = 2.8E-06	$F_{11,23}$ = 17.746, P= 2.0E-05
Bacillariophyta	-	$F_{11,23}$ = 2.284, P= 0.0486
Dinozoa	-	-
Chrysophyta	-	$F_{11,23}$ = 23.456, P= 4.8E-06
Staurastrum spp.	-	$F_{11,23}$ = 9.911, P= 0.0003
Closterium spp.	-	$F_{11,23}$ = 9.423, P= 0.0004
Cosmarium spp.	-	$F_{11,23}$ = 12.138, P= 0.0001
Scenedesmus spp.	$F_{1,23}$ = 11.477, P = 0.0061	$F_{11,23}$ = 22.035, P= 6.5E-06
Ceratium hirudinella	-	$F_{11,23}$ = 8.989, P= 0.00052
Closterium acrosum	-	$F_{11,23}$ = 12.586, P= 0.0001
Cosmarium decoratum	-	$F_{11,23}$ = 8.954, P= 0.0005
Cosmarium granatum	-	$F_{11,23}$ = 16.994, P= 2.4E-05
Dinobryon sociale	-	$F_{11,23}$ = 23.456, P= 4.8E-06
Navicula radiosa	$F_{1,23}$ = 9.702, P = 0.0098	$F_{11,23}$ = 5.849, P= 0.0034
Scenedesmus acuminatus	$F_{1,23}$ = 6.769, P = 0.0246	$F_{11,23}$ = 28.317, P= 1.8E-06
Spirogyra indica	$F_{1,23}$ = 22.118, P = 0.0006	-
Staurastrum arctiscon	-	$F_{11,23}$ = 19.078, P= 1.4E-05
Staurastrum freemani	-	$F_{11,23}$ = 8.653, P= 0.0006
Ulothrix aequalis	$F_{1,23}$ = 57.714, P = 1.1E-06	$F_{11,23}$ = 5.231, P= 0.0053
Diversity indices		
Species Diversity	$F_{1,23}$ = 71.421, P = 3.9E-06	$F_{11,23}$ = 18.166, P= 1.7E-05
Dominance	-	-
Evenness	$F_{1,23}$ = 12.728, P = 0.0044	$F_{11,23}$ = 9.035, P= 0.0005

(-) insignificant variations

Staurastrum spp. > *Closterium* spp. > *Cosmarium* spp. > *Scenedesmus* spp. collectively influence phytoplankton (r_1= 0.953, p < 0.0001; r_2= 0.984, p < 0.0001) and Chlorophyta (r_1= 0.979, p < 0.0001; r_2= 0.997, p < 0.0001) abundance at the two regions. *Closterium* spp. (r_1= 0.806, p = 0.005; r_2= 0.907, p < 0.0003), *Cosmarium* spp. (r_1= 0.929, p = 0.0001; r_2= 0.840, p = 0.002), *Scenedesmus* spp. (r_1= 0.914, p = 0.0001; r_2= 0.824, p = 0.003) and *Staurastrum* spp. (r_1= 0.929, p = 0.0001; r_2= 0.900, p = 0.0004), individually influence phytoplankton at the two regions. *Closterium* spp. (r_1= 0.923,

$p = 0.0001$; $r_2 = 0.908$, $p = 0.0003$), *Cosmarium* spp. ($r_1 = 0.879$, $p = 0.0008$; $r_2 = 0.809$, $p = 0.0045$), and *Staurastrum* spp. ($r_1 = 0.951$, $p < 0.0001$; $r_2 = 0.934$, $p < 0.00031$) influence Charophyta abundance at the two regions. *Scenedesmus* spp. ($r_1 = 0.869$, $p = 0.0011$; $r_2 = 0.779$, $p = 0.008$) influence Chlorophyta abundance at the two regions. *Closterium acrosum* ($r_1 = 0.874$, $p = 0.0009$; $r_2 = 0.877$, $p = 0.0009$), *Cosmarium granatum* ($r_1 = 0.849$, $p = 0.0019$; $r_2 = 0.795$, $p = 0.0060$), *Staurastrum arctiscon* ($r_1 = 0.752$, $p = 0.0121$; $r_2 = 0.810$, $p = 0.0045$) influence Charophyta abundance at both the regions. *Scenedesmus acuminatus* ($r_1 = 0.856$, $p = 0.0016$; $r_2 = 0.933$, $p < 0.0001$) influence Chlorophyta abundance at the two regions. *Navicula radiosa* influences Bacillariophyta abundance at the littoral ($r_1=0.935$, $p=0.0003$) and limnetic ($r_2=0.883$, $p=0.0007$) regions. *Ceratium hirudinella* influences Dinozoa abundance at the littoral region ($r_1 = 0.849$, $p < 0.0019$) and limnetic regions ($r_2 = 0.960$, $p < 0.0001$).

The species diversity is inversely influenced by abundance of *Scenedesmus acuminatus* ($r_1 = -0.736$, $p = 0.015$) and *Ulothrix aequalis* ($r_1 = -0.757$, $p = 0.011$) at the littoral region, and by *Closterium acrosum* ($r_2 = -0.752$, $p=0.012$), *Cosmarium granatum* (($r_2 = -0.844$, $p = 0.002$), *Scenedesmus acuminatus* ($r_2 = -0.809$, $p=0.005$), *Spirogyra indica* ($r_2 = -0.739$, $p = 0.015$), *Ulothrix aequalis* ($r_2 = -0.720$, $p = 0.019$) and *Ceratium hirudinella* ($r_2 = -0.689$, $p = 0.025$) at the limnetic region. It is inversely influenced by dominance ($r_2 = -0.731$ $p = 0.016$) at the limnetic region, and is positively influenced by evenness ($r_1 = 0.776$, $p = 0.008$; $r_2 = 0.797$, $p = 0.006$) at the two regions, respectively. Evenness records an inverse correlation with dominance at the littoral region ($r_2 = -0.842$, $p = 0.002$); is inversely influenced by abundance of phytoplankton ($r_1 = -0.832$, $p = 0.003$), Chlorophyta ($r_1 = -0.768$, $p = 0.009$), Chrysophyta ($r_1 = -0.740$, $p = 0.014$), *Cosmarium granatum* (($r_1 = -0.845$, $p = 0.002$), *Scenedesmus acuminatus* ($r_1 = -0.779$, $p = 0.008$), *Staurastrum freemani* ($r_1 = -0.728$, $p = 0.017$), *Ulothrix aequalis* ($r_1 = -0.945$, < 0.0001) and *Ceratium hirudinella* ($r_1 = -0.891$, $p = 0.0005$) and *Dinobryon sociale* ($r_1 = -0.740$, $p = 0.014$) at the littoral region. Chlorophyta ($r_2 = -0.904$, $p = 0.0003$), Dinophyta ($r_2 = -0.882$, $p = 0.0007$), Chrysophyta ($r_2 = -0.919$, $p = 0.0002$), *Closterium acrosum* ($r_2 = -0.908$, $p = 0.0003$), *Cosmarium granatum* ($r_2 = -0.868$, $p = 0.001$), *Scenedesmus acuminatus* ($r_2 = -0.878$, $p = 0.0008$), *Staurastrum arctiscon* ($r_2 = -0.735$, $p = 0.015$), *Spirogyra indica* ($r_2 = -0.882$, $p = 0.0007$), *Ulothrix aequalis* ($r_2 = -0.826$, $p = 0.003$), *Ceratium hirudinella* ($r_1 = -0.907$, $p = 0.0003$), *Dinobryon sociale* ($r_2 = -0.919$, $p = 0.0002$) and *Navicula radiosa* ($r_1 = -0.762$, $p = 0.010$) inversely influence evenness at the limnetic region. The dominance positively correlates with abundance of phytoplankton ($r_2 = 0.690$, $p = 0.027$), Dinophyta ($r_2 = 0.807$, $p=0.005$), Chrysophyta ($r_2 = 0.807$, $p = 0.005$), *Closterium acrosum* ($r_2 = 0.694$, $p = 0.026$), *Scenedesmus acuminatus* ($r_2 = 0.844$, $p = 0.002$), *Spirogyra indica* ($r_2 = 0.707$, $p = 0.022$), *Ulothrix aequalis* ($r_2 = 0.685$, $p = 0.029$), *Ceratium hirudinella* ($r_2 = 0.825$, $p = 0.003$) and *Dinobryon sociale* ($r_2 = 0.807$, $p = 0.005$) at the limnetic region.

Water temperature registers inverse influence on Charophyta richness ($r_2 = -0.758$, $p = 0.0111$) at the limnetic region, and magnesium registers positive influence on phytoplankton ($r_1 = 0.778$, $p = 0.008$) and Charophyta richness at ($r_2 = 0.759$, $p = 0.011$) at the littoral and limnetic regions, respectively. The rainfall exerts inverse influence on abundance of phytoplankton ($r_1 = -0.796$, $p = 0.006$; $r_2 = -0.819$, $p = 0.004$), Charophyta ($r_1 = -0.871$, $p = 0.001$; $r_2 = -0.835$, $p = 0.003$), Chlorophyta ($r_1 = -0.665$, $p = 0.036$; $r_2 = -0.727$, $p = 0.003$), Chrysophyta ($r_1 = -0.789$, $p = 0.007$; $r_2 = -0.746$, $p = 0.013$), and *Cosmarium granatum* ($r_1 = -0.786$, $p = 0.007$; $r_2 = -0.681$, $p = 0.030$) at the two regions. It exerts inverse influence on *Closterium acrosum* ($r_1 = -0.796$, $p = 0.006$) at the littoral region, and on abundance of Dinozoa ($r_2 = -0.779$, $p = 0.008$), *Ceratium hirudinella* ($r_2 = -0.767$, $p = 0.009$), *Navicula radiosa* ($r_2 = -0.679$, $p = 0.031$) *Scenedesmus acuminatus* ($r_2 = -0.735$, $p = 0.015$), *Spirogyra indica* ($r_2 = -0.788$, $p = 0.007$) at the limnetic region. Transparency records inverse influence on abundance of phytoplankton ($r_1 = -0.804$, $p = 0.005$; $r_2 = -0.749$, $p = 0.013$), Charophyta ($r_1 = -0.777$, $p = 0.008$; $r_2 = -0.716$, $p = 0.020$), Chrysophyta ($r_1 = -0.818$, $p = 0.004$; $r_2 = -0.745$, $p = 0.013$) and *Ceratium hirudinella* ($r_1 = -0.725$, $p = 0.018$; $r_2 = -0.809$, $p = 0.004$) at the two regions. It exerts inverse influence on abundance of Chlorophyta ($r_1 = -0.714$, $p = 0.020$) and *Closterium acrosum* ($r_1 = -0.784$, $p = 0.007$) at the littoral region, and on abundance of *Staurastrum freemani* ($r_2 = -0.685$, $p = 0.029$), and Dinozoa ($r_2 = -0.699$, $p = 0.024$) at the limnetic region. Total hardness positively influences abundance of *Closterium acrosum* ($r_1 = 0.697$, $p = 0.025$; $r_2 = 0.786$, $p = 0.007$) and *Cosmarium granatum* ($r_1 = 0.686$, $p = 0.028$; $r_2 = 0.860$, $p = 0.0014$) at the two regions, and exerts positive influence on phytoplankton ($r_2 = 0.668$, $p = 0.034$), Chlorophyta ($r_2 = 0.714$, $p = 0.020$), Chrysophyta ($r_2 = 0.682$, $p = 0.030$), *Ceratium hirudinella* ($r_2 = 0.792$, $p = 0.006$), *Navicula radiosa* ($r_2 = 0.707$, $p = 0.009$), *Scenedesmus acuminatus* ($r_2 = 0.805$, $p = 0.005$), *Spirogyra indica* ($r_2 = 0.707$, $p = 0.009$) abundance at the limnetic region. Total alkalinity positively influences abundance of *Ceratium hirudinella* ($r_1 = 0.686$, $p = 0.028$; $r_2 = 0.693$, p= 0.026) at the two regions, and that of *Cosmarium granatum* (r_2 = 0.863, p= 0.0013) *Navicula radiosa* (r_2= 0.770, p= 0.009), *Scenedesmus acuminatus* (r_2= 0.706 p= 0.022), *Staurastrum freemani* (r_2= 0.709, p= 0.022), *Spirogyra indica* (r_2= 0.782, p= 0.007) at the limnetic region. Nitrate depicts positive influence on abundance of phytoplankton (r_1 =0.734, p= 0.016), Charophyta (r_1 = 0.674, p= 0.033), Chrysophyta (r_1 = 0.789, p= 0.007), *Cosmarium granatum* (r_1 = 0.750, p= 0.012), *Dinobryon sociale* (r_1 = 0.789, p= 0.0007), *Scenedesmus acuminatus* (r_1= 0.689, p= 0.027) and *Staurastrum arctiscon* (r_1= 0.710, p= 0.021). Specific conductivity exerts inverse influence on *Closterium decorum* (r_1 = -0.808, p= 0.005) abundance at the littoral region.

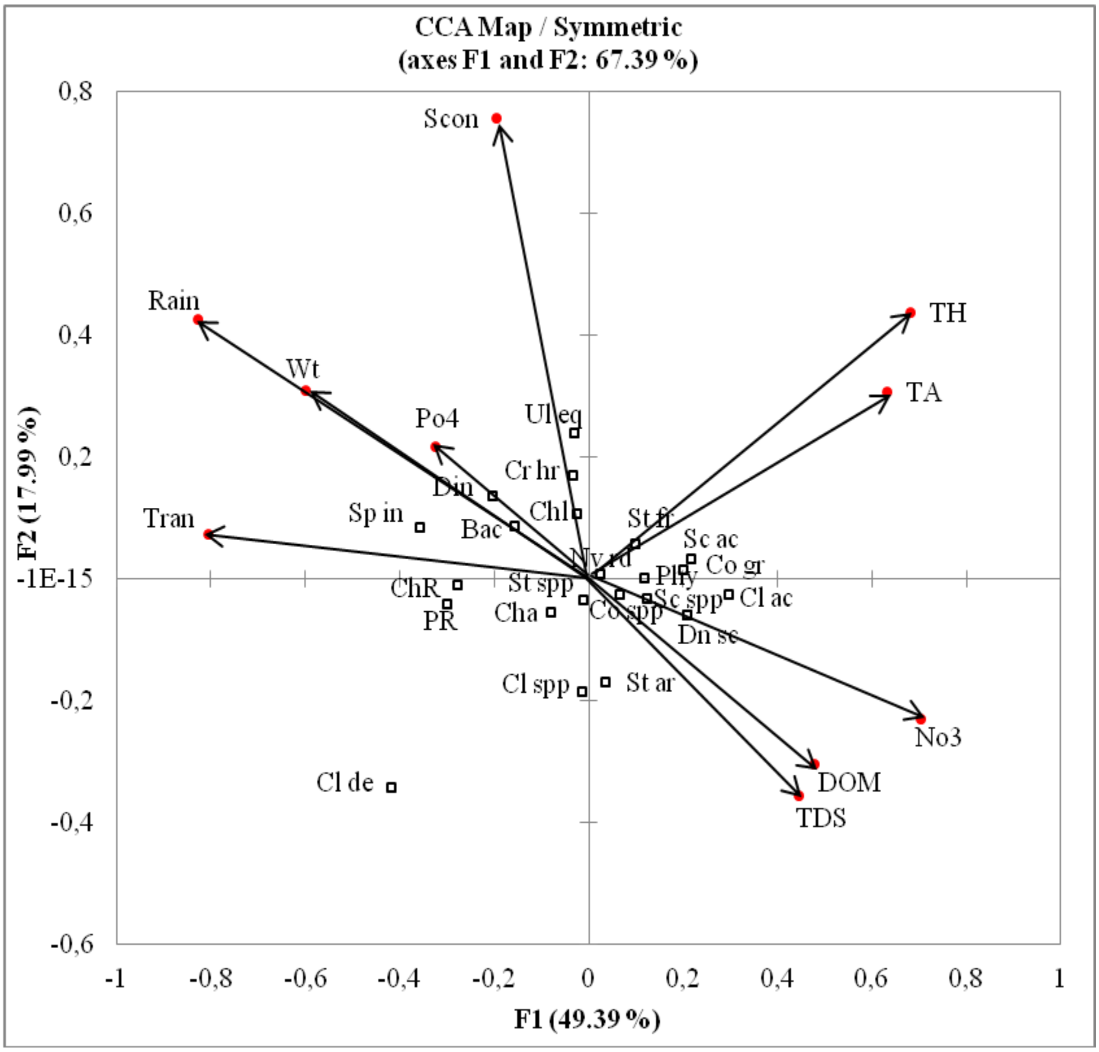

Figure 11. CCA coordination biplot of abiotic factors and phytoplankton assemblage (Littoral)

Abbreviations: Abiotic factors: DOM (dissolved organic matter), Po4 (phosphate), No3 (nitrate), Rain (rainfall), Scon (specific conductivity), TA (Total alkalinity), TDS (Total dissolved solids), TH (Total hardness), Tran (transparency), Wt (water temperature. **Biotic factors**: Bac (Bacillariophyta abundance), Cha (Charophyta abundance), Chl (Chlorophyta abundance), ChR (Charophyta richness), Chr (Chrysophyta), Cl ac (*Closterium acrosum*). Cl spp (*Closterium* species), Cl de (*Closterium decoratum*), Co gr (*Cosmarium granatum*), Co spp (*Cosmarium* species), Cr hr (*Ceratium hirudinella*), Din(Dinozoa), PR (phytoplankton richness), Phy (Phytoplankton abundance), Sc ac (*Scenedesmus acuminatus*), Sc spp (*Scenedesmus* species), Sp in (*Spirogyra indica*), St spp (*Staurastrum* spp.), St ar (*Staurastrum arctiscon*), St fr (*Staurastrum freemani*), Ul ae (*Ulothrix aequalis*)

The canonical correspondence analysis (CCA) registers moderate cumulative influence (67.39 and 66.83 %) of 10 abiotic factors, along the first two axes, on phytoplankton assemblages at the littoral and limnetic stations, respectively (Figures 11-12).

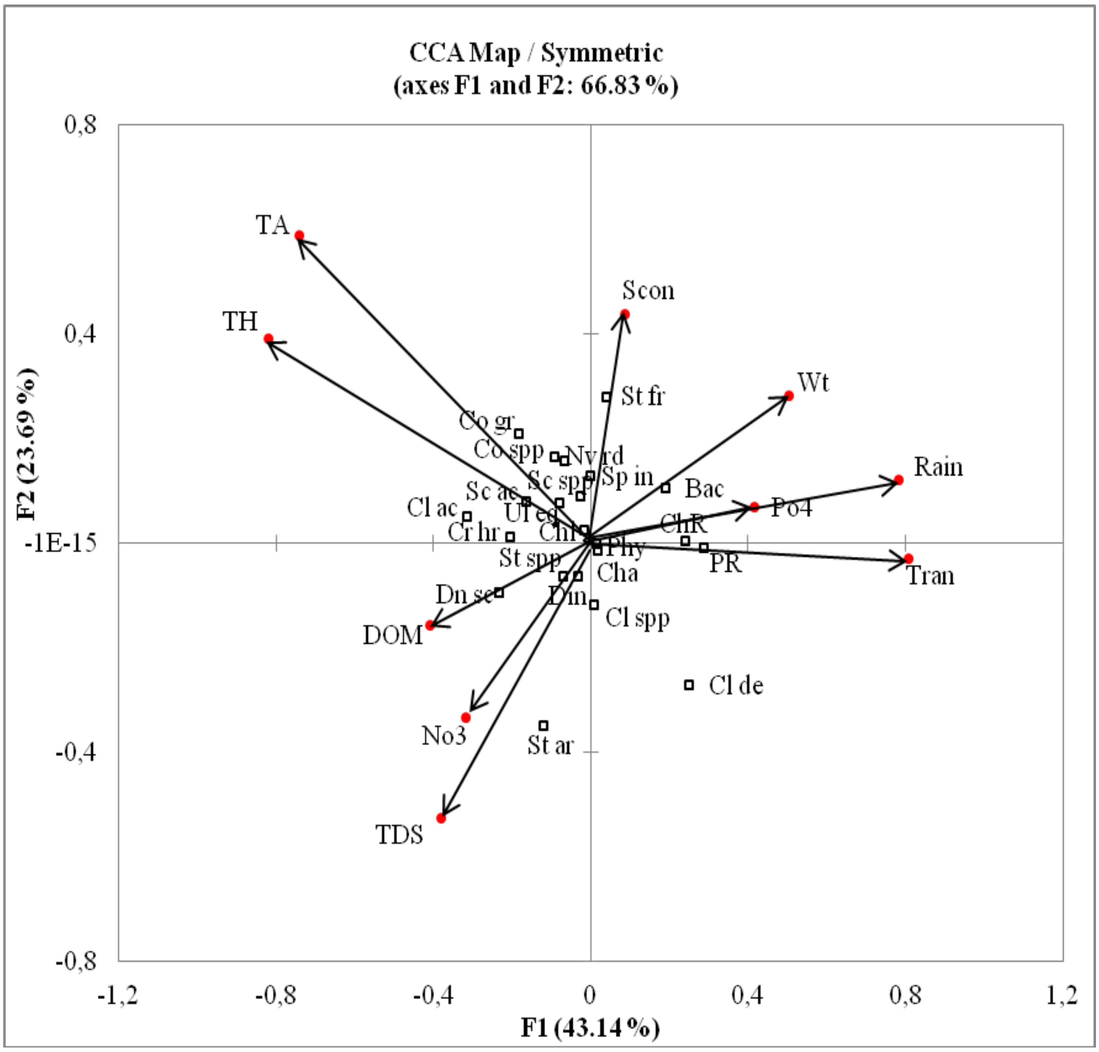

Figure 12: CCA coordination biplot of abiotic factors and phytoplankton assemblage (Limnetic)

Abbreviations: Abiotic factors: DOM (dissolved organic matter), Po4 (phosphate), No3 (nitrate), Rain (rainfall), Scon (specific conductivity), TA (Total alkalinity), TDS (Total dissolved solids), TH (Total hardness), Tran (transparency), Wt (water temperature. **Biotic factors**: Bac (Bacillariophyta abundance), Cha (Charophyta abundance), Chl (Chlorophyta abundance), ChR (Charophyta richness), Chr (Chrysophyta), Cl ac (*Closterium acrosum*). Cl spp (*Closterium* species), Cl de (*Closterium decoratum*), Co gr (*Cosmarium* granatum), Co spp (*Cosmarium* species), Cr hr (*Ceratium hirudinella*),Din (Dinozoa), PR (phytoplankton richness), Phy (Phytoplankton abundance), Nv rd (*Navicula radiosa*), Sc ac (*Scenedesmus acuminatus*), Sc spp (*Scenedesmus* species), Sp in (*Spirogyra indica*), St spp (*Staurastrum* spp.), St ar (*Staurastrum arctiscon*), St fr (*Staurastrum freemani*), Ul ae (*Ulothrix aequalis*)

Discussion

Our results highlight very soft, slightly acidic-circumneutral, calcium poor, de-mineralized and oxygenated waters of Thadlaskein Lake with low transparency, free carbon dioxide, chloride, dissolved organic matter, total dissolved solids and nutrients. The low specific conductivity, attributed to the leached and weathered nature of the rocks and soils because of high rainfall (Sharma and Sharma 2021a, 2021b), warrants the inclusion of this lake under the 'Class I' category of trophic classification vides Talling and Talling (1965) and Payne (1986). ANOVA registers significant spatio-temporal variations of transparency and phosphate, and silicate records significant spatial variations. Water temperature, specific conductivity, total alkalinity, total hardness, magnesium, chloride and dissolved organic matter register significant monthly variations, while pH, dissolved oxygen, free carbon dioxide, calcium, sulphate, nitrate and total dissolved solids record insignificant spatial and temporal variations.

A total of 51 phytoplankton species examined from Thadlaskein Lake compares with the reports from the reservoirs of Meghalaya (Sharma and Sharma 2021a) and Mizoram (Sharma and Pachuau 2016), and the floodplain lakes of Assam (Sharma 2004, 2015) but depicts the species-rich nature than the reports from certain other reservoirs of Meghalaya (Sharma 1995; Sharma and Lyngdoh 2003; Sharma and Sharma 2021b), and the floodplains of Assam (Devi et al. 2016; Deb et al.

2019) and Tripura (Bharati et al. 2020) states of NEI. We report diverse phytoplankton than various lakes of Kashmir (Jeelani and Kaur 2012; Nissa and Bhat 2016), Uttarakhand (Negi and Rajput 2015; Sharma and Singh 2018; Goswami et al. 2018), Himachal Pradesh (Gupta et al. 2018; Jindal and Thakur 2014; Jindal et al. 2014b) from northwest India. The comparisons depict the diverse phytoplankton assemblage of this soft and de-mineralized water sacred lake. Phytoplankton reveals the speciose Charophyta concurrent with the reports from Meghalaya (Sharma and Sharma 2021a, 2021b).

Woelkerling and Gough (1976), Payne (1986) and Sharma and Sharma (2021a, 2021b) hypothesized high desmid richness as a notable feature of phytoplankton assemblages of the soft, calcium-poor, and de-mineralized waters. The speciose desmids (26 species) comprise ~51% and ~96% of Phytoplankton and Charophyta species, respectively observed from Thadlaskein Lake and thus affirm the stated hypothesis. The desmid flora includes *Closterium* (5 species) > *Staurastrum* (4 species) > 3 species each of *Cosmarium, Micrasterias* and *Xanthidium,* and 2 species each of *Arthrodesmus, Euastrum, Netrium* and *Pleurotaenium,* while *Triploceras* is represented by one species. Total desmid richness noted vide our study corresponds with the species listed from Meghalaya (Sharma and Sharma 2021a). Interestingly, this lake records high diversity of desmid genera than reported from the lacustrine environs of Himachal Pradesh (Thakur et al. 2013) and NEI (Sharma 1995, 2015; Sharma and Lyngdoh 2003; Sharma and Pachuau 2016; Sharma and Sharma 2021b).

Phytoplankton significantly influences net plankton richness in the two regions. High richness at the littoral > the limnetic region, except during July and October, is hypothesized to the greater habitat heterogeneity of the former region. Phytoplankton richness follows oscillating temporal variations at the two regions and registers significant spatio-temporal differences (vide ANOVA); the winter peak noticed at the two regions concurs with the reports from Manipur (Sharma 2010), Assam (Devi et al. 2016) and Meghalaya (Sharma and Sharma 2021a). Our report of the speciose constellation of 49 phytoplankton species at the limnetic region during December is attributed to the possibility of co-existence of many species due to the high amount of niche overlap as hypothesized by MacArthur (1965). This instance broadly corresponds with the constellation of 51 species per sample from the Nongmahir reservoir of Meghalaya (Sharma and Sharma 2021a). Charophyta, the speciose group, influences phytoplankton richness at the two regions and records significant temporal variations (vide ANOVA). Phytoplankton richness registers 71.4-94.5 and 67.5-94.7% community similarities (vide Sørensen's index) at the littoral and limnetic regions, respectively; peak similarity values are noted between November-December and lowest similarities between March-June assemblages at the two regions. Our results record similarity values ranging between 71-90% in ~92% and ~ 82% instances at the littoral and limnetic regions, respectively, and thus affirm the relatively more temporal heterogeneity of phytoplankton composition at the latter region. This generalization is endorsed by the differential hierarchical cluster groupings which indicate closer affinity amongst November-December-October assemblage at the littoral region, and the limnetic region indicates closer affinity amongst January-December-November while March assemblages record maximum species divergence at the two regions.

Phytoplankton comprises an important quantitative component and influence net plankton abundance at the littoral and limnetic regions, and thus differ from the distinct predominance vs. net plankton reported from Meghalaya (Sharma 1995; Sharma and Lyngdoh 2003; Sharma and Sharma 2021a, 2021b), Mizoram (Sharma and Pachuau 2016) and Himachal Pradesh (Jindal and Thakur 2014). Higher abundance at the littoral > limnetic region, hypothesized to the greater environmental heterogeneity of the former region, is affirmed by the significant temporal variations (vide ANOVA) between the two regions. This study depicts bimodal temporal patterns of phytoplankton density variations at the two regions concurrent with the reports of Baba and Pandit (2014), Goswami et al. (2018) and Sharma and Sharma (2021a, 2021b). The littoral region records spring peak and autumn maxima, while the limnetic region records autumn peak and winter maxima. The autumn abundance concurs with the reports from Kashmir (Baba and Pandit 2014), Meghalaya (Sharma and Sharma 2021a), Mizoram (Sharma and Pachuau 2016) and Uttarakhand (Sharma and Singh 2018); the winter maxima concur with the results of Wanganeo and Wanganeo (1991), Sharma (1995, 2004, 2009, 2010), Goswami et al. (2018), Sharma and Tiwari (2018) and Sharma and Sharma (2021a, 2021b). The lower abundance observed from early monsoon till late monsoon presents a distinct contrast to the mid-monsoon peak reported from a sub-tropical environment of Bhutan (Sharma and Bhattarai 2005).

Staurastrum spp. > *Closterium* spp. > *Cosmarium* spp. > *Scenedesmus* spp. collectively influence phytoplankton abundance at the two regions. ANOVA registers significant temporal variations of *Staurastrum* spp., *Closterium* spp. and *Cosmarium* spp. abundance, and *Scenedesmus* spp. record significant spatio-temporal variations. The significance of *Staurastrum* spp. > *Closterium* spp. > *Cosmarium* spp. highlights the overall importance of the desmids vis-a-vis phytoplankton abundance concurrent with the reports of Sharma (2009, 2010), Hulyal and Kaliwal (2009), Thakur et al. (2013) and Sharma and Sharma (2021a, 2021b). Our study indicates the relative quantitative importance of *Ulothrix aequalis* ≥ *Ceratium hirudinella* > *Dinobryon sociale* ≥ *Navicula radiosa* > *Closterium acrosum* ≥ *Scenedesmus acuminatus* ≥ *Cosmarium granatum* > *Staurastrum arctiscon* > *S. freemani* > *Cosmarium decoratum* > *Spirogyra indica* at the littoral region. *Ceratium hirudinella* ≥ *Dinobryon sociale* > *Staurastrum arctiscon* > *Closterium acrosum* ≥ *Navicula radiosa* ≥ *Scenedesmus acuminatus* > *Cosmarium granatum* > *Ulothrix aequalis* ≥ *Staurastrum freemani* > *Cosmarium decoratum* indicate importance at the limnetic region, while *Spirogyra indica* records limited importance. These species collectively influence phytoplankton abundance at the two regions, while *Ceratium hirudinella, Dinobryon sociale, Closterium acrosum, Cosmarium granatum, Scenedesmus acuminatus, Staurastrum arctiscon, S. freemani,* and *Navicula radiosa* individually influence abundance at both the regions. The rest of phytoplankton species with lower abundance depict the 'generalist' nature. Following MacArthur (1965), it is thus hypothesized that Thadlaskein Lake has resources for utilization both by the selected important species and 'generalist' species. ANOVA registers significant spatio-temporal density variations of *Navicula radiosa, Scenedesmus acuminatus* and *Ulothrix aequalis*; *Spirogyra indica* records spatial variations; and *Ceratium hirudinella, Closterium acrosum, Cosmarium decoratum, C. granatum, Dinobryon sociale, Staurastrum arctiscon* and *S. freemani* register temporal variations.

Charophyta depicts the quantitative dominance, follow bimodal temporal patterns of density variations identical with that of phytoplankton, and influence abundance of the latter at the littoral and limnetic regions concurrent with the report of Sharma and Sharma (2021b). The Charophyta dominance compares with reports from the reservoirs of Meghalaya (Sharma 1995; Sharma and Lyngdoh 2003; Sharma and Sharma 2021a) and Mizoram (Sharma and Pachuau 2016) and the floodplain lakes (Sharma 2004, 2009, 2010, 2012, 2015) of NEI despite the inclusion of species of this group with Chlorophyta. ANOVA records the significant spatio-temporal density variations of Charophyta. This group records peak abundance during spring at the littoral region, the limnetic region records autumn peak, and lower abundance is recorded during May-September. Charophyta abundance is influenced by *Closterium* spp., *Cosmarium* spp. and *Scenedesmus* spp., while *Closterium acrosum, Cosmarium granatum,* and *Staurastrum arctiscon* individually influence abundance at both regions.

Phytoplankton records sub-dominance of Chlorophyta > Bacillariophyta > Dinozoa > Chrysophyta; these groups except Dinozoa influence phytoplankton abundance at the littoral and limnetic regions, while the latter exerts influence on the limnetic assemblages. ANOVA registers significant spatio-temporal quantitative variations of Chlorophyta and Bacillariophyta, Chrysophyta registers significant temporal variations, and Dinozoa registers insignificant spatio-temporal density variations. Amongst the stated groups, Chlorophyta records higher abundance at the littoral region and follows bimodal patterns of temporal variations at the two regions broadly identical with those of phytoplankton. Peak Chlorophyta abundance during winter and maxima during autumn at both the regions differ from the summer peaks recorded from Assam (Sharma 2012, 2015) and Kashmir (Baba and Pandit 2014) and the spring (Ganai and Parveen 2014) and the late monsoon (Sharma and Sharma 2021b) peaks. *Scenedesmus acuminatus* and *Ulothrix aequalis* influence Chlorophyta density at the two regions.

Bacillariophyta sub-dominance corresponds with the reports from Manipur (Sharma 2009) and Uttarakhand (Sharma and Singh 2018), while it differs from the diatom dominance reported from the lakes of Himachal Pradesh (Jindal et al. 2014b), Kashmir (Baba and Pandit 2014) and Uttarakhand (Goswami et al. 2018). Bacillariophyta records the differential spatial oscillating patterns of density variations influenced by *Navicula radiosa* and depicts autumn peaks at the two regions; the latter concur with the report of Sharma and Sharma (2021a). Dinozoa follows the differential spatial oscillating patterns of density variations with the relative quantitative importance during February-April, June-July and October-November at the littoral region, and during January-March and October-November at the limnetic region; *Ceratium hirudinella* influences its abundance at the two regions concurrent with the reports of Sharma and Sharma (2021b). Our results differ from poor Dinozoa abundance reported by Sharma and Lyngskor (2003) and Sharma (2010), while the present study records the relatively lower abundance than the report from a reservoir of Meghalaya (Sharma and Sharma 2021a). Thadlaskein Lake indicates relatively higher Chrysophyta abundance than the floodplain lakes (Sharma 1995, 2009, 2010, 2012, 2015) and reservoirs (Sharma and Lyngskor 2003; Sharma and Sharma 2021b) of NEI. Chrysophyta follows broadly bimodal patterns of monthly density variations with peaks during winter (February) and maxima during autumn at both regions. Of the other groups, poor abundance Cyanobacteria concurs with the report of Sharma and Sharma (2021a, 2021b), while poor Euglenozoa abundance corresponds with the reports of Sharma (2009), Sharma and Pachuau (2016) and Sharma and Sharma (2021a, 2021b).

Phytoplankton record high species diversity with $H^{/}$ values > 3.0 throughout the study at the littoral region and also at the littoral region except during February and March; ANOVA registers significant spatio-temporal diversity variations. Higher diversity as compared with the reports from reservoirs of NEI (Sharma 1995; Sharma and Lyngdoh 2003; Sharma and Lyngskor 2003; Sharma and Pachuau 2016; Sharma and Sharma 2021a) highlights greater habitat heterogeneity of Thadlaskein Lake. The species diversity is inversely influenced by the abundance of *Scenedesmus acuminatus* and *Ulothrix aequalis* at the littoral region, and it is inversely influenced by *Closterium acrosum, Cosmarium granatum, Scenedesmus acuminatus, Spirogyra indica, Ulothrix aequalis* and *Ceratium hirudinella* at the limnetic region. The diversity is inversely influenced by dominance at the limnetic region, and it is positively influenced by evenness at the two regions. While considering the Shannon Weiner diversity index to assess the trophic status (Wilhm and Dorris 1968; Masson 1998), we categorize the 'oligo-mesotrophic' status of Thadlaskein Lake based on the phytoplankton species diversity results.

Our study depicts high phytoplankton evenness and ANOVA registers its significant spatio-temporal variations. The evenness records inverse correlation with dominance at the littoral region; it is inversely influenced by the abundance of phytoplankton, Charophyta, Chrysophyta, *Cosmarium granatum, Scenedesmus acuminatus*, *Staurastrum freemani*, *Ulothrix aequalis* and *Ceratium hirudinella* and *Dinobryon sociale* at the littoral region. Charophyta, Dinozoa, Chrysophyta, *Closterium acrosum, Cosmarium granatum, Scenedesmus acuminatus, Staurastrum arctiscon, Spirogyra indica*, *Ulothrix aequalis, Ceratium hirudinella, Dinobryon sociale* and *Navicula radiosa* inversely influence evenness at the limnetic region. Our study records low phytoplankton dominance which depicts insignificant temporal variations at the two regions. The dominance is positively influenced by the abundance of phytoplankton, Dinozoa and Chrysophyta, and that of *Closterium acrosum, Scenedesmus acuminatus, Spirogyra indica, Ulothrix aequalis, Ceratium hirudinella* and *Dinobryon sociale* at the limnetic region. Higher evenness and lower dominance are attributed to the lower and equitable abundance of the majority of species and even the relatively lower abundance of notable species. The dominance and evenness record variations concurrent with the reports from the reservoirs (Sharma and Lyngskor 2003) and the floodplains (Sharma 2004, 2009, 2010, 2012, 2015) of NEI but differ from the relatively higher values reported from a reservoir of Meghalaya (Sharma and Sharma 2021b).

Referring to the influence of individual abiotic factors vs. richness, lower Chlorophyta richness during warmer periods affirms inverse influence of water temperature at the limnetic region concurrent with the report of Sharma and Sharma (2021b), while magnesium registers a positive influence on phytoplankton richness at the littoral region, and on Chlorophyta richness at the limnetic region. The limited and differential spatial influence on richness concurs with the report of Sharma and Sharma (2021b) but differs from lack of any influence vides the reports of Sharma and Lyngskor (2003) and Sharma (2012). Regarding the influence on abundance, we record the relative importance of the rainfall, transparency and total hardness. Lower abundance of phytoplankton, Charophyta, Chlorophyta, Chrysophyta, and *Cosmarium granatum* during monsoon at the two regions; *Closterium acrosum* at the littoral region; and that of Dinozoa, *Ceratium hirudinella*, *Navicula radiosa, Scenedesmus acuminatus* and *Spirogyra indica* at the limnetic region depicts adverse influence of the rainfall. Low transparency adversely influences the abundance of phytoplankton, Charophyta, Chrysophyta and *Ceratium hirudinella* at the two regions; it also exerts inverse influence on the abundance of *Closterium acrosum* at the littoral region and Dinozoa at the limnetic region. Total hardness favors abundance of *Closterium acrosum* and *Cosmarium granatum* at the two regions, and that of phytoplankton, *Ceratium hirudinella*, *Navicula radiosa*, *Scenedesmus acuminatus* and *Spirogyra indica* abundance at the limnetic region. Among other factors, this study records the differential spatial importance of total alkalinity and nitrate. The former favours abundance of *Ceratium hirudinella* at the two regions, and that of *Cosmarium granatum, Navicula radiosa*, *Scenedesmus acuminatus, Staurastrum freemani* and *Spirogyra indica* at the limnetic region. Nitrate favours abundance of phytoplankton, Charophyta, Chrysophyta, *Cosmarium granatum*, *Dinobryon sociale*, *Scenedesmus acuminatus* and *Staurastrum arctiscon* at the littoral region. Specific conductivity inversely influences *Closterium decorum* abundance at the littoral region. In general, our results indicate a distinct departure than little insight on the overall influence of individual abiotic factors on phytoplankton assemblages vides the reports of Sharma (1995, 2009. 2010, 2012, 2015), Sharma and Lyngdoh (2003), Sharma and Lyngskor (2003) and Sharma and Pachuau (2016). The differential spatial influence on Charophyta and Chlorophyta and the notable species concurs with the reports of Sharma and Sharma (2021a, 2021b); the lack of influence on Bacillariophyta abundance corresponds with the reports of Sharma (2009), Sharma and Pachuau (2016) and Sharma and Sharma (2021a); the limited influence of specific conductivity differs from lack of any influence (Sharma and Lyngskor 2003), and the role of transparency differs from its limited influence vide the reports of Sharma and Bhattarai (2005) and Sharma and Sharma (2021a).

The canonical correspondence analysis (CCA) registers moderate (67.39% and 66.83%) cumulative influence of 10 abiotic factors, along the first two axes, on the littoral and limnetic phytoplankton assemblages, respectively. The CCA co-ordination biplot indicates the influence of water temperature and rainfall on Bacillariophyta and *Spirogyra indica* abundance; total alkalinity and total hardness on *Cosmarium granatum, Scenedesmus acuminatus Staurastrum freemani* and *Navicula radiosa* abundance; nitrate on phytoplankton and *Closterium acrosum* abundance; nitrate and dissolved organic matter on Chrysophyta, *Cosmarium* spp. and *Scenedesmus* spp. and *Dinobryon sociale* abundance; specific conductivity on Chlorophyta, *Ceratium hirudinella* and *Ulothrix aequalis* abundance; phosphate on Dinozoa abundance; and total dissolved solids on *Staurastrum arctiscon* abundance at the littoral region. The CCA biplot depicts influence of rainfall and phosphate on phytoplankton and Charophyta richness; water temperature on Bacillariophyta abundance; total alkalinity and total hardness on the abundance of phytoplankton, *Ceratium hirudinella*, *Closterium acrosum* and *Scenedesmus acuminatus*; total alkalinity on *Scenedesmus* spp. abundances; and nitrate and dissolved organic matter influence the abundance of Chrysophyta at the limnetic region. Phytoplankton assemblages of Thadlaskein Lake register lower cumulative influence of abiotic factors than the reports from the floodplain lakes of Assam (Sharma 2015; Sharma and Sharma 2021a), while it broadly concurs with the results of Sharma and Sharma (2021b).

To conclude, diverse phytoplankton, Charophyta and desmids, the speciose constellation of 49 species per sample, lower phytoplankton abundance and importance of desmids are notable attributes of the soft, calcium poor and de-mineralized waters of Thadlaskein Lake. Importance of phytoplankton vis-a-vis net plankton abundance, the dominance of Charophyta, sub-dominance of Chlorophyta, Bacillariophyta, Dinozoa and Chrysophyta, the bimodal temporal variations of phytoplankton, Charophyta and Chlorophyta abundance, and the importance of *Staurastrum* spp. > *Closterium* spp. > *Cosmarium* spp. > *Scenedesmus* spp., and 11 species are noteworthy features. The relative importance of rainfall, transparency and total hardness vis-a-vis influence of individual abiotic factors, and moderate cumulative influence (vide CCA) of 10 abiotic factors on phytoplankton assemblages deserve attention. The differential spatial variations of diversity parameters and that of influence of individual abiotic factors are hypothesised to habitat heterogeneity amongst the littoral and limnetic regions.

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