Indian J. Fish., 62 (1): 33-40, 2015

Phytoplankton diversity of Deepor Beel - a Ramsar site in the floodplain of the Brahmaputra River basin, Assam, north-east India

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ABSTRACT

Plankton samples collected from two sampling stations (station I and II) of Deepor Beel, a Ramsar site, during November 2002 to October 2003, revealed occurrence of 59 species of phytoplankton belonging to 55 genera with species rich Chlorophyta > Bacillariophyta. They indicated monthly richness varying between 34 - 53 (39±6) species and 36 - 45 (39±3) species, and recorded 39.4 - 87.4% and 52.8 - 79.6% community similarities (*vide* Sorensen index) at two sampling stations, respectively. Phytoplankton formed 42.1 ± 9.0% and 43.6 ± 8.8% of net plankton abundance at stations I and II, respectively. Chlorophyta > Bacillariophyta influenced quantitative variations; Dinophyta and Cyanophyta were subdominant groups; Chrysophyta and Euglenophyta showed low abundance, while *Ceratium hirudinella, Microcystis aeruginosa, Dinobryon sociale, Cosmarium granatum, Closterium* sp., *Oscillatoria* sp. and *Spirogyra* sp. were important taxa. Phytoplankton recorded high species diversity, high equitability and low dominance. Individual abiotic factors exerted limited influence on richness and abundance of phytoplankton and their constituent groups. The canonical correspondence analysis (CCA) with ten abiotic factors explained 55.3% and 77.9% cumulative variance of phytoplankton along axis 1 and 2 with importance of different factors at two sampling stations, respectively and thus affirmed micro-environmental differences between them.

Keywords: Abundance, Diversity, Ecology, Phytoplankton, Richness, Tropical wetland

Introduction

The floodplain lakes (commonly called *beels* or *pats*) comprise important inland aquatic resources of north-eastern India and deserve special attention for their significant biogenic production potential (Sugunan, 1997). The Indian limnological literature indicates fewer studies on phytoplankton diversity in the floodplain lakes as well as on their role in biological productivity. The studies on diversity of these primary producers from the floodplains of north-east region of India are yet restricted to selected *pats* of Manipur (Sharma, 2009, 2010) and two *beels* (Sharma, 2004, 2012) of Assam. The present study therefore, assumes limnological importance in view of the stated paucity of works and deals with analysis of the net plankton of Deepor Beel, a Ramsar site and an important floodplain lake of the Brahmaputra River basin of lower Assam, for diversity and ecology of phytoplankton and their constituent groups.

Materials and methods

This study formed part of the limnological survey, undertaken during November 2002 to October 2003, in Deepor Beel (long. 91^0 35' - 91^0 43' E, lat. 26^0 05' - 26^0 11' N; area: 40 km^2; altitude: 42 m ASL) located in the Kamrup District of lower Assam, north-east India.

Water samples, collected monthly from two sampling stations (I and II) of Deepor Beel, were analysed for various abiotic parameters. Water temperature, specific conductivity and pH were recorded using field probes and the transparency was noted with a Secchi disc. Dissolved oxygen was estimated by modified Winkler's method and other chemical parameters were analysed following APHA (1992). The qualitative and quantitative net plankton samples were collected at monthly intervals, at both sampling stations, using nylobolt plankton net (# 55 µm) and were preserved in 5% formalin. The former were collected by towing plankton net and the latter by filtering 25 l water each. The qualitative samples were screened and phytoplankton taxa were identified following Islam and Haroon (1980), Adoni *et al.* (1985) and Fitter and Manuel (1986) and several other individual research reports. Quantitative samples were analysed with a Sedgewick-

Rafter counting cell for abundance (individuals per litre/ ind. l^{-1}) of phytoplankton and its constituent groups.

The community similarities (Sorensen's index), species diversity (Shannon's index), dominance (Berger-Parker's index) and evenness (Pileou's index) were calculated following Ludwig and Reynolds (1988) and Magurran (1988). The significance of variations of different parameters between months and sampling stations was ascertained by ANOVA (two-way). The hierarchical cluster analysis, based on Sorensen's similarities was done using SPSS (version11.0). The relationships between abiotic and biotic parameters were determined by Pearson's correlation coefficients (r_1 and r_2 respectively) for each sampling station; their p values were calculated and significance was ascertained after applying Bonferroni corrections. The canonical correspondence analysis (XLSTAT version 2012) was done to observe cumulative influence of ten abiotic factors *i.e*., water temperature, rainfall, pH, transparency, specific conductivity, dissolved oxygen, alkalinity, hardness, phosphate and nitrate on phytoplankton communities of two sampling stations.

Results

The variations in abiotic factors (average ± SD) observed at two sampling stations of Deepor Beel are indicated in Table 1. In general, the ranges of the observed factors are broadly concurrent at stations I and II. Phytoplankton are represented by 59 species (Table 2) belonging to 55 genera and six groups. Chlorophyta (25 species) > Bacillariophyta (20 species) are species rich while Cyanophyta, Euglenophyta, Dinophyta and Chrysophyta included 5, 4, 3 and 2 species respectively. The monthly richness of phytoplankton, Chlorophyta and Bacillariophyta ranged between 34 - 53 (39±6) and 36 - 45 (39±3) species; 13 - 21 and 14 - 20 species; 10 - 18 and 9 - 15 species at stations I and II, respectively (Table 2). The phytoplankton recorded community similarities varying between 39.4 - 87.4% at station 1 (Table 3) and between 52.8 - 79.6% at station 2 (Table 4) with peak richness during April at station I and during May at station II (Fig. 1). The hierarchical cluster analysis exhibited variations in their monthly groupings as shown in Fig. 2 and 3. Phytoplankton (298 - 4 80, 337 ± 50 ind. l^{-1} and 262 - 461, 342 ± 51 ind. l^{-1}) comprised between 42.1 ± 9.0% and 43.6 ± 8.8 % of net plankton abundance at stations I and II, respectively. Their abundance showed (Fig. 4) oscillating monthly variations with peaks during April and May at stations I and II respectively.

Table 1. Temporal variations (average ± SD) of abiotic factors at the samping stations

Factors	Station I	Station II
Rainfall (mm)	204.5 ± 160.4	204.5 ± 160.4
Water temperature (^{0}C)	27.2 ± 4.6	27.4 ± 5.1
pH	6.89 ± 0.18	6.93 ± 0.21
Transparency (cm)	51.9 ± 26.2	52.7 ± 25.3
Specific conductivity (µS cm^{-1})	99.2 ± 13.2	96.8 ± 15.5
Dissolved oxygen (mg l^{-1})	6.7 ± 1.6	7.0 ± 1.1
Free CO_2 (mg l^{-1})	7.2 ± 2.1	6.8 ± 1.9
Alkalinity (mg l^{-1})	66.3 ± 12.1	68.9 ± 10.3
Hardness (mg l^{-1})	62.1 ± 9.9	61.2 ± 12.3
Calcium (mg l^{-1})	20.1± 2.2	22.1± 1.8
Magnesium (mg l^{-1})	4.0 ± 0.7	4.2 ± 0.9
Chloride (mg l^{-1})	34.6 ± 5.2	35.1 ± 5.0
Phosphate (mg l^{-1})	0.18 ± 0.07	0.19 ± 0.10
Sulphate (mg l^{-1})	10.2 ± 3.2	9.9 ± 3.4
Nitrate (mg l^{-1})	0.72 ± 0.12	0.74 ± 0.14
Silicate (mg l^{-1})	3.02± 1.02	3.10 ± 1.27
BOD_5 (mg l^{-1})	3.11 ± 0059	3.21 ± 0.46
Dissolved organic matter (mg l^{-1})	3.84 ± 0.80	3.90 ± 0.64
Total dissolved solids (mg l^{-1})	2.37 ± 0.29	2.57 ± 0.30

Abundance of Chlorophyta ranged between 133 ± 20 ind. l^{-1} at station I and between 130 ± 26 ind. l^{-1} at station II. They followed (Fig. 5-6) multimodal patterns of density variations at both stations and registered peaks during summer (April/May). Bacillariophyta (82±22 ind. l^{-1} and 87±20 ind. l^{-1}) abundance followed (Fig. 5-6) trimodal and multimodal patterns of quantitative variations respectively at the two stations. Dinophyta (47±1 ind.l^{-1}, 41±10 ind. l^{-1}) and Cyanophyta (40±12 ind. l^{-1}, 48±8 ind. l^{-1}) were the other notable groups. Chrysophyta (18±11 ind. l^{-1}, 22±15 ind. l^{-1}) > Euglenophyta (17±4 ind. l^{-1}, 14±2 ind. l^{-1}) showed lower densities (Table 2). Phytoplankton species diversity varied (Table 2) between 2.948-3.696 (3.308±0.218) at station I and between 3.121-3.620 (3.381±0.121) at station II; it followed no particular periodicity (Fig. 7) at the two stations. The dominance varied between 0.114±0.043 and 0.097±0.030, and evenness ranged between 0.902±0.040 and 0.921±0.030 at two sampling stations, respectively. The canonical correspondence analysis ordination biplots of phytoplankton assemblages and abiotic variables at stations 1 and 2 are presented in Fig. 8-9.

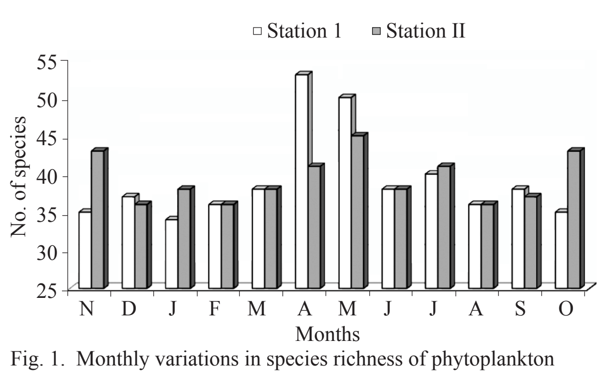

Fig. 1. Monthly variations in species richness of phytoplankton

Table 2. Temporal variations (range, average ± SD) of phytoplankton at the samping stations

Parameters	Station I	Station II
Qualitative		
Total richness	59 species	59 species
Monthly richness		
Phytoplankton	34-53 (39 ± 6)	36-45 (39 ± 3)
Chlorophyta	13-21 (16 ± 2)	14-20 (17 ± 2)
Bacillariophyta	10-18 (13 ± 3)	9-15 (12 ± 2)
Percentage similarity	39.4-87.4	52.8-79.6
Quantitative		
Net plankton (ind.l^{-1})	708 -961 (812 ± 80)	676-1058 (801± 123)
Phytoplankton (ind.l^{-1})	298-480 (337 ± 50)	262-461 (342 ± 51)
Percentage	31.6-66.8 (42.1 ± 9.0)	33.1-64.6 (43.6 ± 8.8)
Species diversity	2.948-3.696 (3.308 ± 0.218)	3.121-3.620 (3.381 ± 0.121)
Dominance	0.051-0.215 (0.114 ± 0.043)	0.058-0.156 (0.097 ± 0.030)
Evenness	0.829-0.980 (0.902 ± 0.040)	0.871-0.994 (0.921 ± 0.030)
Different groups		
Chlorophyta (ind.l^{-1})	102-179 (133 ± 20)	97-186 (130 ± 26)
Percentage	34.4-47.4 (39.5 ± 4.3)	31.0-44.8 (38.0 ± 4.5)
Bacillariophyta (ind.l^{-1})	55-127 (82 ± 22)	68-129 (87 ± 20)
Percentage	18.1-32.2 (24.2 ± 4.1)	16.8-31.1 (25.2 ± 3.4)
Dinophyta (ind.l^{-1})	31-68 (47 ± 11)	22-57 (41 ± 10)
Percentage	9.3-22.8 (14.3 ± 3.9)	7.5-16.8 (12.0 ± 3.3)
Cyanophyta (ind.l^{-1})	19-72 (40 ± 12)	40-66 (48 ± 8)
Percentage	6.4-16.4 (11.8 ± 2.5)	10.4-17.6 (14.1 ± 2.0)
Chrysophyta (ind.l^{-1})	4-40 (18 ± 11)	5-52 (22 ± 15)
Percentage	1.3-11.9 (5.2 ± 3.1)	1.7-14.0 (6.2 ± 4.2)
Euglenophyta (ind.l^{-1})	12-26 (17 ± 4)	11-18 (14 ± 2)
Percentage	3.9-6.4 (4.9 ± 0.8)	3.3-5.7 (4.3 ± 0.6)
Dominant taxon		
Ceratium hirudinella (ind.l^{-1})	18-64 (37 ± 12)	20-52 (33 ± 8)
Important taxa		
Microcystis aeruginosa (ind.l^{-1})	0-28 (12 ± 8)	5-40 (19 ± 8)
Dinobryon sociale (ind.l^{-1})	0-10 (9 ± 7)	2-50 (17 ± 15)
Cosmarium granatum (ind.l^{-1})	0-22 (9 ± 6)	8-22 (15 ± 5)
Closterium sp. (ind.l^{-1})	0-20 (9 ± 6)	0-28 (14 ± 7)
Oscillatoria sp. (ind.l^{-1})	0-20 (9 ± 7)	0-22 (12 ± 9)
Spirogyra sp. (ind.l^{-1})	0-16 (9 ± 5)	0-14 (10 ± 4)

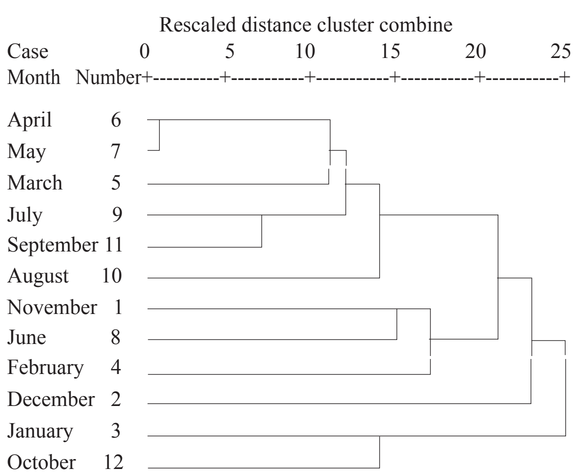

Fig. 2. Dendrogram showing hierarchical cluster analysis of phytoplankton (Station I)

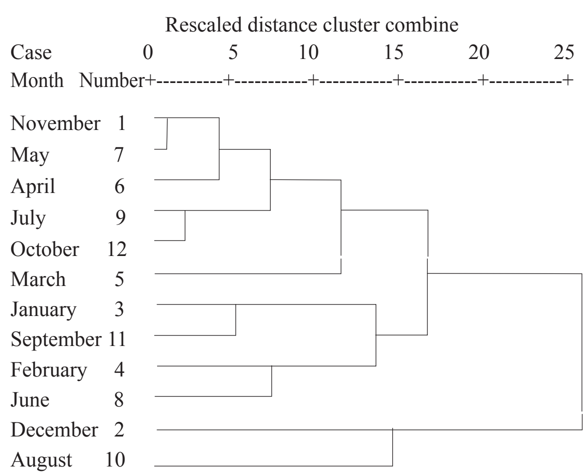

Fig. 3. Dendrogram showing hierarchical cluster analysis of phytoplankton (Station II)

Table 3. Phytoplankton community similarities (Station I)

	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct
Nov.	-	61.1	39.4	65.8	61.3	75.6	71.3	67.6	64.1	63.0	50.0	57.5
Dec.		-	52.2	47.9	65.8	72.7	68.2	63.9	57.9	64.8	56.8	50.7
Jan.			-	54.3	61.1	66.7	71.4	64.8	66.7	54.3	68.5	68.6
Feb.				-	56.8	71.9	65.1	63.0	70.1	63.9	66.7	61.1
March					-	72.5	75.0	58.7	65.8	64.9	70.1	67.6
April						-	87.4	71.1	76.6	76.4	73.9	71.9
May							-	64.4	72.5	69.8	76.4	72.1
June								-	61.5	63.0	52.6	68.5
July									-	67.5	75.0	57.1
Aug.										-	69.3	47.2
Sept.											-	58.7
Oct.												-

Table 4. Phytoplankton community similarities (Station II)

	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct
Nov.	-	68.4	60.0	65.8	74.1	76.2	79.6	77.5	74.7	70.1	60.0	69.0
Dec.		-	57.5	52.8	59.5	64.9	69.1	57.5	60.5	65.7	54.8	57.5
Jan.			-	63.0	56.0	66.7	70.7	67.6	67.5	50.7	73.0	79.0
Feb.				-	62.2	62.3	74.1	71.2	60.5	65.7	68.5	75.0
March					-	73.4	67.5	66.7	66.7	61.1	58.7	70.7
April						-	74.4	59.0	74.1	66.7	66.7	68.2
May							-	68.3	75.3	70.9	70.7	78.7
June								-	67.5	67.6	73.0	69.1
July									-	67.6	75.3	78.6
Aug.										-	64.8	56.4
Sept.											-	71.6
Oct.												-

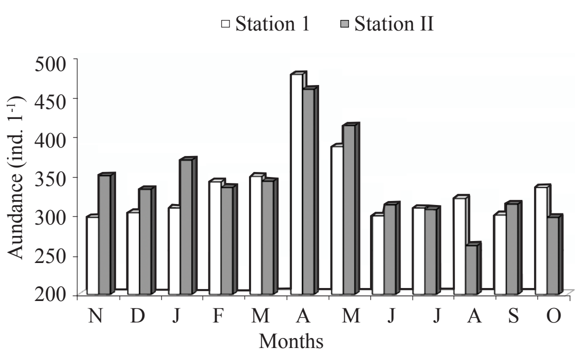

Fig. 4. Monthly variations in abundance (ind. l-1) of phytoplankton

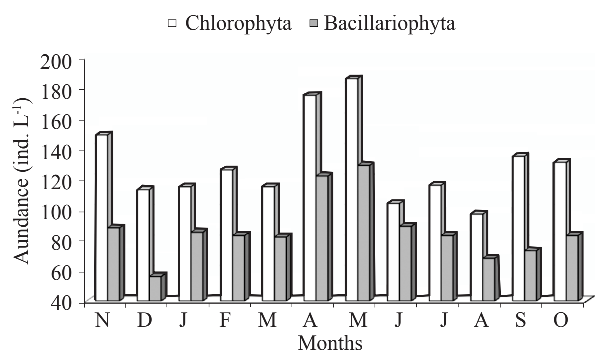

Fig. 6. Monthly variations in abundance (ind. l-1) of dominant groups (Station II)

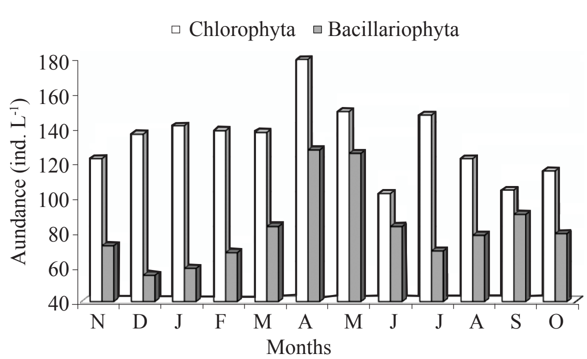

Fig. 5. Monthly variations in abundance (ind. l-1) of dominant groups (Station I)

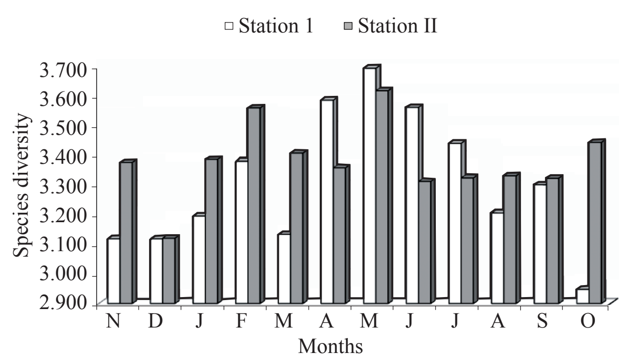

Fig. 7. Monthy variations in species diversity of phytoplankton

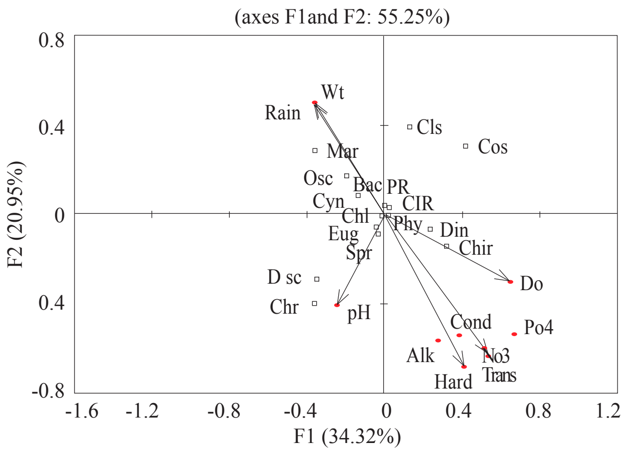

Fig. 8. CCA ordination biplot of phytoplankton and abiotic variables (Station I)

ClR - Chlorophyta richness, PR - Phytoplankton richness, Bac - Bacillariophyta, Chl - Chlorophyta, Chr - Chrysophyta, C hir - *Ceratium hirudinella*, Cls - *Closterium* sp., Cos - *Cosmarium granatum*, Cyn - Cyanophyta, Din - Dinophyta, D soc - *Dinobryon sociale*, Eug - Euglenophyta, M ar - *Microcystis aeruginosa*, Osc - *Oscillatoria* sp., Phy - phytoplankton, Spr - *Spirogyra* sp.

Alk - alkalinity, Cond - conductivity, Do - dissolved oxygen, Hard - hardness, pH - hydrogen-ion concentration, NO_3 - nitrate, PO_4 - phosphate, rain - rainfall, Trans - transparency, Wt - water temperature

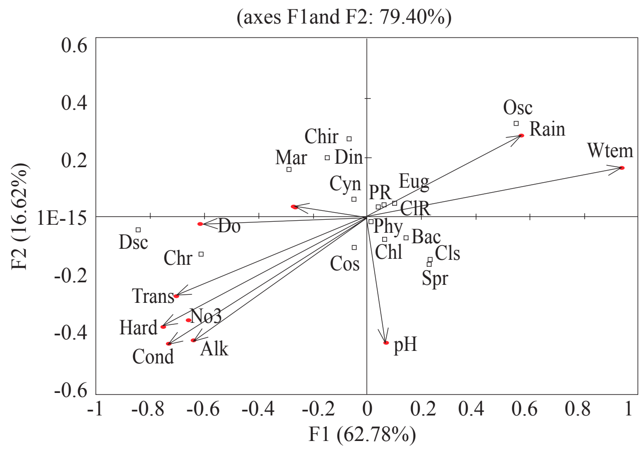

Fig. 9. CCA ordination biplot of phytoplankton and abiotic variables (Station II)

ClR - Chlorophyta richness, PR - Phytoplankton richness, Bac - Bacillariophyta, Chl - Chlorophyta, Chr - Chrysophyta, C hir - *Ceratium hirudinella*, Cls - *Closterium* sp., Cos - *Cosmarium granatum*, Cyn - Cyanophyta, Din - Dinophyta, D soc - *Dinobryon sociale*, Eug - Euglenophyta, Mar - *Microcystis aeruginosa*, Osc - *Oscillatoria* sp.,Phy - phytoplankton, Spr - *Spirogyra* sp.

Alk - alkalinity, Cond - conductivity, Do - dissolved oxygen, Hard - hardness, pH - hydrogen-ion concentration, NO_3 - nitrate, PO_4 - phosphate, rain - rainfall, Trans - transparency, Wt - water temperature

Discussion

The circum-neutral and marginally hard waters of tropical Deepor Beel are characterised by low ionic concentrations and thus warranted inclusion of this Ramsar site under 'Class I' category *vide* Talling and Talling (1965). This wetland recorded moderate dissolved oxygen, low free CO_2 and low concentration of micro-nutrients. Chloride and BOD_5 values reflected some possible impact of human activity.

The fairly speciose and diverse phytoplankton (59 species, 55 genera and six groups) of Deepor Beel are hypothesised to environmental heterogeneity of this Ramsar site. The richness is relatively lower than the report of 75 species (Sharma, 2009) from Loktak Lake (another Ramsar site), Manipur while it broadly concurred with 62 and 61 species recorded from Utra and Waithou *pats* of the latter state. Phytoplankton of Deepor are however, distinctly diverse than the reports from the floodplains of Bihar (Baruah *et al*., 1993; Sanjer and Sharma, 1995), Assam (Goswami and Goswami, 2001; Sharma, 2004; Sharma and Sharma, 2012) and Maharashtra (Patil, 2002). Chlorophyta > Bacillariophyta, the two speciose groups, showed concurrence with the report of Sharma and Sharma (2012) but differed from distinct richness of the green algae noticed by Goswami and Goswami (2001) and Sharma (2009, 2010) and also from the greater diatom richness reported by Baruah *et al*. (1993) and Sharma (2004). Interestingly, the present results differed from the reports of Sharma (2009, 2010, 2012) in lack of distinct richness of any desmid genus. This salient feature is attributed to circum-neutral and marginally hard waters of this Ramsar site in spite of its 'calcium-poor' nature**.**

The occurrence of all species of phytoplankton and concurrent mean monthly richness at both sampling stations reflected homogeneity in their composition. This generalisation is endorsed by insignificant variations of richness between the two sampling stations and months. These remarks also hold true for the Bacillariophyta while Chlorophyta showed significant monthly variations ($F_{11,23}$=3.981, p>0.01) but indicated insignificant variations between stations I and II. In general, this study indicated no definite pattern of monthly variations of phytoplankton richness except summer peaks. The former feature concurred with the author's earlier remarks (Sharma, 2004) in a *beel* of upper Assam while peak summer richness corresponded with the report from a *beel* of lower Assam (Sharma, 2012).

The community similarity at station I (39.4-87.4%) indicated relatively wider differences in phytoplankton composition than at station II (52.8-79.6%). The divergence is supported by the fact that only single species occurred throughout the study period at the former station in contrast to six perennial species observed at the latter station. The majority of instances included in the matrices of both sampling stations, however, indicated similarities ranging between 60-70%. Peak similarities are noticed between April *vs* May (station I) and November *vs* May (station II) samples. The hierarchical cluster analysis exhibited notable variations in monthly groupings particularly at station 1 with wider divergence in different months except during April and May. Further, December, January and October communities exhibited maximum differences at this station. On the other hand, November - May > July-October samples showed high phytoplankton affinities while June, December and August collections indicated maximum differences in their composition at station II.

ANOVA indicated significant differences in phytoplankton abundance between months ($F_{11,\ 23}$ = 8.031, p>0.005), while it was insignificant between two sampling stations. They formed a sub-dominant quantitative component of net plankton throughout the study except during April (station I) and, April and May (station II). This salient feature is in concurrence with earlier reports from the flood plains of north-east India (Sharma, 2004, 2009, 2010, 2012). This feature is, however, in contrast to phytoplankton predominance reported from the flood plain lakes of Kashmir (Kaul and Pandit, 1982), Bihar (Rai and Dutta-Munshi, 1982, Baruah *et al.,* 1993; Sanjer and Sharma, 1995), West Bengal (Sugunan, 1989), Rajasthan (Vyas, 1989), Assam (Yadava *et al.,* 1987; Goswami and Goswami, 2001), Kerala (Krishnan *et al.,* 1999) and Maharashtra (Patil, 2002). In general, lower phytoplankton abundance suggested availability of other food resources such as organic matter absorbed in sediments, detritus and bacteria as hypothesised by Sharma (2012). Further, the insignificant correlations between phytoplankton *vs* zooplankton indicated no evidence of an important control of former by the latter; which is in agreement with the results in certain flood plain lakes of Argentina (Jose de Paggi and Paggi, 2007) and also supported the remarks of Sharma (2009, 2012). The abundance of phytoplankton in Deepor Beel is nearly two and half times higher than in Samuajan *beel* (Sharma, 2004) but is distinctly lower than the reports from certain *beels* of West Bengal (Sugunan, 1989; Vass, 1989) and Bihar (Baruah *et al.,* 1993; Sanjer and Sharma, 1995). The present study exhibited trimodal and multimodal patterns of quantitative variations of phytoplankton at the two stations in contrast to bimodal periodicity reported by Yadava *et al.* (1987) and Sanjer and Sharma (1995). The peak density observed presently during April (early summer) however, differed from winter peaks recorded by Yadava *et al.* (1987) and Sanjer and Sharma (1995).

Chlorophyta>Bacillariophyta are dominant quantitative groups of phytoplankton of Deepor Beel. The green algae (r_1=0.776, p=0.0030; r_2=0.804, p=0.0016) and the diatoms (r_1=0.805, p=0.0016; r_2=0.798, p=0.0019) contributed significantly to density variations of phytoplankton. Higher abundance of the former matched with the reports of Yadava *et al.* (1987), Choudhary and Singh (2001), Goswami and Goswami (2001) while it differed from the diatom predominance reported by Baruah *et al.* (1993) and Krishnan *et al.* (1999). Chlorophyta formed between 39.5±4.3% and 38.0 ± 4.5% of phytoplankton abundance at station I and II, respectively. ANOVA showed significant differences in their abundance between months ($F_{11.23}$=2.986, p<0.0.05) and insignificant variations between two sampling stations. This group followed multimodal patterns of quantitative variations with differences at individual stations but registered peaks during summer (April/ May). Among the recorded taxa, *Cosmarium granatum, Closterium* sp.*, Oscillatoria* sp. and *Spirogyra* sp. showed quantitative importance. Bacillariophyta, another notable group, comprised between 24.2±4.1% and 25.2 ± 3.4% of phytoplankton; registered significant density variations between months ($F_{11,23}$=11.820, p > 0.005) but showed no distinct density importance of any species. The diatoms followed trimodal and multimodal quantitative variations with peaks during April and May at the two sampling stations, respectively.

Dinophyta>Cyanophyta and Cyanophyta>Dinophyta are subdominant groups at the stations I and II, respectively; both recorded insignificant variations between sampling stations and months. The two groups exhibited broadly multimodal and indefinite monthly patterns. *Ceratium hirudinella* mainly influenced density variations of Dinophyta while *Microcystis aeruginosa* and *Oscillatoria* sp. influenced abundance of Cyanophyta. The quantitative importance of Dinophyta in general and *C. hirudinella* in particular is in concurrence with the results of Sharma (2009, 2012) while it is in contrast to the report of Sharma (2010). The other groups namely Chrysophyta>Euglenophyta indicated lower abundance in Deepor Beel.

Higher phytoplankton species diversity observed in this study stressed environmental heterogeneity of this Ramsar site. The diversity varied between 2.948-3.696 (3.308±0.218) at station I and recorded marginally higher values (3.121-3.620, 3.381±0.121) at station II. It exhibited insignificant temporal variations between months as well as stations and followed no particular periodicity at the two sampling stations but recorded its peak during May (summer). The diversity is positively correlated with richness (r_1=0.758, p=0.0043; r_2 =0.768, p=0.0035). Its values broadly matched with the reports from the floodplains of north-east India (Sharma, 2009, 2010, 2012) while it is distinctly high than the report from Samuajan Beel (Sharma, 2004) of upper Assam.

Lower dominance (0.188±0.067) and higher evenness (0.878 ± 0.051) of phytoplankton of Deepor Beel are attributed to equitable abundance and low densities of majority of species which in turn, is in agreement with the reports from various aquatic environments of north-east India (Sharma, 1995; Sharma and Lyngskor, 2003; Sharma, 2004, 2009, 2010, 2012). The former aspect is affirmed by quantitative importance of fewer species in general and of *Ceratium hirudinella* in particular. Further, the two parameters followed multimodal variations with insignificant variations between months as well as sampling stations. Evenness is positively correlated with species diversity (r_1 = 0.839, p=0.0006; r_2 = 0.821, p=0.0011) but recorded insignificant relationships both with richness and abundance. The dominance is inversely correlated with richness (r_2=-0.774, p=0.0031) and diversity (r_1 = - 0.706, p=0.0103; r_2 = - 0.726, p=0.0076).

The study indicated very limited influence of individual abiotic parameters on richness and abundance of phytoplankton and their constituent groups and thus supported earlier results (Sharma, 2012). The phytoplankton richness is positively correlated with water temperature (r_1 = 0.799, p=0.0018) at station I only. Their abundance is inversely correlated with sulphate (r_2=-0.772, p=0.0033) at station II. No single abiotic factor significantly influenced Chlorophyta abundance. Bacillariophyta abundance is positively correlated with water temperature at station I (r_1=0.691, p=0.0128). Cyanophyta are inversely correlated with transparency (r_1=-0.667, p=0.0178), dissolved oxygen (r_1=-0.676, p=0.0158) and phosphate (r_1=-0.685, p=0.0140) at station I. Dinophyta indicated positive correlations with nitrate (r_1=0.681, p=0.0148) at station I. Canonical correspondence analysis with ten abiotic factors explained 55.5% cumulative variance of phytoplankton along axis 1 and 2 at station 1 while it explained high cumulative variation (79.4%) along the two axes at station II. At station 1, water temperature and rainfall collectively influenced phytoplankton richness and abundance of Chlorophyta, Bacillariophyta, Cyanophyta, *Microcystis aeruginosa* and *Oscillatoria* sp.; while abundance of Euglenophyta and *Spirogyra* sp. is influenced by pH; and dissolved oxygen influenced abundance of phytoplankton, Dinophyta and *Ceratium hirudinella*. At station II, the richness of phytoplankton and abundance of Chlorophyta as well as Euglenophyta are influenced by high rainfall and water temperature. *Oscillatoria* sp. density is influenced by low rainfall; phytoplankton abundance is influenced by low pH; high alkalinity influenced *Cosmarium granatum* while phosphate influenced Cyanophyta. The stated remarks affirmed micro-environmental differences between the sampling stations.

Results of the present study showed that phytoplankton of Deepor Beel are fairly diverse and speciose; richness indicated insignificant variations between months and sampling stations while Chlorophyta, the most diverse group, showed significant monthly variations. Phytoplankton formed subdominant quantitative group of net plankton with importance of Chlorophyta>Bacillariophyta, subdominant nature of Dinophyta and Cyanophyta, and poor abundance of other groups. Phytoplankton, their constituent groups or individual species showed lack of definite monthly variations of abundance. Phytoplankton is characterised by higher diversity, lower dominance and higher equitability. Individual abiotic factors depicted limited influence on richness and abundance but the CCA analysis explained high cumulative variance; the importance of different factors explained micro-environmental differences between two sampling stations.

Acknowledgements

The author is thankful to the G. B. Pant Institute of Himalayan Environmental Development, Almora for a research grant under which this study was undertaken. Thanks are also due the Head, Department of Zoology, North-Eastern Hill University, Shillong for laboratory facilities.

References

Adoni, A. D., Ghosh, G., Chourasia, S. K., Vaishya, A. K., Yadav, M. and Verma, H. G. 1985. *Workbook on limnology*. Pratibha Publishers. 216 pp.

A PHA 1992. *Standard methods for the examination of water and waste water,* 18th edn. American Water Works Association and Water Pollution Control Federation, New York, 1198 pp.

Baruah, A., Sinha, A. K. and Sharma, U. P. 1993. Plankton variability of a tropical wetland, Kawar (Begusarai), Bihar. *J. Freshwater Biol.,* 5: 27-32.

Choudhary, S. and Singh, D. K. 2001. Phytoplankton population of Boosra Lake (Gaighat block, Muzaffarpur, Bihar). *Env. Ecol.,* 19: 171-174.

Fritter, R. and Manuel, R. 1986. *Field guide to the freshwater life of Britain and north-west Europe*. William Collins Sons & Co. Ltd, London. 382 pp.

Goswami, M. M. and Goswami, N. 2001. Studies on productivity indicators in Mori Beel of Assam. *Trop. Zool.,* 2&3: 1-9.

Islam, A. K. M. N. and Haroon, A. K. Y. 1980. Desmids of Bangladesh. *Int. Revue ges. Hydrobiol.,* 65(4): 551-604.

Jose de Paggi, S. and Paggi, J. C. 2007. Zooplankton. In: Iriondo, M. H., Paggi J. C., and Parma, M. J. (Eds.), *The middle Paraná River: Limnology of a subtropical wetland.* Springer-Verlag, Berlin, Heidelberg, p. 229-248.

Kaul, V. and Pandit, A. K. 1982. Biotic factors and food chain structure in some typical wetlands of Kashmir. *Poll. Res.,* 1: 49-54.

Krishnan, K. H., Thomas, S. George, S., Murugan , R. P., Mundayoor, S. and Das, M. R. 1999. A study on the distribution and ecology of phytoplankton in the Kuttanad wetland ecosystem, Kerala. *Poll. Res.,* 18: 261 – 269.

Ludwig, J. A. and Reynolds, J. F. 1988. *Statistical ecology: a primer on methods and computing*. John Wiley & Sons, New York, 337 pp.

Magurran, A. E. 1988. *Ecological diversity and its measurement*. Croom Helm Limited, London, 179 pp.

Patil, S. G. 2002. Limnological studies - Biotic factors. In: *Fauna of Ujjani (Maharashtra). Wetland ecosystem series No.,* 3: 27 – 61.

Rai, D. N. and Dutta-Munshi, J. M. 1982. Ecological characteristics of `Chaurs' of North Bihar. In: Gopal, B., Turner, R. E., Wetzel, R. G. and Winghon, D. F. (Eds.), *Wetlands-ecology and management*, Vol. II: International Scientific Publications and National Institute of Ecology, Jaipur, India, p. 89-95.

Sanjer, L. R. and Sharma, U. P. 1995. Community structure of plankton in Kawar Lake wetland, Begusarai, Bihar: II Zooplankton. *J. Freshwater Biol.,* 7: 165-167.

Sharma, B. K. 1995. Limnological studies in a small reservoir in Meghalaya, N. E. India. In: Timotius, K. H. and Goltenboth, F. (Eds.), *Tropical limnology* Vol. II. Satya Wacana University Press, Salatiga, Indonesia, p. 1-11.

Sharma, B. K. 2004. Phytoplankton communities of a floodplain lake of the Brahmaputra River basin, Upper Assam. *J. Inland Fish. Ass.,* 31: 27-35.

Sharma, B. K. 2009. Phytoplankton communities of Loktak Lake (a Ramsar site), Manipur, N. E. India: composition, abundance and ecology. *J. Threatened Taxa,* 1(8): 401-410.

Sharma, B. K. 2010. Phytoplankton diversity of two floodplain lakes (pats) of Manipur, N. E. India. *J. Threatened Taxa,* 2(11): 1273-1281.

Sharma, B. K. 2012. Phytoplankton diversity of a floodplain lake of the Brahmaputra River basin, Assam, north-east India. *Indian J. Fish.,* 59(4) : 131-139.

Sharma, B. K. and Lyngskor, C. 2003. Abundance and ecology of net and phytoplankton of a subtropical reservoir of Meghalaya,N. E. India. *Ecol. Env. Cons.,* 9 (4)**:** 497-503.

Sinha, A. K, Baruah, A., Singh, D. K. and Sharma, U. P. 1994. Biodiversity and pollution status in relation to physico-chemical factors of Kawar Lake (Begusarai), North Bihar. *J. Freshwater Biol.,* 6: 309-331.

Sugunan, V. V. 1997. Fisheries management of small bodies in seven countries in Africa, Asia and Latin America. *FAO Circular No., 933*, Rome, 149 pp.

Talling, J. F. and Talling, I. B. 1965. The chemical composition of African lake waters. *Int. Rev. Hydrobiol.,* 50: 421-463.

Vass, K. K. 1989**.** Beel fisheries resources in West Bengal. *Bulletin of the Central Inland Capture Fisheries Research Institute, Barrackpore,* 63: 29-35.

Vyas, L. N. 1989. State of art of Pichhola - Fatehsagar wetland complex. In: *Wetlands, mangroves and biosphere resources: Proceedings of the Indo-US workshop*. Ministry of Environment and Forests, Govt. of India, New Delhi, p. 66-81.

Yadava, Y. S., Singh, R. K., Choudhury M. and Kolekar, V. 1987. Limnology and productivity in Dighali Beel, Assam. *Trop. Ecol.,* 28: 137-146.

Date of Receipt : 25.09.2012
Date of Acceptance : 15.07.2014