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Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak Valley, Assam, North East India - A seasonal study

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Abstract: *A study was carried out in Chatla floodplain lake, Barak Valley, Assam, North East India on phytoplankton diversity, density and distribution in different seasons and their correlations with physico-chemical properties of water. A total of 34 phytoplankton taxa belonging to Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae were recorded. Highest number of species was present in pre-monsoon (29) and lowest in winter (23). Members of Chlorophyceae were present in a reasonable number throughout the year while being most abundant in pre-monsoon and monsoon. Bacillariophycae and Cyanophyceae populations did not show much seasonal variation. Percentage composition of Euglenophyceae showed clear seasonal change, being most dominant in post monsoon, moderate in pre-monsoon and winter and nearly absent in monsoon. Total phytoplankton density showed highly significant positive correlation with transparency ($p< 0.01$) and significant positive correlation with total suspended solids, total hardness and calcium ($p < 0.05$). Shannon-Wiener diversity index ($H^{/}$) value (2.66) was found to be the highest during pre-monsoon while the highest evenness ($J^{/}$) value (0.89) was recorded during winter. Berger-Parker index of dominance (0.45) was highest in post- monsoon. Our study revealed that the growth of phytoplankton is governed by transparency, total suspended solids, calcium and total hardness. These types of studies are prerequisites for evolving fish culture programmes and management of water resources.*

Key words: *Chatla floodplain lake, Phytoplankton, Pre- monsoon, Monsoon, Post-monsoon, Density*
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Introduction

Floodplain lakes are common features of the river systems in North East India. The floodplain lake of Assam are highly productive systems producing around 100 kg $ha^{-1}yr^{-1}$ of fish in contrast to a meagre 6-7 kg $ha^{-1}yr^{1}$ from Indian reservoirs (Jhingran, 1991).

Diversity, distribution, abundance and variation in the biotic factors provide information of energy turnover in the aquatic systems (Forsberg, 1982). In these systems phytoplankton is of great importance as a major source of organic carbon located at the base (Gaikwad *et al.*, 2004). Their sensitivity and large variations in species composition are often a reflection of significant alteration in ambient condition within an ecosystem (Devassy and Goes, 1988, 1989). Hence for any scientific utilization of water resources plankton study is of primary interest. Several studies on phytoplankton diversity made in India and abroad on the ponds, lakes and reservoirs (Tiwari and Chauhan, 2006; Sridhar *et al.,* 2006; Tas and Gonulol, 2007; Senthilkumar and Sivakumar, 2008) also revealed the importance of this type of study. In this paper an attempt has been made to study the seasonal variation of phytoplankton diversity and dynamics of a part of Chatla floodplain lake and its correlations with the physico-chemical properties of water. This study may be of help to the poor people of Chatla as abundance of phytoplankton is of considerable assistance in evolving fish culture programmes (Bohra and Kumar, 2002).

Materials and Methods

The study was conducted in a part of Chatla floodplain lake during September 2006 to August 2007. Chatla floodplain lake ($24^{o}42^{/}697^{//}$ N, $92^{o}46^{/}264^{//}$ E) situated about 20 km south of Silchar, Barak Valley, Assam, has a number of small inlets and a single outlet which drains into river Barak. It attains an area of about 1750 ha during monsoon. The inhabitants of the floodplain lake depend mostly on its water resource particularly fish for their livelihood. Phytoplankton and water samples were collected in pre-monsoon (March-May), monsoon (June-August), post-monsoon (September-November) and winter (December-February) from different areas of the floodplain lake. Physico-chemical parameters such as dissolved oxygen, total alkalinity, pH, transparency, electrical conductivity, total dissolved solid, total suspended solid, free carbon-di-oxide, chloride, total hardness, calcium, magnesium and biological oxygen demand were analyzed by standard methods (Michael, 1984; APHA, 2005). Qualitative and quantitative estimation of phytoplankton from each site was carried out with the help of "Sedgwick Rafter" counting cell and identified using standard literature (Edmondson, 1959; Anand, 1998). The community structure was analysed using the Shannon-Wiener index of diversity ($H^{/}$), Evenness index ($J^{/}$) and Berger-Parker index of dominance (D_{BP}) (Magurran, 2004). The Pearson correlation coefficient was used to examine the relationships among the different environmental variables including phytoplankton density. The linear regression model was performed using SPSS 12.0.

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Results and Discussion

The biological spectrum of the lentic fresh water bodies is multidimensional where phytoplankton are useful in biomonitoring the ecological disturbance caused by a number of physico-chemical factors, sewage pollutants and other anthropogenic factors. Limnological characteristics of floodplain lakes in different seasons are related to the hydrological condition of the river (Gabellone *et al*., 2001). This influence is reflected in the physico-chemical characteristics and the plankton communities of water in different seasons in the present study.

A total of 34 phytoplankton taxa were recorded in the floodplain lake of which 18 belong to Chlorophyceae, 9 to Cyanophyceae, 6 to Bacillariophyceae and 1 to Euglenophyceae. The major taxa of phytoplankton in terms of frequency and abundance were *Spirogyra, Maugeotia, Desmidium, Microspora, Closterium, Chlorella, Cladophora, Zygnema, Golenkinia,* (Chlorophyceae); *Anabaena, Oscillatoria* (Cyanophyceae); *Euglena* (Euglenophyceae); *Synedra, Cymbella, Navicula and Nitzschia* (Bacillariophyceae). Seasonal variations in phytoplankton diversity was not very pronounced, although the highest number of species was recorded in pre-monsoon (29), followed by that in monsoon (28), post-monsoon (27) and winter (23). The family Chlorophyceae was represented by highest number of species and Euglenophyceae was represented by a single species. Seasonal distribution pattern of phytoplankton density revealed it to be the highest in post-monsoon, followed by monsoon, pre-monsoon and winter (Table 1). In the floodplain lakes of Bug river, eastern Poland, both diversity and abundance of phytoplankton were highest in summer (Wojciechowska *et al.,* 2007). Similar high density in summer was also observed in the floodplain lakes of Argentina (Garcia de Emiliani, 1993). However, a study on the south Pantanal

Table - 1: Seasonal variation of composition, density and distribution of phytoplankton taxa of Chatla floodplain lake during September 2006 to August 2007

	Mean number x 10^2 l^{-1} ± SD			
	Post-monsoon 2006	**Winter 2006-07**	**Pre-monsoon 2007**	**Monsoon 2007**
Actinastrum sp.	0	0	1.16±0.16	0.5±0.5
Chlorella sp.	9±2.7	1.67±0.16	3.84±1.16	10.34±2.02
Chlamydomonas sp.	6.34±3.2	0	0.17±0.16	1.5±0.76
Cladophora sp.	4.5±1.8	4±2.08	9.16±1.87	9.67±2.61
Closterium sp.	1.5±1.5	3±0.28	4.34±0.92	12.34±3.37
Cosmarium sp.	1.6±0.83	3.5±0.5	2.34±2.34	5.67±3.17
Cylindrocapsa sp.	1±0.5	0	0.34±0.34	0
Desmidium sp.	0.5±0.5	0.67±0.44	13.5±1.89	8.34±3.71
Golenkinia sp.	7.67±2.13	1.5±0.76	5.5±1.32	3.84±2.89
Microspora sp.	7.83±2.4	3.67±0.60	13±1.6	1.34±0.88
Maugeotia sp.	2.5±0.86	0	13.67±2.9	42.5±8.08
Spirogyra sp.	22.34±1.87	6±0.5	2.34±0.6	18.34±9.8
S. indica	1.34±1.34	0.83±0.83	0.34±0.16	7.84±4.95
Scenedesmus quadricauda (Turp.) Breb.	2.67±0.88	0	0	1.5±1.25
Triploceros sp.	0.84±0.6	0	6.17±3.6	0
Ulothrix sp.	6.17±1.74		4±4	10±4.48
Volvox sp.	0	6±0.28	0.84±0.6	0
Zygnema sp.	9.16±2	1.84±1.01	0.4±0.3	0.16±0.16
Total Chlorophyceae	**85**	**32.67**	**81.67**	**134.34**
Anabaena sp.	2.5±0.5	4.16±1.16	7.67±2.45	4.84±1.87
Microcoleus acutissimus	1.17±0.67	1.5±0.76	0	1.67±0.88
Chlorococcus sp.	0	2.5±1.25	0.5±0.5	0
Aulosira fertilissima	0	0	1.5±1.25	0
Nostoc sp.	0.84±0.16	3.84±0.73	0	3.84±0.92
Rivularia sp.	0	0	2.17±0.16	2.34± 0.34
Oscillatoria sp.	9±4.82	25.84±1.84	0	16.84±2.12
Scytonema sp.	0	1.83±1.67	0	*0*
Spirulina sp.	2.5±1.44	2.67±0.16	1.17±0.92	0.84±0.84
Total Cyanophyceae	**16**	**42.34**	**13.1**	**30.34**
Euglena sp.	106.84±5.98	6±0.28	11.16±4.49	0.67±0.67
Total Euglenophyceae	**106.84**	**6**	**11.16**	**0.67**
Cymbella sp.	1±0.5	1.84±0.92	24.5±4.19	4.5±2.5
Fragillaria sp.	0.67±0.44	0	4.84±1.74	3.67±2.02
Gyrosigma sp.	1.84±0.92	0	7.67±3.87	0.5±0.5
Navicula sp.	21.5±7	3.5±1.75	27.5±2.17	27.84±4.2
Nitzschia sp.	3.17±0.44	3.5±1.8	4.17±4.17	2.17±1.48
Synedra sp.	0	4.5±1.44	0.34±0.34	11.34±5.73
Total Bacillariophyceae	**28.17**	**13.34**	**69.02**	**50.02**
Total Phytoplankton	**236.01**	**94.35**	**174.95**	**215.37**

Mean ± standard deviation (SD) of 3 samples

Table - 2: Physical and chemical characteristics of water of Chatla floodplain lake and rainfall during September 2006 to August 2007

Parameters	**Post-monsoon 2006 (Mean ± SE)**	**Winter 2006-07 (Mean ± SE)**	**Pre-monsoon 2007 (Mean ± SE)**	**Monsoon 2007 (Mean ± SE)**
DO (mg l^{-1})	6.96±0.7	7.26±0.4	3.91±0.06	2.31±0.42
Total Alkalinity (mg l^{-1})	131.84±6.12	69.83±8.84	69.12±2.95	17.15±1.15
pH	7.05±0.06	6.71±0.15	6.2±0.14	6.8±0.05
Conductivity (µS cm^{-1})	3670±115.9	284±92.42	3770±121.24	6466.67±534.4
TDS (mg l^{-1})	25.64±2.95	43.93±3.82	13.04±1.6	62.64±11.5
TSS (mg l^{-1})	26.4±3.22	9.3±0.3	14.07±2.65	10.45±±0.97
Free CO_2 (mg l^{-1})	11 .71±0.64	12.35±0.33	12.9±1.8	10.7±0.15
Water Temperature (°C)	18.67±0.34	18±1.15	30.83±0.44	33.83±0.44
Transparency (cm)	1.76±0.05	0.44±0.05	0.5±0.11	1.18±0.06
Chloride (mg l^{-1})	6.24±0.31	5.61±0.23	61.6±4.3	5.06±0.53
Total Hardness (mg l^{-1})	80.67±2.96	32.03±2.41	14.92±2	62.2±3.38
Calcium (mg l^{-1})	42.56±3.04	16.7±2	9.72±0.9	38.26±1.27
Magnesium (mg l^{-1})	38.1±1.55	15.34±0.7	5.2±2.82	23.93±2.14
BOD (5 day at 20°C)	7.13±1.27	7.8±0.32	8±0.93	13.87±0.66
Rainfall (mm)	108.34±66.27	31.1±30.35	265.97±107.3	470.1±18.27

DO = Dissolved oxygen, TDS = Total dissolved solids, TSS = Total suspended solids, BOD = Biological oxygen demand, Mean ± standard error of 3 samples

floodplain, Brazil, recorded highest phytoplankton density at the rising water period (Oliveira and Calheiros, 2000).

Table 2 depicts the physico-chemical properties of water and table 3 the Pearson correlation matrix of different physico-chemical variables including total phytoplankton density. Simple linear regression performed to evaluate the effect of physico-chemical properties of water on the dynamics of phytoplankton density is depicted in Fig.1. Total phytoplankton density showed significant positive correlation with total suspended solid ($r=0.67, p<0.05$), total hardness ($r=0.64, p<0.05$) and calcium ($r=0.71, p<0.05$) and highly significant positive correlation with transparency ($r=0.78, p<0.01$).

The dissolved oxygen values ranged from 2.31 to 7.26 mg l^{-1} and BOD (Biological oxygen demand) fluctuated between 7.13 to 13.87 mg l^{-1}. Highest DO was recorded in the winter followed by post monsoon. Water temperature ranged from 18 to 33.83°C with the minimum value in winter and the maximum in monsoon. It showed significant positive relationship with rainfall and negative relationship with dissolved oxygen. Highest dissolved oxygen during winter could be attributed to the fact that in lower temperature oxygen carrying capacity of water increases (Wetzel, 1983; Desai *et al*., 1995). A study made on the Moirang river of Manipur, North Eastern India, also revealed highest DO in winter (7.26 mg l^{-1}) (Kosygin *et al*., 2007). Dissolved oxygen showed significant negative correlation with BOD and rainfall. BOD and rainfall also showed significant positive relationship with each other (Table 3). During monsoon, surface runoff carries waste and sewage from the surrounding areas into the lowlying beds of the floodplain lakes, thereby increasing the respiratory activity of the heterotrophic organisms (Singhal *et al*., 1986). This might be the reason for lowest DO and highest BOD values in monsoon. The transparency (0.44 to1.76 cm) showed significant positive correlation with pH, total hardness, calcium and magnesium. The pH also showed significant positive correlation with total hardness, calcium and magnesium and negative correlation with chloride. Highest transparency was recorded in post-monsoon and lowest in winter. The narrow range of pH (6.2-7.05) indicated stability as most of the aquatic organisms are adapted to an average pH and do not withstand abrupt changes (George, 1997). Similarly the free CO_2 value (10.7-12.9 mg l^{-1}) did not show much fluctuations contributing to the fitness of natural water as it serves to buffer the environment against rapid shifts in the acidity or alkalinity and also regulates the biological processes in aquatic communities (Prasannakumari *et al*., 2003). The total alkalinity varied from 17.15 to131.84 mg l^{-1} with the highest value recorded during post-monsoon. The highest phytoplankton density during post-monsoon could be linked to this as natural waters containing 40 mg l^{-1} or more total alkalinity are more productive (Manna and Das, 2004). During monsoon, fertilizers *etc.* from the surrounding tea gardens accumulate in the system and subsequent drying during post-monsoon might have contributed to the highest alkalinity. Electrical conductivity ranged from 284 µS cm^{-1} to 6466.67 µS cm^{-1}. There is sudden increase of electrical conductivity during monsoon while post- monsoon, winter and pre-monsoon revealed more or less similar values. A similar pattern was also recorded in a study made by Senthilkumar and Sivakumar (2008) in the Veeranam lake of Tamil Nadu. This indicated addition of pollutants in the system along with surface runoff (Trivedy and Goel, 1984). Record of highest electrical conductivity in monsoon, lowest in winter and significant positive relationship of electrical conductivity with rainfall revealed that changes in conductivity were clearly associated with the water level of the system. A study on the back water ponds of Salodia river, Argentina also revealed the same (Gabellone *et al*., 2001). A little rise in the anions at the onset of the rainy season and a gradual decrease in winter is as a result of influx of runoff water and low flow rate (Ogbeibu and Anozia, 2007). The total dissolved solids ranged from 13.04 to 62.64 mg l^{-1} and maximum value was recorded in monsoon. It showed significant positive correlation with BOD and significant negative relationship with chloride. Although the range of chloride value (5.06 to 61.6 mg l^{-1}) was more or less similar in winter, post-

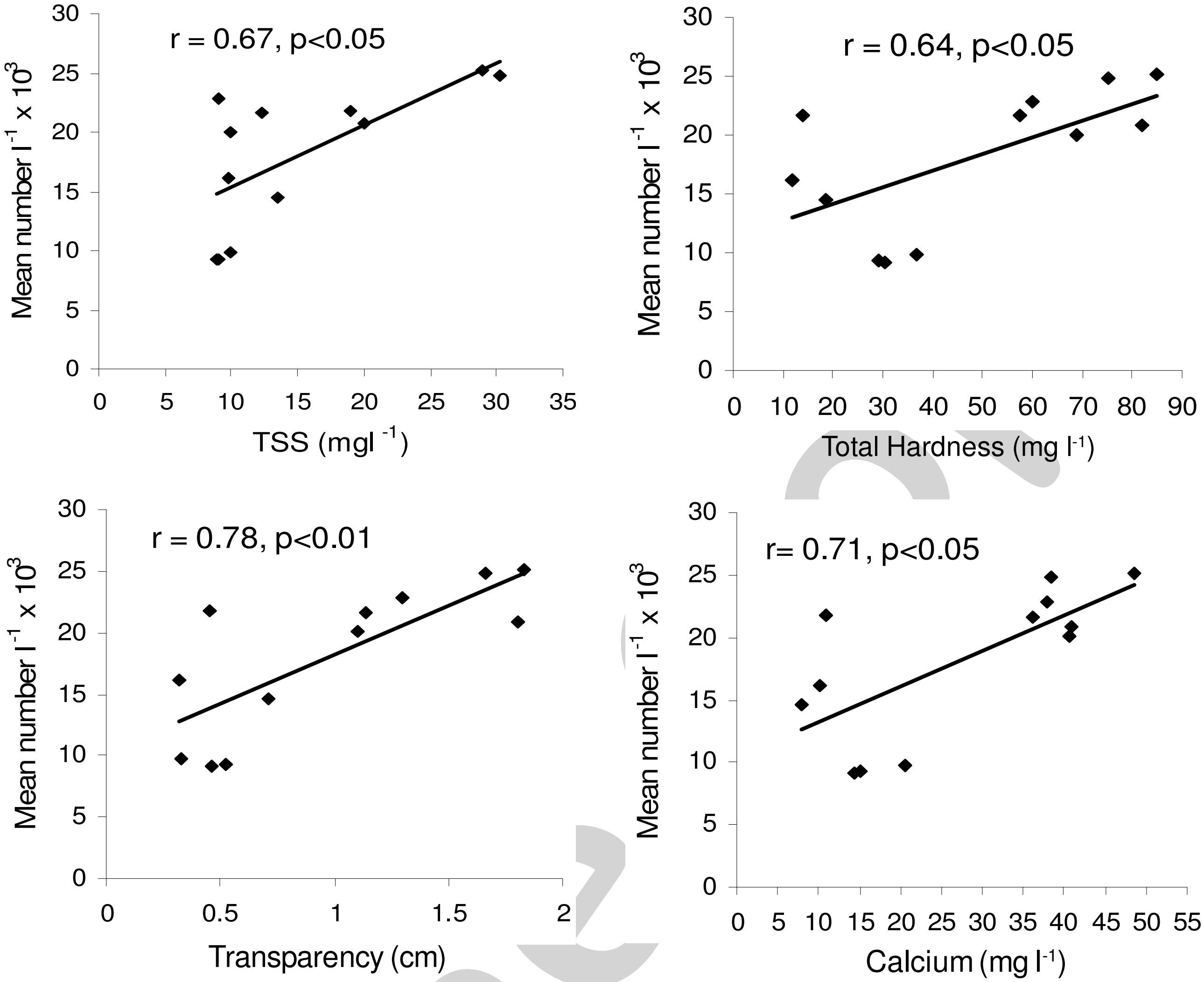

Fig. 1: Simple linear regression between phytoplankton density and total suspended solids (TSS), transparency, total hardness and calcium

monsoon and monsoon, it recorded a sharp rise in pre-monsoon (61.6 mg l^{-1}). Significant negative correlations of chloride with pH, total hardness, calcium and magnesium were recorded (Table 3). Total suspended solid ranged from 9.3 to 26.4 mg l^{-1} and the highest value was recorded in post- monsoon. It showed significant positive correlation with magnesium. In the present study, highest calcium, magnesium, total hardness and pH along with highest plankton density recorded in post-monsoon is in agreement with the findings of Desai (1995) and Sahu *et al.* (1996). Total hardness showed highly significant positive correlation with calcium and magnesium. Calcium and magnesium play an important role in antagonizing the toxic affect of various ions and in neutralizing the excess acid produced (Das and Shrivastava, 2003). Highly significant positive correlation of pH with total hardness, calcium and magnesium could be attributed to this. In this study, significant relationship of total phytoplankton density with calcium and total hardness could be attributed to the fact that calcium is an important part of plant tissue, increases the availability of other ions, reduces the toxic effect of NO_2-N (Manna and Das, 2004) and thus might have played a vital role in the growth of phytoplankton. Further, studies on the *Euglena* bloom in the same area (Duttagupta *et al.,* 2004; Bhuiyan and Gupta, 2007) and another study on lake Manasbal of Kashmir valley of India (Khan and Bhat, 2000) emphasized the importance of calcium in stimulating the growth of *Euglena.*

Table 1 represents the seasonal variations in the density of different groups of phytoplankton. During post-monsoon of 2006 Euglenophyceae density was the highest, while in winter Cyanophyceae exhibited the highest density. In contrast, Chlorophyceae was the dominant group in both pre-monsoon and monsoon. Both highest and lowest densities for any given group were that of Chlorophyceae and Euglenophyceae respectively, in monsoon.

Table 4 depicts the percentage composition of seasonal distribution of phytoplankton. In post-monsoon, Euglenophyceae was the most dominant group followed by Chlorophyceae, Bacillariophyceae and Cyanophyceae (Table 4). Abundance of Euglenophyceae showed clear seasonal change being most dominant in post monsoon, very low in winter, moderately present

Table - 3: Correlation matrix among the physico-chemical properties and phytoplankton density (no.l $^{-1}$) of the water of Chatla floodplain lake and rainfall data during September 2006 to August 2007

Parameters	DO	TA	pH	EC	TDS	TSS	FCO_2	WT	TRNS	CHL	TH	Ca	Mg	BOD	RF	PHYTO
DO	-	0.72**	0.35	-0.69*	-0.37	0.32	0.24	-0.95**	0.06	-0.30	0.12	-0.06	0.30	-0.77**	-0.78**	-0.37
TA		-	0.36	-0.55	-0.59*	0.77**	0.24	-0.73**	0.42	-0.03	0.32	0.19	0.45	-.72**	-0.63*	0.18
pH			-	0.19	0.32	0.41	-0.45	-0.45	0.72**	-0.80**	0.86**	0.81**	0.88**	0.16	-0.04	0.29
EC				-	0.55	-0.16	-0.29	0.64*	0.29	-0.17	0.30	0.45	0.11	0.83**	0.71*	0.51
TDS					-	-0.42	-0.42	0.20	0.13	-0.66*	0.28	0.36	0.18	0.73**	0.30	-0.02
TSS						-	0.04	-0.39	0.70*	-0.09	0.55	0.49	0.59*	-0.46	-0.12	0.67*
FCO_2							-	-0.19	-0.41	0.27	-0.42	-0.41	-0.41	-0.57	-0.28	-0.11
WT								-	-0.14	0.43	-0.22	-0.07	-0.37	0.69*	0.81**	0.31
TRNS									-	-0.48	0.93 **	0.90**	0.92**	0.15	0.12	0.77**
CHL										-	-0.71**	-0.69*	-0.70*	-0.22	0.12	-0.09
TH											-	0.98**	0.97**	0.23	0.08	0.64*
Ca												-	0.90**	0.37	0.18	0.71*
Mg													-	0.05	-0.05	0.52
BOD														-	0.63*	0.23
RF															-	0.46
PHYTO																-

** = Correlation is significant at $p<0.01$ level, '-' indicate negative correlation; * = Correlation is significant at $p<0.05$ level, DO = Dissolved oxygen, TA = Total alkalinity, EC = Electrical conductivity, TDS = Total dissolved solids, TSS = Total suspended solids, FCO_2 = Free CO_2, WT= Water temperature, TRNS = Transparency, CHL = Chloride, TH = Total hardness, Ca = Calcium, Mg = Magnesium, BOD = Biological oxygen demand, RF = Rainfall, PHYTO = Phytoplankton

Table - 4: Percent composition of seasonal distribution of different groups of phytoplankton in Chatla floodplain lake during September 2006 to August 2007

Phytoplankton classes	Post-monsoon 2006	Winter 2006-07	Pre-monsoon 2007	Monsoon 2007
Total Chlorophyceae	36	34.63	46.71	62.4
Total Cyanophyceae	6.78	44.9	7.44	14.08
Total Euglenophyceae	45.27	6.36	6.39	0.31
Total Bacillariophyceae	11.9	14.13	39.47	23.22

Table - 5: Seasonal variation of diversity indices of different groups of phytoplankton in Chatla floodplain lake during September 2006 to August 2007

Diversity indices	Post-monsoon 2006	Winter 2006-07	Pre-monsoon 2007	Monsoon 2007
Shannon - Wiener diversity index (H')	2.09 ± 0.15	2.62 ± 0.04	2.66 ± 0.09	2.58 ± 0.09
Evenness Index (J')	0.66± 0.05	0.89 ± 0.005	0.86 ± 0.01	0.84 ± 0.02
Berger – Parker index of dominance (D_{BP})	0.45 ±0.05	0.27 ± 0.01	0.16 ± 0.007	0.20 ± 0.04

in pre-monsoon, and nearly absent in monsoon. Abundance of this group, represented by single taxa, *Euglena sp.* can be attributed to the influx of domestic sewage in monsoon and their increased concentration in post-monsoon. The conditions that predispose bloom include warm summer temperature and high organic load derived from domestic sewage (Zafaar, 1986; Shamsudin and Shazali, 1991). Further, high concentration of calcium and magnesium in the system during post- monsoon might also have played a key role (Duttagupta *et al.,* 2004; Bhuiyan and Gupta, 2007). Drastic reduction in the population of Euglenophyceae in winter could be attributed to the use up of essential nutrients during their boom and bust period in post-monsoon (Duttagupta *et al*., 2004). Seasonal distribution and abundance pattern of Cyanophyceae revealed that there was not much fluctuation. However they were dominant during winter followed by Chlorophyceae, Bacillariophyceae and Euglenophyceae. In both pre-monsoon and monsoon Chlorophyceae dominated which was followed by Bacillariophyceae, Cyanophyceae and Euglenophyceae. Maximum growth of Bacillariophyceae in pre-monsoon could be linked to the increased temperature of water as has also been shown by Kant and Anand (1978). The present study also revealed that the percentage composition of Chlorophyceae was quite high in the system throughout the year. Despite a low percentage composition in winter, they had a sizeable population. Boom of Chlorophyceae in monsoon could be attributed to high water temperature, high rainfall and resultant dilution of water (Valecha and Bhatnagar, 1988). Further, Chlorophyceae associated with open water is the characteristic of floodplain lakes with long annual flood duration (Van den Brink *et al.,* 1994). Analysis of community structure revealed that Shannon-Wiener Diversity Index was highest in pre-monsoon, evenness in winter, and Berger-Parker index of dominance in post-monsoon (Table 5).

Gabellone *et al*. (2001) suggested that the four major regulatory factors of the ecology of the pond of floodplain ecosystem are dry season, a high and sudden increase of river flow, increase in particulate material and clear water conditions. A study in a shallow lake in the south of Brazil showed transparency and water temperature as the important environmental variables in the variation of phytoplankton composition (Avila *et al*., 2004). Our study revealed that factors that governed the growth of phytoplankton are transparency, total suspended solid, calcium and total hardness. As floodplain lake retaining their riverine connection for a reasonably long period of time are relatively free from weeds, phytoplankton mainly sustains planktophagus and predatory fish populations either directly or indirectly. Hence based on the seasonal variation of physico-chemical properties of water and phytoplankton population, an integrated management approach combining capture and culture fishery during monsoon and dry spell in different areas of the Chatla floodplain lake could be taken up for augmenting fish production to a great extent.

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