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Research Article

IMPACT OF JUTE RETTING ON PHYTOPLANKTON DIVERSITY AND AQUATIC HEALTH: BIOMONITORING IN A TROPICAL OXBOW LAKE

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ABSTRACT
Phytoplankton acts as a primary producer and biological filter of aquatic ecosystem. Jute retting during monsoon is a common anthropological activity in the rural Bengal. Quantitative seasonal bio-monitoring of phytoplankton community composition with relative abundance and its diversity indices was carried out in this study from April 2013 to March 2014 to assess water quality and the impact of jute retting on phytoplankton diversity of a tropical fresh water oxbow lake in Nadia district of India. We recorded a total of 34 genera of 5 distinct classes, Chlorophyceae (15), Bacillariophyceae (13), Cyanophyceae (4), Dinophyceae (1) and Euglenophyceae (1). Members of Chlorophyceae dominated throughout the year. Unlike Cyanophyceae, Bacillariophyceae was found to be significantly increased during monsoon when compared to the rest of the year. Average phytoplankton density was highest in post-monsoon (8760/L) followed by monsoon (4680/L) and pre-monsoon (3650/L). Owing to the dominance of class Chlorophyceae and Bacillariophyceae we found this lake to be oligotrophic to mesotrophic. Indices values of genera richness, Shannon-Wiener, evenness and Simpson's diversity reached their lowest 14, 1.61, 0.61 and 0.68 in monsoon and highest 23, 2.42, 0.77 and 0.86 in post monsoon respectively. The lowest diversity values during monsoon clearly suggested that the selected lake has highest anthropogenic pollution due to jute retting which impacted significantly on phytoplankton diversity. Therefore, the lake is not conducive for fish growth especially during monsoon and we opine that there is a need to regulate jute retting process, intensity and its density in the lake during the monsoon to ensure enhanced biodiversity for sustainable management and conservation of aquatic environment of this Oxbow lake.

Keywords: bio-monitoring, oxbow lake health, jute retting, phytoplankton, diversity index.

INTRODUCTION

Studies on fresh water bodies, natural or manmade have gained much importance in recent years mainly because of their multiple uses. Several workers have attempted to study the hydro biological profile of varied water bodies with intent of assessing the quality of water. Wetlands represent a transitional zone between terrestrial uplands and aquatic bodies and characterized by a large number of ecological niches which establishes huge biological diversity. The wetlands of West Bengal have been worked out by several authors in the past [Mukherjee and Palit, 2001; Mandal *et al.*, 2003; Chakraborty *et al.*, 2004; Palit *et al.*, 2006; Palit and Mukherjee, 2007; Mandal and Mukherjee, 2007; and Bala and Mukherjee, 2007; 2011]. Jute retting during monsoon is a common anthropological activity in the rural Bengal. Population pressure, urbanization, industrialization and increased agricultural activity including jute retting have significantly contributed to the pollution and toxicity of aquatic ecosystems including oxbow lakes. Pollutants bring about a change not only in the physical and chemical quality of water but also modify the biotic components, resulting in the elimination of some potentially valuable species. Chemical analyses of water provide a good indication of the quality of aquatic systems, but they do not integrate ecological factors such as altered riparian vegetation or altered flow regimes and, therefore, do not necessarily reflect the ecological state of the system [Karr et.al. 2000]. Biological assessment or monitoring is a useful alternative for assigning the ecological quality of aquatic ecosystems since biological communities integrate the environmental effects of water chemistry in addition to the physical and geomorphologic characteristics of rivers and lakes [Steven and Pan, 1999]. Phytoplankton is the base in the food chain and forms an important component of fish food in aquatic environment and they act as a primary producer and biological filter of water ecosystem and as such, the knowledge of their production and abundance is essential for sustainable management of fishery. The occurrence and abundance of phytoplankton community provides ways of predicting productivity, reflects average ecological condition and, therefore, it may be used as an indicator of water quality. They are used in assessment of aquatic pollution because of their sensitivity to small changes in environment, short generation time. Phytoplankton community is cosmopolitan in nature and they inhabit all freshwater habitats of the world. These are not only useful as bio indicators, but are also helpful for ameliorating polluted waters. Hence qualitative and quantitative studies of Phytoplankton diversity are of great importance.

However, phytoplankton abundance, density and diversity for biological assessment of the water quality of oxbow lake are poorly documented. Limited numbers of studies have been carried out on the ecological aspects of it in oxbow lakes. The phytoplankton was studied as bioindicator for water quality in Taipei [Wu, 1984]. The role of plankton community and its trophic status was studied to assess water quality of lakes in the Nagpur city [Kumari *et al*., 2008]. Pollution status of the assessed lakes was determined on the basis of Palmer's pollution index, Shannon Wiener index and physico-chemical parameters. Phytoplankton was studied as an index of water quality with reference to industrial pollution of the Bhadra River [Shekhar *et al*., 2008]. The plankton diversity of the oxbow lake, *Maijan* Beel in Dibrugarh district, Assam was studied [Abujam *et al*., 2011]. The spatial variation in phytoplankton diversity was studied in the Sabarmati River at Ahmadabad, Gujarat, India [Kumar *et al.*, 2012]. The Shannon Diversity Index was analyzed indicating slight pollution level and good water quality of Kankaria Lake in Ahmadabad city [Kumar and Sharma, 2014].

Existing works on the impact of jute retting and the quantitative bio-assessment of phytoplankton diversity and aquatic health of the oxbow lake in northern part of Nadia district in particular and West Bengal in general are quite scanty. The effect of jute retting on the physico-chemical and biological condition of water of an oxbow lake was studied in Nadia district without any quantitative bio-assessment [Dasgupta *et al*., 2006]. Phytoplankton diversity was studied of a freshwater, seasonal oxbow lake [Keshri *et al*., 2013], Baishar Beel located within Chakdaha block in southern part of Nadia district with various diversity indices to illustrate seasonal changes of phytoplankton and to rate water quality based on diversity index without any assessment on the impact of jute retting. The impact of jute retting was assessed on native fish diversity and aquatic health of roadside transitory water bodies around 50 km away from this study site in Nadia district [Ghosh and Biswas, 2015c] without any information of the impact on phytoplankton diversity.

In the present study, seasonal surveys of the phytoplankton communities and the analysis of diversity indices like Shannon-Wiener and Simpson, richness, and evenness, density and composition with relative abundance of different phytoplankton were conducted on a freshwater tropical oxbow lake ecosystem in northern part of Nadia district of West Bengal in eastern India. The purpose of this study was to bio-assess the impact of jute retting on phytoplankton diversity with its seasonal fluctuations and ecological health quality of this oxbow lake. This type of study in continuation can pin point the seasonal changes of phytoplankton and the effects of anthropogenic load. So it would hopefully be a reference archive for future studies on aquatic health of oxbow lake ecosystem for its sustainable management.

MATERIAL AND METHODS

Study area

The Chhariganga oxbow lake, abandoned, fractioned and derived from the river Ganga is located in Nakashipara development block of Nadia district, West Bengal, India. It is situated at 23.5800° N latitude, 88.3500° E longitude, about 90 Km away from Kalyani University Campus,

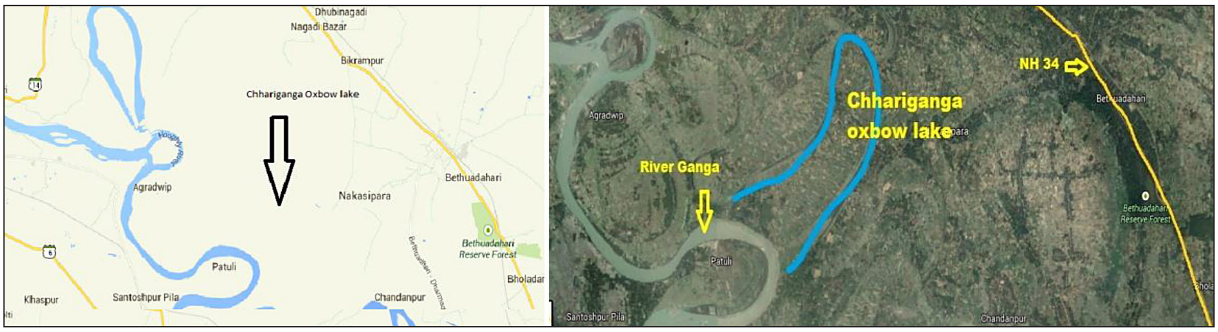

Figure 1. Map showing study area

Nadia and nearly 40 km away from the line of Tropic of Cancer towards the north. It is a fresh water and semi open type oxbow lake and receives water from the river Ganga during monsoon through a narrow channel at the North East corner of a loop of the river. The oxbow lake is spread over an area of 145.69 Acres with an annual average depth of 8.5 ft. It also stores rain water. The catchment area of the oxbow lake is nearly 600 hectare (Figure 1).

There are three distinct annual seasons observed in changed climate of this region: the monsoon (MON) or rainy season generally from July to October when jute retting period lies normally during August – September, post monsoon (POM) or winter from November to February) and the pre monsoon (PRM) or dry season from March to June. There was an occasional inundation of the surrounding banks during the monsoon. The oxbow lake is subjected to all forms of human activities including jute retting during monsoon, agriculture and fishing. It is the only source of irrigation water to the immediate agriculture communities.

Plankton collection, preservation, identification and density analysis

The samples of phytoplankton were collected from selected study site of this tropical oxbow lake for a period of one year (April 2013 to March 2014) during three seasons namely PRM, MON and POM. Collection of plankton was made by filtering 50 liters of water through conical shape plankton net made of nylon blotting silk cloth of 60µ mesh size and of reducing cone (having filtering area three times larger than the area of the mouth) with the bottle at its end. The oxbow lake water was measured in a graduated bucket and filtered through the net and concentrated into a 100 ml bottle. For a precise collection, the plankton net was towed in open water area of each site three times (horizontally, vertically and obliquely). Care was taken to avoid trapping of floating debris while towing the net. The net was lowered as close to the bottom as possible without disturbing the sediment and carefully hauled to allow the water to drip. The net was rigged with a weight to enhance vertical sinking. Three replicate samples were combined to make a composite sample. Samplings were made between 7 to 10 AM. Immediately after the collection of the samples, the plankton was preserved with 4% formaldehyde solution and samples were kept for setting for a period of 48 hrs to quantitative estimation. In the laboratory each sample was diluted, stirred well and sub-sampled with a 5ml syringe before microscopic examination. One ml of sample was transferred to Sedge wick Rafter cell (S-R cell) and examined under the microscope at ×40 magnification. Qualitative and quantitative plankton analyses were done up to the genus and planktonic organisms were numerically counted, identified and confirmed by the following handbooks and publications [Cox, 1996; Desikachary, 1959; Hustedt, 1930; Komarek and Anagnostidis, 1998; 2005; Prescott, 1962; Smith, 1950; Turner, 1982; Pillai, 1986; Trivedy and Goel, 1986; Wehr and Sheath, 2003; Vuuren *et al*., 2006; and Huynh and Serediak, 2006]. After accurate identification of each genus, the density of plankton was calculated as per the Lackey's drop method. The formula for calculating the number of organisms per litre of the sample using the drop count method as [Lackey, 1938]:

$$\textit{Total plankton count per litre} = A \cdot (1/L) \cdot (n/v),$$

where: A – number of organisms per drop,
L – volume of original sample (l),
n – total volume of concentrated sample (ml),
v – volume of one drop (ml).

In the present study: n = 100 ml, L = 50 litre, 20 drops = 1 ml, v = 1/20 ml = 0.05 ml. The relative abundance (RA equaling to percentage composition) was worked out for those three seasons. RA of individual genus was calculated by dividing the product of a number of samples of particular genus and 100 by total number of samples. The genus diversity was determined. Statistical analysis of biological indices, such as genus richness, evenness (E) Shannon-Wiener diversity (SWI) and Simpson's diversity index was done by using the following diversity index formulas:-

Simpson's dominance index (D)

The Simpson's index (D) is calculated using the following equation [Simpson, 1949]:

$$D = \frac{\sum_{i=1}^{s} n_i(n_i - 1)}{n(n-1)} \quad (1)$$

Where 'n_i' is the proportion of individuals of the i^{th} genus in the community. Simpson's index gives relatively little weight to the rare genus and more weight to the common genus. It weighs towards the abundance of the most common genus. It ranges in a value from 0 (low diversity) to a maximum of (1–1/s), where s is the number of genus. In nature the value of d ranges between 0 and 1. With this, index 0 represents infinite diversity and 1, no diversity. The bigger the (D) value, the smaller the diversity.

Simpson's diversity index (1-D)

It represents the probability that two individual organisms randomly selected from a sample will belong to different genera. The value of this index also ranges between 0 and 1, the greater the value, the greater the sample diversity.

Shannon-Wiener Index (H')

This is a widely used method of calculating biotic diversity in aquatic and terrestrial ecosystems and is expressed as SWI [Shannon and Wiener, 1963]:

$$H' = \sum_{i=1}^{s} \frac{n_i}{n} \ln \frac{n_i}{n} \quad (2)$$

where: H – SWI of genus diversity,
s – number of genus,
n_i – proportion of total sample belonging to the i^{th} genus.

This diversity index helps in genus relative abundance. A large H value indicates greater diversity, as influenced by a greater number and/or a more equitable distribution of genus. The index values ranges between 0 and 5, where higher index values demonstrates higher diversity, while low index values are considered to indicate pollution. Diversity and anthropogenic disturbances are inversely related to each other. The SWI takes account of genus richness as well as abundance. It is simply the information entropy of the distribution, treating genus as symbols and their relative population sizes as the probability. The advantage of this index is that it takes into account the number of genus and the evenness of the genus. The index is increased either by having additional unique genus, or by having greater evenness. Diversity is maximum when all genera that made up the community are equally abundant (i.e. have a similar population sizes). The diversity is partly a function of the variety of habitats; the more varied habitats tend to be inhabited by a large number of genera than less variable ones. Secondly the older habitats usually contain more genera than younger ones.

Evenness index (E)

This is relative distribution of individuals among taxonomic groups within a community and is expressed as [Pielou, 1966]:

$$E = H'/\log S \quad (3)$$

where: H' – SWI,
log S – natural log of the total number of genus (S defined as genus Richness) recorded.

It is used for the degree to which the abundances are equal among the groups present in a sample or community.

RESULTS AND DISCUSSION

Seasonal compositions and relative abundance (RA%) of individual phytoplankton in Chhariganga Oxbow Lake differed from one season to another and these influence the phytoplankton density and their biological spectrum (Table 1). A total of 34 genera of phytoplankton of 5 distinct classes, Chlorophyceae (15), Bacillariophyceae (13), Cyanophyceae (4), Dinophyceae (1) and Euglenophyceae (1) were recorded from the lake. Three classes of phytoplankton represented

Table 1. Seasonal variations in density and relative abundance (RA%) of phytoplankton

Class	Genera	PRM		MON		POM		Year Mean	
Bacillariophyceae		nos/lit	RA%	nos/lit	RA%	nos/lit	RA%	nos/lit	RA%
	Cocconeis sp	–	–	–	–	480	5.48	480	8.31
	Cyclotella sp	–	–	1160	24.79	320	3.65	740	12.81
	Cymbella sp	25	0.68	–	–	160	1.83	93	1.60
	Fragillaria sp	50	1.37	–	–	–	–	50	0.87
	Gyrosigma sp	150	4.11	40	0.85	–	–	95	1.64
	Mastogloia sp	–	–	–	–	320	3.65	320	5.54
	Navicula p	75	2.05	–	–	80	0.91	78	1.34
	Nitzschia sp	50	1.37	–	–	80	0.91	65	1.13
	Pinnularia sp	25	0.68	80	1.71	–	–	53	0.91
	Pleurosigma sp	–	–	240	5.13	–	–	240	4.15
	Synedra sp	50	1.37	40	0.85	–	–	45	0.78
	Rhopalodia sp	–	–	40	0.85	–	–	40	0.69
	Diatom sp	300	8.22	280	5.98	640	7.31	407	7.04
Total Bacillariophyceae (Diatoms)		725	19.86	1880	40.17	2080	23.74	1562	27.03
Chlorophyceae	*Chlorella sp.*	25	0.68	40	0.85	80	0.91	48	0.84
	Chlorococcum sp	325	8.9	120	2.56	880	10.05	442	7.65
	Closterium sp	–	–	–	–	80	0.91	80	1.38
	Cosmarium sp	50	1.37	–	–	–	–	50	0.87
	Scendesmus sp	–	–	–	–	80	0.91	80	1.38
	Spirogyra sp	–	–	–	–	80	0.91	80	1.38
	Volvox sp	25	0.68	–	–	–	–	25	0.43
	Ankistrodesmus sp.	50	1.37	–	–	80	0.91	65	1.13
	Chlamydomonas sp.	25	0.68	–	–	240	2.74	133	2.29
	Mougeotia sp.	25	0.68	–	–	80	0.91	53	0.91
	Pediastrum sp.	–	–	–	–	240	2.74	240	4.15
	Tetradesmus sp.	50	1.37	160	3.42	240	2.74	150	2.60
	Tetraedron sp	25	0.68	–	–	–	–	25	0.43
	Desmids sp	1200	32.88	2320	49.57	2360	26.94	1960	33.93
	Characium sp	–	–	40	0.85	–	–	40	0.69
Total Chlorophyceae (Green algae)		1800	49.32	2680	57.26	4440	50.68	2973	51.47
Cyanophyceae	*Lyngbya sp*	75	2.05	–	–	–	–	75	1.30
	Oscillatoria sp	75	2.05	–	–	80	0.91	78	1.34
	Microcoleus sp.	925	25.34	40	0.85	1840	21	935	16.18
	Microcystis sp	50	1.37	–	–	160	1.83	105	1.82
Total Cyanophyceae (Blue Green algae)		1125	30.82	40	0.85	2080	23.74	1082	18.72
Dinophyceae	*Ceratium sp*	–	–	–	–	80	0.91	80	1.38
Euglenophyceae	*Phacus sp*	–	–	80	1.71	80	0.91	80	1.38
Total phytoplankton		3650	100	4680	100	8760	100	5777	100.00

in PRM when Dinophyceae and Euglenophyceae were found absent. Dinophyceae class was present during POM only in the year. As were found richness (Chlorophyceae – 19, Bacillariophyceae – 16, Cyanophyceae – 07, Euglenophyceae – 2 and Chrysophyceae – 1) of surface phytoplankton tolerant to industrial effluent pollution and emphasized the necessity of using phytoplankton as effective and appropriate method of bio-monitoring for evaluation of river water quality [Shekhar *et al*., 2008]. Phytoplankton composition of the Baishar Beel was found fluctuated [Keshri *et al*., 2013] by seasonal changes for 4 algal classes namely Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae. Among this, Chlorophyceae dominated in MON and POM like our study and Cyanophyceae dominated in PRM when it was 2nd dominant class in the present study.

Average phytoplankton density was highest in POM (8760/L) followed by MON (4680/L) and PRM (3650/L). Density of 7266, 10500, 12633/L of water was found [Keshri *et al*., 2013] for those three seasons respectively which are much higher (almost double) than our study. The phytoplankton density was also fluctuated due to environmental criteria. In hot and dry situation of PRM it was lowest and somewhat increased in MON but not so pronounced due to dilution effect of water. The monsoon condition helped to collect more nutrients from other sources by rain water and by jute retting process and these increased the fertility condition of the oxbow lake, which resulted into maximum density and diversity in POM. Other factors like competition between and within species are also directly or indirectly influenced under environmental guidance. Similar results were observed by [Keshri *et al*., 2013].

The percentage composition (RA%) of the phytoplankton class (Figures 2, 3 and 4) showed that member of Chlorophyceae dominated throughout the year and Cyanophyceae was highest in PRM and lowest in MON. The lowest percentage composition was represented by the member of Bacillariophyceae for the PRM, Cyanophyceae for MON and Dinophyceae and Euglenophyceae each for POM. Bacillariophyceae was found to be significantly increased unlike Cyanophyceae during MON when compared to rest of the year. Cyanophyceae on the other hand got increased significantly from MON to POM (may be due to nutrient mobilization in POM) and further to PRM period. It is said that Cyanophyceae members by their heat stress tolerating capacities can withstand the environmental temperature and other conditions of the PRM and flourish their maximum limit. Similar result was shown by [Keshri *et al*., 2013]. Relative abundance of genus showed that *Desmids* (Chlorophyceae) dominated throughout the year, while *Microcoleus* (Cyanophyceae) during pre & post monsoon and *Cyclotella* (Bacillariophyceae) during MON were dominant genera in the lake. Significant changes in relative abundance were observed during MON from PRM (Figures 9 and 10). Reductions were noticed for total Cyanophyceae abundance (97%), genus like *Microcoleus* (97%), *Gyrosigma* (79%), *Chlorococcum* (71%), *Synedra* (38%) and *Diatom* (27%) while increases in RA% were observed in *Pinnularia* (151%), *Tetradesmus* (150%), and total *Bacillariophyceae* abundance (102%), *Desmids* (51%), *Chlorella* (25%) and total *Chlorophyceae* (16%). These changes may be attributed to the different tolerance level to organic pollution due to jute retting and nutrient mobilization in the lake during MON. This study also showed that the oxbow lake is in oligotrophic to mesotrophic conditions as revealed by the dominance of phytoplankton belonging to class Chlorophyceae and Bacillariophyceae throughout the year. Similar results were shown by [Tapati *et al*. 2011].

Indicative association of 5 phytoplankton in 3 saprobic classes like oligosaprobity (includes genus like *Cyclotella, Cymbella, Fragillaria, Synedra, Rhopalodia*), beta mesosaprobity (genus like *Scendesmus, Pediastrum, Tetraedron, Microcystis*) and alpha mesosaprobity (genus like *Nitzschia, Oscillatoria, Phacus*) as bioindicator for water quality in Taipei as was reported [Wu, 1984]. The algal genera, Euglena, *Oscillatoria*, *Scenedesmus*, *Navicula*, *Nitzschia* and *Microcystis* was found in organically polluted waters [Nandan and Aher, 2005]. Similar genera were also recorded in the present study. The occurrence of *Oscillatoria* was recorded in the present study. They also noticed alga like *Microcystis* as the best single indicator of pollution and it was associated with the highest degree of pollution. The lower abundance of *Navicula, Oscillatoria*

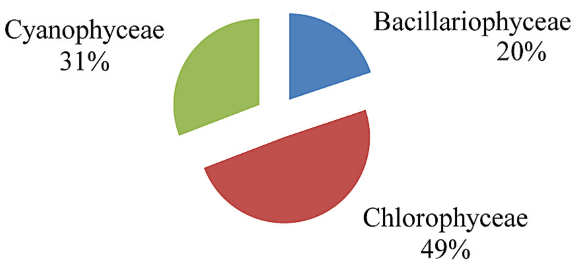

Figure 2. Pre-monsoon composition

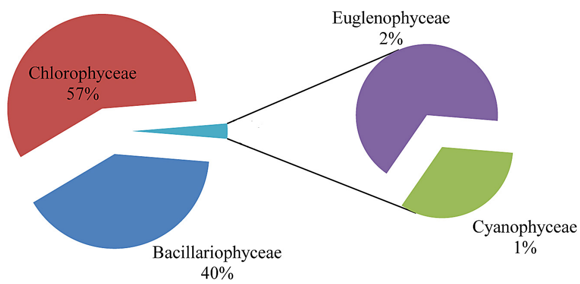

Figure 3. Monsoon composition

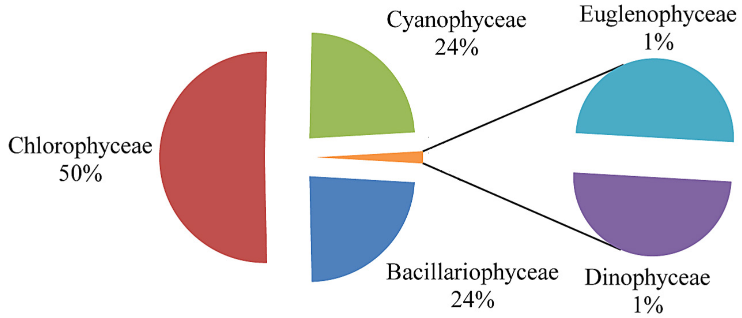

Figure 4. Post-monsoon composition

indicated the lower degree of organic pollution. Unpolluted water is characterized by abundance of green algal flora followed by Cyanophyceae, as it was supported by earlier workers [Verma and Mohanty, 1994; Nandan and Aher, 2005; and Beyhan and Gonulal, 2007]. Species like *Anabaena, Chlorella, Euglena, Eudorina, Volvox, Oscillatoria and Navicula* was found during study by [Dasgupta *et al*., 2006] in the Nadia oxbow lake but we did not encounter genus like *Anabaena, Euglena* and *Eudorina* in our study on oxbow lake in the same district. It is reported pollution indicator genus like *Anabaena, Oscillatoria, Fragilaria, Pediastrum, Spirogyra, Zygnema, Oedogonium, Ulothrix, Cladophora, Volvox, Cosmarium* etc. from the oxbow lake in Assam [Abujam *et al*., 2011], which has quite similarity with the present study.

Phytoplankton richness value reached its maximum (23) during POM and its minimum (14) during the MON. PRM contained the lowest values of class richness (3) during the year. The SWI, evenness and Simpson's diversity index values showed their highest 2.42, 0.77 and 0.86 in POM and the lowest 1.61, 0.61 and 0.68 during MON respectively (Table 2). Richness, SWI, evenness and Simpson's diversity index of phytoplankton diversity showed highest values during POM and almost all lowest values during MON (Figures 5, 6, 7 and 8) unlike the Simpson's dominance index which otherwise showed highest values 0.32 during MON and lowest 0.14 in POM. Seasonal variations in phytoplankton genera numbers with diversity indices and class diversity indices are given in the Table 3 and 4 respectively. SWI was found (1.64–4.07) by [Shekhar *et al*., 2008]. The SWI (3.18–3.97) of phytoplankton community in lakes in Nagpur was observed much higher than the present study [Kumari *et al*., 2008]. They observed a considerable increase in *Chlorophyceae* during MON from PRM like the present study. The SWI was observed maximum (2.5) during October – December and minimum (0.5) occurred in August during MON [Mukherjee *et al*., 2010] like our study. In tune with this rhythm the minimum dominance was in October and the maximum in August. This was the period of abundance of Bacillariophyceae, especially *Nitzschia* unlike our study. The SWI values (1.16 to 2.04) were found for phytoplankton community structure in the Sabarmati River [Kumar *et al*., 2012], which is slightly lower than the present study. Almost similarity was found for SWI values (2.52, 2.33 and 2.66), evenness index (0.68, 0.68, and 0.69) and Simpson's Dominance index (0.91, 0.88, and 0.90) for PRM, MON and

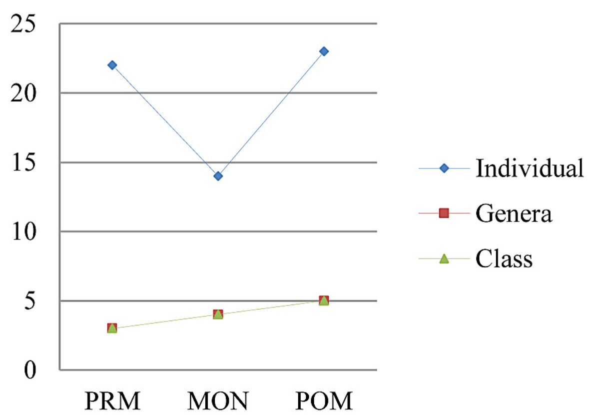

Figure 5. Seasonal variations in richness

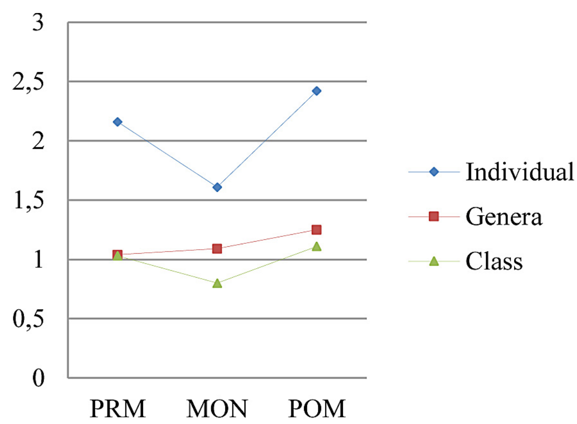

Figure 6. Seasonal variations in Shannon-Weiner index

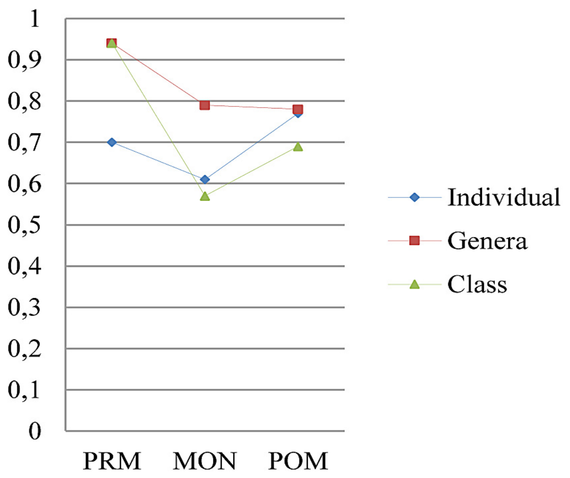

Figure 7. Seasonal variations in evenness

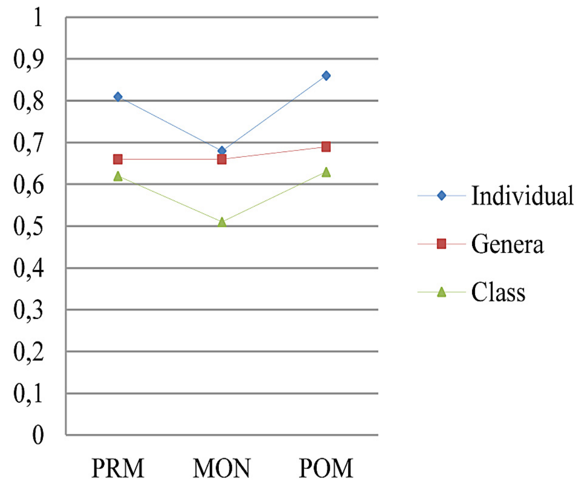

Figure 8. Seasonal variations in Simpson's dominance index

Table 2. Seasonal variations in phytoplankton individual diversity indices

Diversity Indices	PRM	MON	POM	Year mean	SD
Richness	22	14	23	20	4.93
Shannon-Wiener Index (SWI)	2.16	1.61	2.42	2.06	0.41
Evenness	0.70	0.61	0.77	0.69	0.08
Simpson's Dominance Index	0.19	0.32	0.14	0.22	0.09
Simpson's Diversity Index	0.81	0.68	0.86	0.78	0.09

Table 3. Seasonal variations in phytoplankton genera numbers and diversity indices

Parameters	PRM	MON	POM	Year mean	SD
Bacillariophyceae (Diatoms)	8	7	7	7	0.58
Chlorophyceae (Green Algae)	10	5	11	9	3.21
Cyanophyceae (Blue Green Algae)	4	1	3	3	1.53
Dinophyceae	–	–	1	1	0.00
Euglenophyceae	–	1	1	1	0.00
Total Genera	22	14	23	20	4.93
Richness	3	4	5	4	1.00
Shannon-Wiener Index (SWI)	1.04	1.09	1.25	1.13	0.11
Evenness	0.94	0.79	0.78	0.84	0.09
Simpson's Dominance Index	0.34	0.34	0.31	0.33	0.02
Simpson's Diversity Index	0.66	0.66	0.69	0.67	0.02

Table 4. Seasonal variations in phytoplankton class diversity indices

Diversity Indices	PRM	MON	POM	Year mean	SD
Class Richness	3	4	5	4	1.00
Shannon-Wiener Index (SWI)	1.03	0.80	1.11	0.98	0.16
Class Evenness	0.94	0.57	0.69	0.73	0.19
Simpson's Dominance Index	0.38	0.49	0.37	0.41	0.07
Simpson's Diversity Index	0.62	0.51	0.63	0.59	0.07

POM respectively with moderate pollution status [Keshri *et al.*, 2013] like our study from an oxbow lake in Nadia. Higher SWI was reported by [Laskar and Gupta, 2013] (varied between 2.40 to 2.65), and Taxon richness (17 to 38) for phytoplankton community indicating fairly high

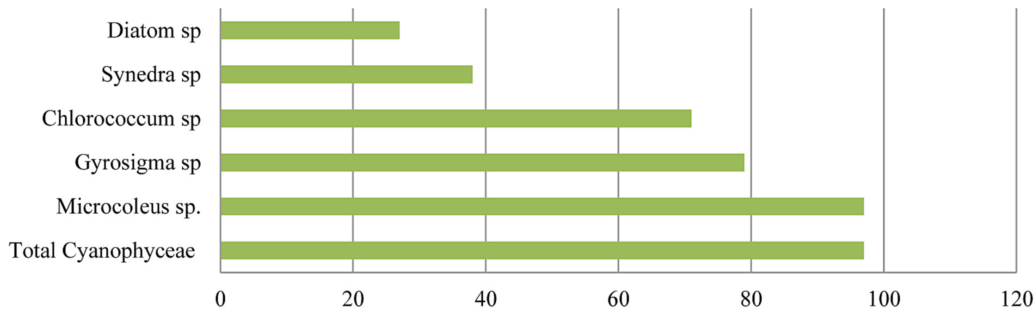

Figure 9. Decrease (%) during monsoon from premonsoon

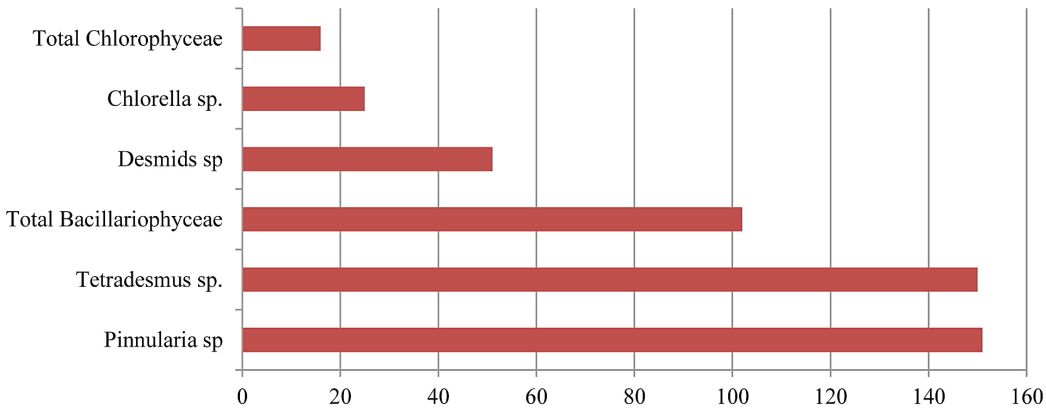

Figure 10. Increase (%) during monsoon from premonsoon

diversity in wetlands of Assam. The SWI of phytoplankton was found community in the range of 3.4-3.5 (much higher than the present study) indicating slight pollution level and good water quality of Kankaria Lake in Ahmadabad city [Kumar and Sharma, 2014] unlike the present study and they also found *Navicula* to be dominant among the investigated phytoplankton genera with great impact on the lake water quality. Higher phytoplankton diversity value was found by [Jamal *et al.*, 2014] of SWI (near 3.2–3.5) with evenness index (0.82–0.85) from manmade lake in Malaysia compared to the present study.

Table 5 depicted SWI with pollution level as given by [Biligrami, 1988] and study values of phytoplankton diversity indices suggesting moderate to light pollution status of the oxbow lake. No qualitative variation was found in the plankton [Dasgupta *et al.*, 2006] excepting population which was decreased due to impact of jute retting during the jute retting period (unlike this study) and increased in the post jute retting period like our study. According to observations made [Ghosh and Biswas, 2015c] jute retting impacted lower native fish diversity indices like SWI values (1.94 to 2.68), Evenness Index (0.84–0.94), quite similar to the present study, indicated poor to moderate pollution status of the transitory water body in Nadia during MON in particular and throughout the year in general. Low diversity values of Shannon and Simpson indices of the present study clearly stated that the selected lake is polluted and has high anthropogenic activity and not conducive for fish growth especially during MON and lake showed a poor to moderate level of pollution load. This pollution status showed similar status when assessed with rotifer diversity indices [Ghosh and Biswas, 2014], zooplank-

Table 5. Shannon-Wiener index and pollution level as given [4]

Shannon-Wiener diversity index	Pollution level	Study values of individual SWI				Study values of genera SWI			
		PRM	MON	POM	Year	PRM	MON	POM	Year
3.0 – 4.5	slight								
2.0 – 3.0	light	2.16		2.42	2.06				
1.0 – 2.0	moderate		1.61			1.04	1.09	1.25	1.13
0.0 – 1.0	heavy								

ton diversity indices [Ghosh and Biswas, 2015a], macro invertebrates diversity indices [Ghosh and Biswas, 2015b] and also with aquatic macrophytes diversity indices [Ghosh and Biswas, 2015d] on the same oxbow lake during the same year.

CONCLUSIONS

The present investigation on phytoplankton diversity revealed its phytoplankton spectrum within the specific time period. This study not only pinpointed the diversity status but also depicted the pollution load of the water body using phytoplankton as bio-monitoring tool. As the phytoplankton constitute the basis of the food chain, their study and characterization helps us to understand the details of the nature and type of members of the subsequent trophic levels. Owing to dominance of class Chlorophyceae and Bacillariophyceae we found this lake to be oligotrophic to mesotrophic. Lowest diversity values during monsoon clearly suggested that the selected lake has highest anthropogenic pollution due to jute retting which impacted significantly on phytoplankton diversity. Therefore, the lake is not conducive for fish growth especially during monsoon and we opine that there is a need to regulate and prevent jute retting process, intensity and its density in the lake during the monsoon to ensure enhanced biodiversity for sustainable management and conservation of aquatic environment of this Oxbow lake.

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