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Seasonal Variation of Phytoplankton Diversity in Relation to Eutrophication of Mathura Beel, a Floodplain Lake in West Bengal, India

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Abstract: Current study deals with the phytoplankton structure and seasonal variation in Mathura Beel (wetland), a floodplain lake in Gangetic plane of West Bengal, India. The generic composition of phytoplankton was studied monthly during August 2008 to February 2011. All the relevant calculations were done according to three seasons viz. pre-monsoon, monsoon and post-monsoon. A total of 96 species belonging to 87 genera were identified under six algal classes. Chlorophyceae showed their maximum species diversity with 45% whereas the Cyanophycean algae showed maximum relative density i.e. 93.11% throughout the study period with *Microcystis aeruginosa* (45.08%) followed by *Aphanocapsa rosena* (15.53%). Phytoplankton species of *Bacillariophyceae, Euglenophyceae, Xanthophyceae and Dinophyceae* were negligible in number. Maximum and minimum phytoplankton diversity was found in post-monsoon ($H' = 0.38$) and pre-monsoon ($H' = 0.09$) respectively. Cyanophycean algae ($D = 0.97$) dominated in pre-monsoon season. The temperature increased upto 2°C in pre-monsoon season during the study period. Dominance of cyanophycean algae (*Microcystis* sp.) has been found to be the main reason of eutrophication in Mathura beel.

Key words: Mathura beel, *cyanophyceae*, phytoplankton, eutrophication.

Introduction

Floodplain lakes are common features of river systems in India. Floodplain lakes support a substantial fisheries system in India, particularly in the eastern and north-eastern states and are considered as the second most important inland fisheries resources of the country (Bhaumik et al., 2003). In these floodplain ecosystems phytoplankton are 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). Phytoplankton species distribution shows wide spatio-temporal variations due to the differential effect of hydrographical factors on individual species and they serve as good indicators of water quality including pollution (Gouda and Panigrahy, 1996).

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The present study deals with one of the largest floodplain wetlands of 263.8 hectares of Gangetic river basin, spread over the district North 24 Paraganas and Nadia named Mathura Beel[1] in West Bengal, India. In the transient phase it was bestowed with rich resources of flood plain wetland, having several connections with the river Ganga (Kusler et al., 1999). The channels used to maintain most of the inflow and outflow of the Mathura Beel resulting in pronounced oscillation in the wetland (Biswas, 2008) collapsed by siltation and ignorance. It is an important wetland ecosystem for its biological diversity and multifarious features like pisciculture, recreational and cultural activities. Moreover it acts as a natural sink for removal of pollutants from the surrounding areas. Nearabout 600 families are dependant on Mathura Beel for fish cultivation. But now-a-days mainly because of human activities, Mathura Beel is facing problems like gradual siltation and increasing pollution load that is coming from the lake bank habitation. This environmental degradation of the Beel consequently threatens the sustainable development of aquatic and terrestrial ecosystem of the area.

This is a pioneering study in the field of algology on Mathura Beel. The purpose of this study was to analyze the attributes of the phytoplankton community of Mathura Beel, with respect to plankton density, species richness, dominance and abundance of the species composition and community structure. The influence of wet and dry seasons between 2008 and 2011 on the phytoplankton was evaluated.

Study Site

Mathura Beel is 7.5 km long and the width of the beel varies from 0.3 to 1.0 kilometres. This 259.5 ha sword shaped beel (Figure 1) lies between 22°25’ N-23°55’ N and 88°30’ E-88°50’ E. The region has a hot and humid monsoonal climate, with average annual rainfall mainly in the monsoon months (Table 1). The summer temperature ranges between 30.4 and 40.2 °C, while winter temperature varies between 13.6 and 14.2 °C. Due to excessive heat, the total monthly evaporation during pre-monsoon and post-monsoon (393.61 mm) exceeds the total monthly rainfall of 235.48 mm

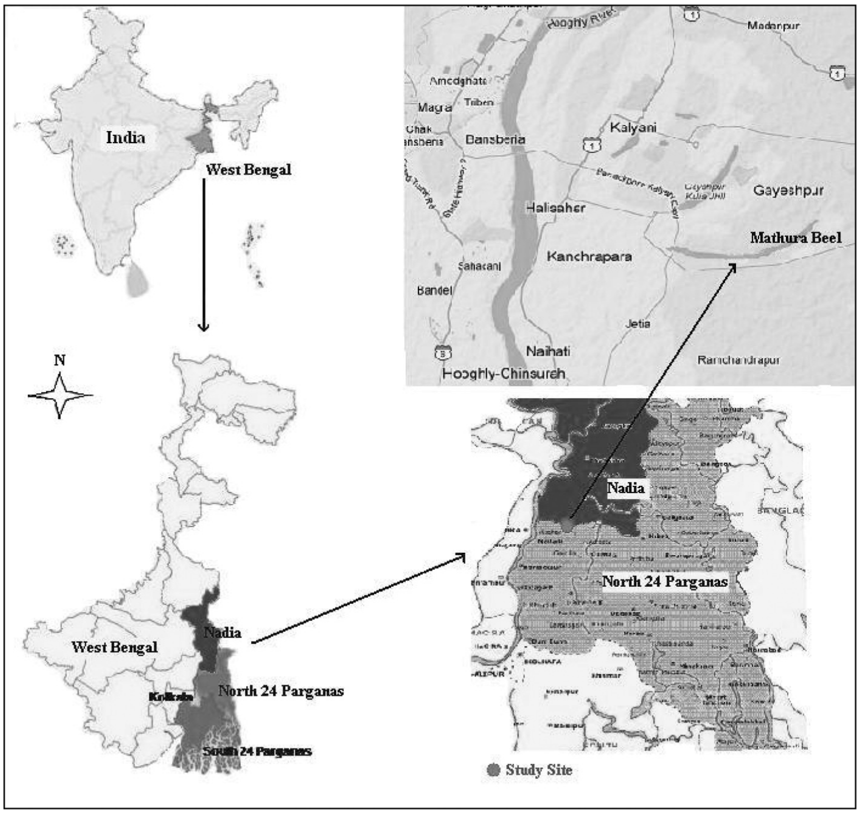

Figure 1: Location of study area, Mathura Beel, India.

[1] Beel: Beel (or Bheel) is a natural lake, generally an oxbow in Assam and West Bengal (Gopal and Sah, 1995). Beel is a term for a pond (wetland) with static water (as opposed to moving water in rivers and canals).

Table 1: Morphological and hydrological properties of Mathura Beel, India

Properties	*Mathura Beel*
Total area (ha)	259.55
Surface water area (ha)	182.75
Maximum depth* (m)	1.5
Mean depth* (m)	0.2
Annual rainfall (mm)	1600
Maximum rainfall* (mm)	506.8
Minimum rainfall* (mm)	0
Maximum temperature* (°C)	40.2
Minimum temperature* (°C)	13.6

(*): During study period, August '08-February '11.
Source: India Meteorological Department's official website.

(Biswasroy et al., 2011). The annual average rainfall was 1200 mm during the study period with maximum 506.8 mm in August, 09. It is a shallow lake with maximum depth of 1.5 m. The elevation of the area is about 9 to 10 metres above mean sea level. The general slope of the area ranges from 0-10% (Biswasroy et al., 2011).

Sampling Strategy and Period of Sampling

To assess the ecological status of Mathura Beel, ten strategic sampling sites were selected (by using GPS reading) for this study of phytoplanktons on the basis of accessibility, sources of different types of pollution (agricultural runoff, vegetative decomposition, sewage inflow and bathing zone) and lake depth etc. Monthly sampling was carried out from August, 2008 to February, 2011, and the months were grouped together in three successive seasons: pre-monsoon (March-May), monsoon (June-October) and post-monsoons (November-February).

Methodology

Collection and Identification

Subsurface phytoplankton samples were collected from ten sampling sites by filtering 50 litres of lake water through bolting silk plankton net (No. 25) and preserved in 4% formalin (Trivedy et al., 1982; Adoni, 1985). A Sedgewick-rafter counting cell was used under a compound light microscope (Leica 351 Model) for quantitative analysis. Single cells, colonies and filaments were all considered as individuals and the results are expressed as individuals per litre (ind. L^{-1}). The identification of phytoplankton was done following Fritsch (1948), Palmer (1980), Bold and Wynne (1978) and Gupta (2005).

Community Structure Analysis

To study phytoplankton community dynamics, Shannon-Wiener diversity index (Shannon and Wiener, 1949), Index of dominance (Simpson, 1949), Evenness index (Pielou, 1969) and richness index (Margalef, 1951) were calculated. The taxa were classified in functional groups according to Reynolds et al. (2002).

Result

In this study 96 phytoplankton species were identified belonging to 87 genera under six algal classes (Table 2). Chlorophyceae group shows maximum species diversity (45%) with 39 species followed by 26 species of Cyanophyceae (30%), 13 species of Bacillariophyceae (15%), three species of Euglenophyceae (6%) and two species each in Xanthophyceae (2%) and Dinophyceae (2%) (Figure 2). *Microcystis* spp. is dominant (59.5%) among all the species found in Mathura Beel during study period. It constitutes 93.1% among all the Cyanophytes. *Microcystis aeruginosa* Kütz., *Microcyctis flos aquae* (Witter.) Kirchn., *Microcystis pulverea* (Wood) Forti., *Microcyctis viridis* (A. Braun) Lemmermann and *Microcyctis wesenbergii* (Komărek) Komărek were identified under this dominant genus. *Microcystis aeruginosa* (45%) showed the maximum population followed by *Aphanocapsa roseana* de Bary (15.5%) and *Aphanocapsa pulchra* (Kütz.) Rabenth (6.5%) among all (Table 4). Euglenophyceae represents less frequent class with five species of phytoplankton among which three represent below 20% frequency class (Table 2).

Total species richness was highest in post-monsoon with 77 species, followed by monsoon (74 species) and pre-monsoon (64 species) respectively. The quantitative analysis showed that the highest average phytoplankton

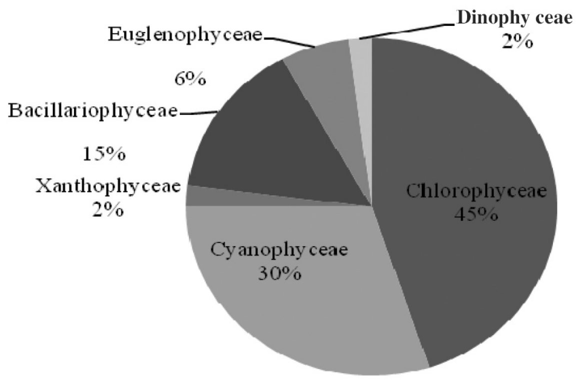

Figure 2: Dominance of phytoplankton classes in Mathura Beel, India.

Table 2: Seasonal variation of the phytoplankton in Mathura Beel during August 2008-February 2011

Sl no.	*Name of class with species*	*Seasonal distribution (in frequency class)*		
		M	P	P M
	Class: Cyanophyceae			
1	*Anabaena* sp. Bory.	+	+	+
2	*Anabaenopsis* sp. Wolosz.	+	+	+
3	*Apanocapsa* sp. Nageli	+	+	+
4	*Aphanocapsa banarasensis* Bharadw.	–	+	+
5	*Aphanocapsa roseana* de Bary	+	+	+
6	*Aphanocapsa pulchra* (Kütz.) Rabenth.	+	+	+
7	*Aphanothece* sp. Nag.	+	+	+
8	*Aphanizomenon* sp. Morren.	+	–	–
9	*Clathrocystis aeruginosa* (Kutz.) Henfrey	+	+	+
10	*Chlorogloea* sp. Wille	+	+	+
11	*Chroococcus tenax* (Kirchn.) Hieron	+	+	+
12	*Coelosphaerium* sp. Nag.	+	+	+
13	*Cylindrospermum* sp. Kütz.	+	+	+
14	*Gloeocapsa* sp. Kütz.	+	+	+
15	*Gloeocystis* sp. Nageli	+	+	+
16	*Gloeotrichia* sp. J.g.Agardh	+	+	+
17	*Gomphosphaeria* sp. Kützing.	+	-	-
18	*Lyngbya* sp.Agardh	+	+	+
19	*Merismopedia minima* Beck..	+	+	+
20	*Mischococcus* sp. Nageli.	+	+	+
21	*Microcyctis aeruginosa* Kütz.	+	+	+
22	*Microcyctis flos aquae* (Witter.) Kirchn.	+	+	+
23	*Microcystis pulverea* (Wood) Forti.	+	+	+
24	*Microcyctis viridis* (A. Braun) Lemmermann	+	+	+
25	*Microcyctis wesenbergii* (Komărek) Komărek	+	+	+
26	*Myxosarcina* sp. Printz	+	+	+
27	*Nostoc* sp. Vaucher	+	+	+
28	*Oscillatoria* sp.Voucher	+	+	+
29	*Petalonema* sp. Berk.	–	+	–
30	*Phormidium* sp. Kütz.	+	+	+
31	*Raphidiopsis* sp. Fritsch et Rich	+	+	+
32	*Schizothrix* sp. Kütz.	+	+	–
33	*Synechocystis* sp. Kazusa	+	+	+
34	*Spirulina* sp. Turpin.	–	+	+
	Class: Chlorophyceae			
35	*Ankristodesmus falcatus* (Corda) Ralfs	+	+	+
36	*Apiocystis* sp. Nag.	+	+	–
37	*Calothrix* sp.Agardh	+	–	+
38	*Characium* sp. A.Br. ex Kütz.	–	+	+
39	*Chlamydomonas* sp. Ehrenberg.	+	–	+
40	*Chlorella* sp. Beyerinck.	+	+	+
41	*Chlorococcum* sp. Fries.	–	–	+
42	*Cladophora* sp. Kütz.	+	–	–
43	*Closterium* sp. Ehr.	+	+	+
44	*Coelastrum* sp. Nag.	+	+	–
45	*Crucigenia* sp. Morren.	+	+	+
46	*Dichotomosiphon* sp. Ernst	–	+	–
47	*Eudorina elegans* Ehr.	+	+	+
48	*Gloeocystis* sp. Nageli	+	+	–
49	*Golenkinia* sp. Chodat.	+	–	+
50	*Hormidium* sp. Kütz.	+	+	+
51	*Hormotila* sp. Borzi.	–	–	+
52	*Kirchneriella* sp. Schmidle.	–	+	–
53	*Lagerheimia* sp. Chodat.	–	+	–
54	*Mesotaenium* sp. Nag.	+	+	+
55	*Micrasterias* sp. Agardh.	–	–	+
56	*Micractinium* sp. Fresinius.	–	–	+
57	*Nephrocytium* sp. Nag	+	+	+
58	*Oedogonium crassum* Link.	+	+	+
59	*Oocystis naegelii* A. Br.	+	+	+
60	*Pediastrum muticum* Kütz.	+	+	+
61	*Pediastrum ovatum* (Ehr.) A. Br.	+	–	+
62	*Pediastrum simplex* Meyen	+	+	+
63	*Pleurococcus* sp. Menegh.	+	–	–
64	*Scenedesmus quadricauda* (Turpin) Brebission	–	+	+
65	*Schroederia* sp. (Schroeder) Limm.	–	–	+
66	*Sorastrum* sp. Kütz.	–	–	+
67	*Spirogyra* sp. Link.	–	–	+
68	*Spondylosium* sp. Archer.	–	+	+
69	*Staurastrum* sp. Meyen	+	+	+
70	*Tetraedron* sp. Kützing.	–	–	+
71	*Tetraspora* sp. Link.	–	+	–
72	*Tabellaria* sp. Ehr.	–	+	+
73	*Ulothrix* sp. Kütz.	–	+	+
74	*Uronema* sp. Lagerheim	–	+	–
75	*Volvox* sp. L. emend. Ehr.	+	+	+
	Class: Bacillariophyceae			
76	*Amphora* sp. Ehrenberg.	–	+	–
77	*Chaetoceros* sp. Ehrenberg	–	+	+
78	*Coscinodiscus* sp. Ehr.	–	–	+
79	*Cymbella* sp. Agardh.	+	+	+
80	*Denticula* sp. Kützing.	–	+	+

(*Contd.*)

(**Table 2:** *Contd.*)

Sl no.	*Name of class with species*	*Seasonal distribution (in frequency class)*		
		M	P	P M
81	*Fragileria* Lyngbye	–	–	+
82	*Gomphonema lanceolatum* Ehr.	+	–	–
83	*Melosira islandica* O. Muller	+	+	+
84	*Navicula* sp. Bory.	+	+	+
85	*Pinnularia* sp. Ehr.	+	+	+
86	*Pluerosigma* sp. W. Smith	+	–	+
87	*Rhizosolenia* sp. Ehrenberg	–	+	+
88	*Synedra* sp. Ehr.	+	+	+
	Class: Euglenaceae			
89	*Atasia braviciliata* Matv.	–	–	+
90	*Colacium vesiculosum* Ehr.	–	–	+
91	*Euglena elastica* Ehr.	+	+	+
92	*Phacus caudatus* Hubner	–	–	+
93	*Trachelomonas* sp. Ehr.	+	+	+
	Class: Xanthophyceae			
94	*Brotryococcus* sp. Kütz.	+	+	+
95	*Botryposis* sp. Borzi	+	+	+
	Class: Dinophyceae			
96	*Peridinium* sp. Ehr.	+	+	+

NB.: Absent (-); Present (Frequency Class) + (to 20%); ++ (21-40%); +++ (41-60%); * (61-80%); # (81-100%);
Season: P – Pre-monsoon; M – Monsoon; PM – Post-monsoon;

of 1045 ind. L^{-1} were recorded in post-monsoon and lowest in pre-monsoon with 662 ind. L^{-1} (Table 4). The frequency of Cyanophytes (94.5%) were highest in pre-monsoon season (Figure 3). It was found from the average data of three successive years that the diversity Index of Phytoplanktons (H′) were highest (0.309) in post-monsoon and lowest in pre-monsoon season (0.191) whereas dominance index (D) was lowest in post-monsoon (0.867) and highest in pre-monsoon season (0.925). In terms of evenness and richness indices post-monsoon represented the highest values whereas pre-monsoon recorded the lowest values (Table 3). The average values of DO and BOD show an increase in monsoon (DO – 9.73 ppm and BOD – 6.18 ppm) followed by post-monsoon season (DO – 8.43 ppm and BOD – 5.593 ppm) which is not a normal scenario (Figure 5) whereas their value is lowest in pre-monsoon season (DO – 7.58 ppm and BOD – 4.475 ppm).

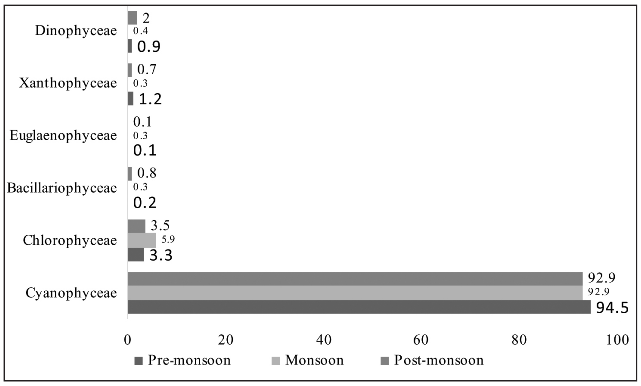

Figure 3: Relative density of phytoplankton classes in Mathura Beel, India.

Discussion

Planktonic populations have long been used as ecological indicators (Jones, 1969; Webber et al., 1998; Webber et al., 2005). According to Schreurs (1992), long-term dominance by colony forming species are more commonly dominating in deeper lakes. These may be the reason behind the dominance of Cyanophycean group at the deepest study site.

Excess nutrient availability for the high precipitation might be the reason for maximum diversity of phytoplanktons (Kant and Anand, 1978) in monsoon season (Table 4). It was found that low rainfall had

Table 3: Seasonal variation in diversity, dominance, evenness and richness indices of phytoplankton in Mathura Beel during August 2008-February 2011

Statistical indices	*Pre-monsoon*	*Monsoon*	*Post-monsoon*
Index of diversity (H')	0.19	0.29	0.31
	0.09-0.29	0.17-0.35	0.27-0.38
Index of dominance (D)	0.93	0.87	0.87
	0.88-0.97	0.82-0.94	0.84-0.90
Evenness index (j)	0.05	0.08	0.08
	0.04-0.07	0.05-0.10	0.07-0.09
Richness index (d)	5.24	6.75	6.79
	1.89-8.60	5.67-8.65	5.40-8.51

Table 4: Mean, minimum and maximum values of number of genera and phytoplankton density (indiv. L^{-1}) in seasons

Phytoplankton	*Pre-monsoon*	*Monsoon*	*Post-monsoon*
Number of genera	24	27	26
	3-39	15-45	7-44
Species richness	24	33	31
	7-45	18-52	10-50
Total density (No. of Indiv.)	622	852	1045
	117-1207	198-1843	148-1687
Cyanophyceae (No. of Indiv.)	625	791	975
	115-1134	178-1694	137-1595
Chlorophyceae (No. of Indiv.)	23	50	32
	2-43	7-123	11-56
Bacillariophyceae (No. of Indiv.)	1	3	7
	0-2	0-7	0-14
Euglaenophyceae (No. of Indiv.)	1	3	2
	0-1	1-6	0-4
Xanthophyceae (No. of Indiv.)	16	5	16
	0-16	0-6	0-28
Dinophyceae (No. of Indiv.)	11	3	20
	0-11	0-7	0-32

occurred in post-monsoon season which generated high density of phytoplanktons (Figure 4). Run off from adjacent agricultural field during monsoon added nutrients suitable for the growth of all phytoplankton groups. The over-dominated colony forming *Microcystis* sp. was the main reason behind this finding. The temporary elevation in temperature may be a reason for abundance of Cyanobacteria (Jackson, 1984; Tilman and Kiesling, 1984; McQueen and Lean, 1987; Robarts and Zohary, 1987). The above studied lake shows that this type of condition occurs due to the dominance of phytoplankton of Cyanophycean group. The toxicity of Cyanophyceae limits the growth of other phytoplankton groups as well as the Zooplankton group (Bary, 1959).

The lake is associated with reduced transparency, decreased biodiversity and oxygen depletion which resulted in massive fish kills, production of odour etc. Cyanobacterial toxins pose a severe health hazard causing anything from skin irritation to intoxication and may be most harmful through chronic uptake with drinking water leading to liver damage (Chorus, 1993). Among the entire Cyanophyceaen colony forming *Microcystis* sp., found in the largest phytoplankton community may lead to a pivotal role for water quality degradation (Gopal and Sah, 1995). The growth of colony forming Cyanophycean phytoplankton may be triggering eutrophication (Nygaard, 1949) in Mathura

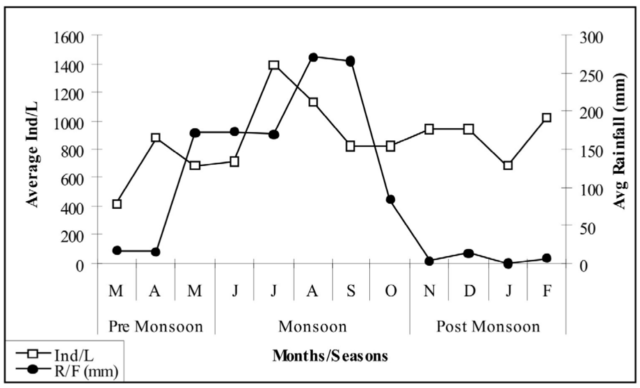

Figure 4: Monthly variation of average density of phytoplankton in relation to volume of rainfall in Mathura Beel, India.

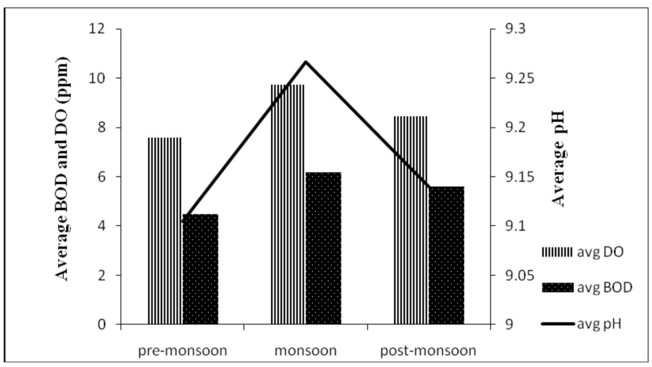

Figure 5: Seasonal variation of average DO, BOD and pH in Mathura Beel, India.

Beel. The average Cyanophycean population was very high than Chlorophyceae and other groups (Table 4). Physico-chemical parameters like DO, BOD and pH at different season (pre-monsoon, monsoon and post-monsoon) show variation in the water quality of the lake Mathura Beel (Figure 5). The load of phytoplankton (ind/L) is also highest at monsoon season followed by post-monsoon season (Figure 4) which supports the increased amount of DO in both the seasons. During monsoon season rate of supply of biodegradable organic matter from adjoining land was relatively high in comparison to the rate of degradation by dissolved oxygen causing an increase in the BOD values parallel to DO values in monsoon and post-monsoon seasons.

Increased amount of photosynthesis by the phytoplankton and algal population trapped the dissolved CO_2. Removal of acidic component of the water by phytoplankton and algae through photosynthesis process caused gradual increase in average pH value in monsoon resulting in alkaline lake water. These are not good indications for the quality of lake water. It may be concluded from the above data that the lake is eutrophic in nature. Eutrophication causes alteration in biogeochemical processes which in turn changes the physico-chemical characteristic of the water-body. Microbial, algal, plant, invertebrate and vertebrate communities are all affected by these changes. These changes affect the different purposes of the wetlands: principally aquatic life and recreational (wildlife viewing, fishing) uses, and importantly reduce the effectiveness of wetlands as effective filters that protect downstream and groundwater resources. Steps should be taken to restore this wetland of wide use.

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