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Variability in Water Quality and Phytoplankton Community during Dry and Wet Periods in the Tropical Wetland, Bhopal, India

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Abstract

The Bhoj wetland, a Ramsar site has been found to be under huge pressure due to burgeoning human population in its catchment area. The present investigation spread across nine stations has revealed higher algal diversity (294 species) during the period of 2008-2009. The phytoplankton diversity belonging to six groups revealed 46% contribution of Chlorophyceae followed by Bacillariophyceae (28%), Cyanophyceae (15%), Euglenophyceae (9%), while Pyrophyceae and Chrysophyceae contributed 1% each, respectively. *Closterium* sp., *Cosmarium* sp., *Pediastrum* sp., *Scenedesmus* sp., *Staurastrum* sp. and *Tetraedron* sp. contributed the bulk of Chlorophyceae was dominated by these various species and from Bacillariophyceae was mostly represented by *Achnanthes* sp., *Cymbella* sp., *Navicula* sp., *Gomphonema* sp. and *Synedra* sp. Cyanophyceae was represented by *Anabaen* sp., *Aphanocapsa* sp. and *Oscillatoria* sp., *Aphanocapsa* sp., *Microcystis* sp. and *Oscillatoria* sp. Species like *Euglena* sp. and *Phacus* sp. represented euglenophyceae. The higher abundance of (*Closterium, Pediastrum, Scenedesmus, Navicula, Anabaena, Microcystis* and *Phacus*) and nutrient concentration (nitrate-nitrogen and phosphorus) during the dry and wet periods reflect higher organic pollution in the Bhoj wetland. There should be strict legislation to protect the wetland from undue exploitation.

Keywords: Wetland; Wet/dry periods; Water quality; Phytoplankton

Introduction

Anthropogenic activities have been considered to be the most important factor for the degradation of aquatic environments, over the last centuries [1-5]. The main environmental pressures were thought to be pollution from excess nutrient loading, which resulted from agricultural, urban and suburban runoff, wastewater [6-8]. Phytoplankton communities are important sentinels of environmental changes, since they integrate the effects of increased nutrient loads, and they can be more sensitive to the combined impacts of stressors than a single stressor [9-12].

Wetland ecosystems are particularly vulnerable to eutrophication because freshwater enters these areas via rivers which are highly susceptible to pollution from urban, agricultural and industrial wastewater [13]. The study of both abiotic and biotic components is complementary to each other. The abiotic components give information about the type of a substance or pollutants and its concentration, while biotic components indicate their general effect but no clue to the nature and quality of a substance. Biological components show the degree of ecological imbalance, which has been caused. The changes in the physico-chemical conditions of water can be reflected directly in the biotic community of ecosystem. Biological monitoring based on ecology of flora and fauna has been recognized as an excellent and inexpensive tool for measuring pollution level in water. This study attempts to determine the water quality conditions and phytoplankton composition status during wet and dry periods in Bhoj wetland (a Ramsar site).

Study Area

Bhoj wetland was credited by Raja Bhoj, the famous Parmar king in 1010AD is now an exemplary case of degradation on account of its excessive use by the fast increasing urban population comprised of multiple stakeholders. The Bhoj wetland is located between latitude 23° 13'-23° 16' N and longitude 77° 18'-77° 24' E. It is a shallow water body with a watershed area of 361 sq. Km. and a maximum submergence area of about 37 sq. Km. the attainment of maximum water level (508.04 meters above sea level) of the lake depends on the magnitude of monsoon in its watershed area. As per the topography of the catchment area the north side of the lake is having major thrust of urban and semi-urban activities which contribute the solid and liquid waste. On the southern side of the water body a national park and national museum or Manav Sangrahalaya is situated. Although sewage inflow from this area is insignificant but eroded soil gets deposited in to the lake and enriches the water with nutrients. The southwest and northwest of the catchment area of the wetland brings in sizeable amounts of waste water, nutrients and silt. This area is mainly under rural activities, in which agriculture is practiced (Figure 1).

Materials and Methods

The study was carried out during Feb. 2008 to May 2010. Nine sampling stations were selected based on different human activities such as washing, bathing, fishing and boating etc. The inlets, outlets, morphometric features and growth of aquatic vegetation etc., where other important factors considered during the selection of the sampling sites.

The water samples have been collected in one liter polyethylene canes between 8 AM to 12PM from the selected site of the Bhoj wetland. Air temperature, water temperature, dissolved oxygen and total alkalinity have been determined on the spot and the rest of the

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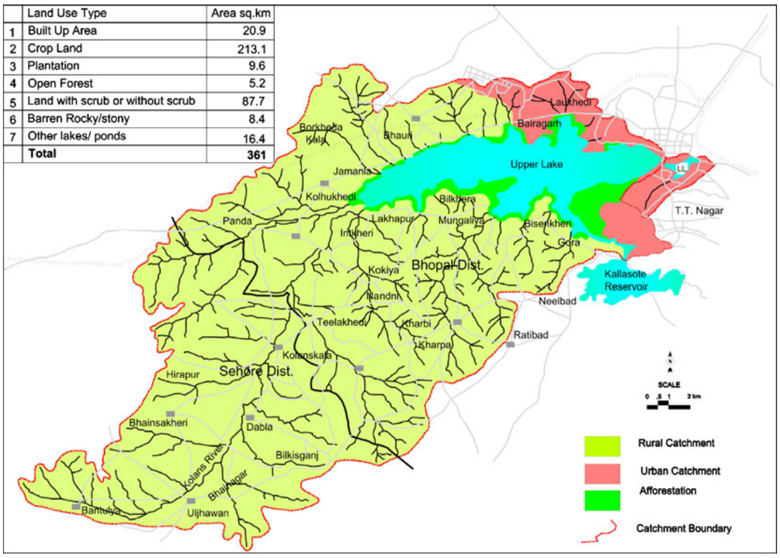

Figure 1: Catchmentarea of Bhoj Wetland.

parameters have been analyzed in laboratory within time period of 24 h after collection. The various physico-chemical parameters have been analysed according to the standard methods [14-16].

The collection of phytoplankton samples have been done by using plankton net and the samples have been preserved simultaneously by adding formaldehyde (4%) and allowed to stand for 24 hours. The quantitative enumeration of phytoplankton has been done with the help of Sedgwick rafter counting cell (1ml capacity). The identification of aquatic biota (phytoplankton) has been done following the standard works and methods of Desikachary [17], Edmondson [18], Needham and Needham [19], Prescott [20], and Sinha and Naik [21]. The unicellular algae were counted as unit per liter (unit/l) while in case of filamentous forms of Chlorophyceae and Cyanophyceae one filament of a specific size was taken as single unit while in colonial forms one colony was taken as a unit. Results were expressed as units/1 [22].

Results and Discussion

Wetlands exhibit different water quality status depending on the inflow from its general catchment besides wastewater [23]. The dry season values observed for pH, DO, Total Alkalinity, Total Hardness and water temperature were slightly higher than the values observed in the wet season. Electrical conductivity, total phosphorus (PO_4-P) and nitrate nitrogen (NO_3-N) concentration was higher in the wet season than observed in the dry season (Table 1). The present study confirms that with the increase in water temperature the chemical reaction and biological activity speed up that reduces the solubility of gases in water [24].The lack of seasonal variation in pH of the waters may be attributed to the relatively high total alkalinity of the waters. Fluctuation in dissolved oxygen is also due to fluctuation in water temperature and addition of sewage waste demanding oxygen [25]. The amount of oxygen dissolved in water is essential for respiratory metabolism of most aquatic organisms and affects the solubility and availability of many nutrients and therefore determine the productivity of aquatic ecosystems [26].

The total alkalinity ranged from 66.61 to 80.48 mg/l in both the years of the wetland (Table 1) which makes the reservoir as nutrient rich and highly productive water body as suggested by Munawar [27].

		First year		Second year	
Parameter	**Units**	**Dry**	**Wet**	**Dry**	**Wet**
Air temperature	°C	37.31	30.63	30.13	28.77
Water temperature	°C	25.07	24.02	27.08	25.17
pH	units	8.46	7.86	8.26	8.16
Total Dissolved Solids	mg/1	169.26	197.61	182.08	149.26
Elect. Conductivity	mg/1	254.07	268.98	285.83	239.35
Dissolved Oxygen	mg/1	7.04	6.93	5.72	5.39
Total Alkalinity	mg/1	80.48	79.86	78.67	66.61
Total Hardness	mg/1	96.59	85.93	98.67	93.76
Nitrate nitrogen	mg/1	0.5	0.57	0.53	0.87
Total Phosphorus	mg/1	0.21	0.26	0.26	0.31

Table 1: A Physico-chemical characteristics of Bhoj wetland.

High hardness of aquatic ecosystem points out towards eutrophication. Rai [28] and Sawyer [29] classified water on the basis of hardness into three categories that is, soft (0.00-75 mg/l), moderately hard (75.00-150.00 mg/l) and hard (151.00-300.00 mg/l). According to this classification, Bhoj wetland falls in the category of moderately hard water body with hardness ranging from 85.93 to 98.67mg/l. The higher electrical conductivity observed in the wet season may be due to inflow of surface runoff. Lashari et al. [30] while working on Keenjhar Lake reported electrical conductivity range from 320 to 496 µS/cm, during monsoon and summer season. Olsen [31] classified water bodies having conductivity values greater than 500 µS/cm as eutrophic. According to this criteria, Bhoj wetland water falls under the category of mesotrophic water body. PO_4-P and NO_3-N act as limiting nutrients for the growth of phytoplankton and other aquatic plants. Below 0.1mg/1and 0.090 mg/1 respectively for NO_3-N and PO_4-P are expected in natural unpolluted water [32]. The concentrations observed in the present investigation are capable of stimulating algal bloom (Table 1).

During the two years of study period, a total of 294 phytoplankton species were recorded from the two years of dry/wet seasons (Table 2). The total phytoplankton diversity belonged to six groups. This diversity in species was contributed by Chlorophyceae to the tune of (46%) followed by Bacillariophyceae (28%), Cyanophyceae (15%),

Group and Species	Dry	Wet	Dry	Wet
Chlorophyceae				
Actinastrum hantzschii	+	+	+	+
Ankistrodesmus convolutus	+	+		
Ankistrodesmus falcatus	+	+	+	+
Ankistrodesmus sp.	+	+	+	+
Ankistrodesmus spiralis		+		+
Arthrodesmus sp.	+	+	+	+
Botryococcus braunni	+	+		+
Chaetophora sp.		+		
Chodatella quadriseta				+
Cladophora sp.				+
Closteriopsis longissima	+	+		+
Closteriopsis sp.	+	+	+	+
Closterium acutum	+	+		+
Closterium ehrenbergi			+	
Closterium dianae			+	+
Closterium eboracense	+	+		
Closterium idiosporum				+
Closterium leibleini	+	+		+
Closterium parvulum	+	+	+	+
Closterium sp.	+	+	+	+
Closteridium obesum	+	+	+	+
Colastrum microspora	+			+
Coelastrum microporum	+	+	+	+
Conococcus elongates		+	+	+
Cosmarium acutum			+	+
Cosmarium aequale			+	
Cosmarium bireme	+			
Cosmarium botrytis	+	+	+	
Cosmarium depressium	+			+
Cosmarium depressum	+	+	+	+
Cosmarium ehrenbergii				+
Cosmarium granatum	+		+	+
Cosmarium javanicum				+
Cosmarium margaritatum				+
Cosmarium ochthodes			+	+
Cosmarium pachydermum		+		+
Cosmarium perforatum	+	+		
Cosmarium pseudonitidulum				+
Cosmarium quadrum	+			
Cosmarium regulare				+
Cosmarium reniforme	+	+	+	+
Cosmarium sp.	+	+	+	+
Cosmarium sublatere-undatum			+	+
Cosmarium subturgid	+			
Cosmarium subturgidum		+	+	+
Crucigenia quadrata				+
Dactylococeopsis raphidiodes				+
Desmidium sp.	+	+	+	+
Dictyococcus braunii	+			
Dictyosphaerium pulchellum				+
Draparnaldia glomerata				+
Draparnaldia sp.	+	+	+	
Ealkatothrix sp.	+	+	+	
Echnosphaerella limnetica		+		
Euastrum. spinulosum	+	+		+
Euastrum turneri				+
Gloeocapsa atrata	+	+		
Golenkinia chlorelloides				+
Golenkiniopsis minutissima		+		
Gonatozygon sp.	+	+		
Gonium compactum	+	+	+	+
Hyalotheca sp.				+
Hydrodictyon sp.	+	+		
Kirchneriella lunaris	+	+		+
Microasterias pinnatifida	+	+		
Microspora sp.	+	+		
Monoidium sp.	+			
Mougeotia sp.	+	+	+	+
Oedogonium capiliare			+	+
Oedogonium sp.	+	+	+	+
Pachycladon umbrinus				+
Pandorina cylindricum				+
Pediastrum angulosum	+	+	+	
Pediastrum biradiatum	+	+	+	+
Pediastrum duplex	+	+	+	+
Pediastrum ovatum	+	+	+	+
Pediastrum simplex	+	+	+	+
Pediastrum sp.	+	+		
Pediastrum tetras	+	+	+	+
Pediastrum tetras excisum	+	+		+
Polyedriopsis spinulosa		+	+	+
Quadrigula closteriodes			+	
Scenedesmus acuminatus	+	+	+	+
Scenedesmus acutiformis	+	+	+	+
Scenedesmus acutus	+	+		
Scenedesmus arcuatus	+	+	+	+
Scenedesmus armatus	+	+	+	+
Scenedesmus bijugatus	+	+	+	+
Scenedesmus brasiliensis	+			
Scenedesmus carinatus		+		+
Scenedesmus dimorphus	+	+	+	+
Scenedesmus indicus	+			
Scenedesmus longus			+	+
Scenedesmus obliquus	+	+		+
Scenedesmus platydiscus			+	
Scenedesmus protuberans	+			
Scenedesmus quadricauda	+	+	+	+
Scenedesmus sp.	+	+	+	
Scenedesmus tropicus	+	+	+	+
Scenedesmus westtii	+	+		
Schroederia indica	+	+		+
Selenastrum bibraianum	+	+	+	+
Selenastrum westtii	+	+	+	+
Sirogonium sp.	+		+	+
Sorestrum spinulosum	+			+
Spirogyra sp.	+	+	+	+
Spirotaenia sp.	+			+
Staurastrum commutatum	+	+		+
Staurastrum crenulatum	+	+	+	+
Staurastrum lacustre		+	+	+
Staurastrum proboscidium	+	+	+	+
Staurastrum regulosum	+			

Staurastrum sp.	+	+	+	+
Staurastrum turgescens		+		
Stigeoclonium sp.		+		+
Tetraedron caudatum	+	+		
Tetraedron gracile			+	+
Tetraedron hastatum	+	+		
Tetraedron limneticum	+	+	+	+
Tetraedron proteiforme	+	+	+	+
Tetraedron pusillum	+	+	+	
Tetraedron pusillum angolense		+		
Tetraedron quadratum minus				+
Tetraedron regulare	+	+		+
Tetraedron trigonum	+	+	+	+
Tetraedron victorieae		+		
Tetromonas robusta			+	
Treubaria sp.	+			+
Treubaria triappendiculate	+	+		+
Trochiscia aciculifera	+			+
Ulothrix sp.	+	+	+	+
Ulothrix zonata	+		+	+
Uronema sp.	+	+		+
Volvox sp.	+	+	+	+
Zygnema sp.	+	+		+
Zygnema stellinum				+
Bacillariophyceae				
Achnanthes biasoletttiana			+	
Achnanthes exigua	+	+		
Achnanthes lanceolata	+	+		
Achnanthes microcephala	+	+	+	+
Achnanthes minutissima	+	+	+	+
Achnanthes sp.	+	+		
Amphora minutissima	+	+		
Amphora ovalis	+	+	+	+
Anomoeoneis sphaerophora	+		+	+
Cocconeis placentula	+	+		
Cymbella acqualis	+	+		+
Cymbella affinis	+	+		
Cymbella cleve	+		+	
Cymbella delicutala			+	
Cymbella helvitica	+	+	+	+
Cymbella hustedtii	+	+	+	
Cymbella naviculiformis	+	+	+	
Cymbella parva	+	+	+	+
Cymbella parva cleve	+			
Cymbella sp.	+	+	+	+
Cymbella tumida	+	+	+	+
Cymbella tumidula	+			+
Cymbella turgida	+	+		
Cymbella ventricosa	+	+		
Diploneis subovalis	+	+	+	+
Eunotia major indica	+	+		
Fragilaria construens	+	+	+	+
Fragilaria intermediate	+			+
Frustulia sp.				+
Gomphonema constrictum			+	+
Gomphonema intricatum	+			+
Gomphonema lacus rankala	+	+		+
Gomphonema lanceolatum	+	+	+	+
Gomphonema monantum			+	
Gomphonema montanum	+	+		+
Gomphonema olivaceum	+	+	+	
Gomphonema parvulum	+	+		+
Gomphonema sp.	+	+	+	+
Gomphonema sphaerophorum	+		+	
Gomphosphaeria aponina				+
Lyngbya martensiana	+	+		
Melosira sp.	+	+		
Navicula amphibia			+	+
Navicula anglica	+			
Navicula cincta			+	
Navicula confervacea	+	+		+
Navicula cryptocephala				+
Navicula cuspidata	+		+	+
Navicula exigua	+	+		
Navicula halophila	+	+	+	+
Navicula halophila robusta			+	+
Navicula menisculus	+	+		
Navicula palea			+	+
Navicula phyllepta	+			
Navicula radiosa	+	+	+	
Navicula similis			+	
Navicula sp.	+	+		+
Navicula subrhyncocephala	+	+	+	+
Navicula subtilissima				+
Navicula virudula	+	+		
Neidium bisulcatum	+	+	+	+
Neidium iridis	+	+		
Neidium sp.	+	+		
Nitzschia amphibia	+		+	+
Nitzschia denticula	+	+	+	
Nitzschia palea	+	+	+	
Nitzschia sp.			+	
Pinnularia gibba	+	+	+	
Pinnularia karelica	+	+	+	+
Pinnularia pisulla	+	+	+	
Pinnularia rangoonensis			+	+
Rhopalodia gibba	+	+	+	+
Synedra acus			+	+
Synedra acus acula	+	+	+	+
Synedra affins			+	
Synedra minuscula	+	+		
Synedra nana	+	+	+	
Synedra rumpens	+	+		+
Synedra sp.		+		
Synedra ulna	+	+	+	
Tabellaria fenestrate	+		+	+
Cyanophyceae				
Anabaena aphanizomanoides		+		+
Anabaena circularis		+		
Anabaena circinalis	+	+		
Anabaena naviculoides	+	+		+
Anabaena sp.	+	+	+	
Anabaena utermohlii	+	+	+	+
Aphanocapsa elachista				+

Aphanocapsa grevillei	+			+
Aphanocapsa koordesi	+	+	+	+
Aphanocapsa muscicola	+	+		+
Aphanocapsa pulchra	+	+	+	+
Aphanocapsa roseana	+	+		
Arthrospira massartii			+	
Chroococcus turgidus		+		
Coelosphaerium kuetzingianum	+			
Gomphosphaeria aponina	+			
Lyngbya borgerti	+			+
Lyngbya limnetica	+			
Merismopedia convoluta	+	+	+	+
Merismopedia punctata	+	+	+	+
Merismopedia tenuissima				+
Microcystis aeroginosa	+	+	+	+
Nostoc sp.	+	+		
Oocystis crassa				+
Oscillatoria acuminata	+		+	+
Oscillatoria amphibia	+			
Oscillatoria animalis	+			
Oscillatoria chalybea		+		+
Oscillatoria chlorina	+			
Oscillatoria limnetica	+	+		
Oscillatoria ornata				+
Oscillatoria peronata	+	+	+	+
Oscillatoria pseudogeminata	+			
Oscillatoria quadripunctulata	+			
Oscillatoria rubescens	+	+		
Oscillatoria sp.		+	+	+
Oscillatoria splendida	+			
Oscillatoria subbrevis	+	+		
Phormidium tenue	+	+		
Spirulina labyrinthiformis	+	+	+	+
Spirulina sp.		+		+
Spirulina subrhynthiformis		+		+
Spirulina subtilissima			+	+
Synechocystis aquatilis	+	+		
Synechocystis pevalekii				+
Euglenophyceae				
Euglena acus	+	+	+	+
Euglena acutissima	+	+		+
Euglena caudata	+		+	+
Euglena elastica				+
Euglena graciles	+	+	+	+
Euglena ignobilis		+	+	
Euglena limnophila			+	+
Euglena proxima			+	+
Euglena spirogyra	+		+	+
Euglena vagans	+	+		
Euglenomorpha hegneri	+		+	
Lepocinclis fusiformis	+	+	+	
Lepocinclis salina			+	
Lepocinclis spirogyra			+	
Lepocinclis steinii	+			
Lepocinclis ovum			+	
Phacus acuminatus	+	+	+	+
Phacus anomalus				+
Phacus caudatus	+	+	+	+
Phacus circumflexus	+	+	+	
Phacus ephippion		+	+	+
Phacus meson				+
Phacus pyrum	+		+	+
Phacus sesquitortus		+		+
Phacus sp.	+	+	+	+
Phacus tortus			+	+
Phacus wettzteinii	+	+		
Dinophyceae				
Ceratium sp.	+	+	+	+
Peridinium sp.	+		+	+
Chrysophyceae				
Anthophysa vegetans				+
Dinobryon sp.			+	
Gonyaulax sp.				+
Total number of phytoplankton 294				

Table 2: Phytoplankton diversity observed during dry and wet periods in the Bhoj wetland.

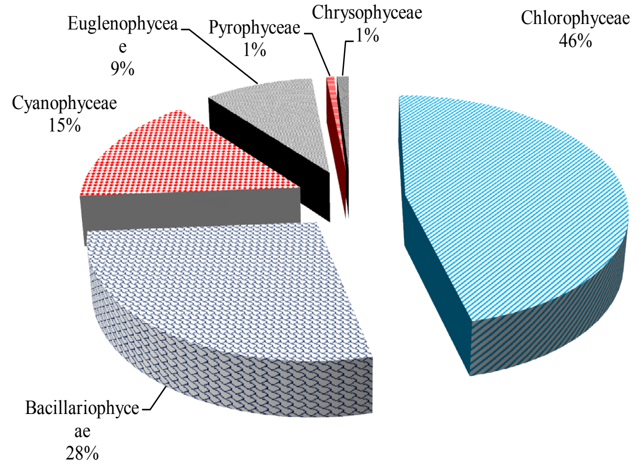

Figure 2: Per cent contribution of different groups of phytoplankton diversity.

Euglenophyceae (9%), while Pyrophyceae and Chrysophyceae contributed 1% each, respectively (Figure 2).

A total density of 25495 and 24222 units/1 of phytoplankton was on account of 227 and 225 species recorded during the dry and wet seasons respectively (Tables 3 and 4). A comparison of two years dry season reveals that in first year the diversity was 202 species that declined to 146 species in the second year of dry season, similarly the density in first year was 14788 units/l, which decreased to 8366 units/l in second year. This variation in diversity and density during two years may be attributed to significant hydrological changes encountered in the second year, mainly caused by acute drought conditions.

An assessment of two years of wet season reveals that in first year the diversity of phytoplankton was 179 species that slightly increased to 183species in the second year, similarly the density of phytoplankton in the first year was 10673 units/l, which increased to 15856 units/l in second year respectively.

General decrease in density of phytoplankton during wet season

Density	First year (2008)			Second year (2009)		
	Dry	Wet	Total	Dry	Wet	Total
Chlorophyceae	5327	5853	11214	3033	3710	6744
Bacillariophyceae	2634	1010	3644	1366	1573	2939
Cyanophyceae	4263	3367	7630	730	1647	2377
Euglenophyceae	237	277	513	1340	517	1856
Pyrophyceae	2327	167	2493	1890	8397	10287
Chrysophyceae				7	13	20
Total	**14788**	**10673**	**25495**	**8366**	**15856**	**24222**

Table 3: Phytoplankton density observed during dry and wet periods of the Bhoj wetland.

Diversity	First year (2008)			Second year (2009)		
	Dry	Wet	Total	Dry	Wet	Total
Chlorophyceae	91	87	105	65	97	108
Bacillariophyceae	63	52	64	46	41	60
Cyanophyceae	31	26	38	13	24	26
Euglenophyceae	15	13	18	19	17	26
Pyrophyceae	2	1	2	2	2	2
Chrysophyceae	-	-	-	1	2	3
Total	**202**	**179**	**227**	**146**	**183**	**225**

Table 4: Phytoplankton density observed during dry and wet periods of the Bhoj wetland.

may be due to dilution from monsoon rains in the first year and in the second year, the density decreased in dry season, mainly due to acute drought conditions. Barone and Flores [33], Adesalu and Nwankwo [34], and Rajagopal [35] also reported that the low value of phytoplankton population in wet season was due to dilution, increased outflow and silting. Rana [36], and Pundhir and Rana [37] have observed that rainy season, cloudy weather, low transparency and heavy flood contribute to the decline in phytoplankton density. Henry et al. [38] in his studies also showed a reduction in phytoplankton population and diversity with drought progression in Coqueiral lake.

Chlorophyceae, the dominant class was mainly represented by *Cosmarium* (21 sp.), *Scenedesmus* (18 sp.), *Closterium* (8 sp.), *Pediastrum* (8 sp.), *Staurastrum* (7 sp.) and 11 species of *Tetraedron* (Table 2). Increased temperature and long photoperiod may explain increased Chlorophycean diversity. Nandan and Aher [39] and Tiwari and Chauhan [40], reported that high content of phosphate, calcium and nitrate influence the growth of *Closterium* and *Scenedesmus* species. Other workers also suggested that the organisms of this species attain high or low diversity according to their tolerance to environmental conditions [34,41,42] related *Closterium* sp. to long term organic pollution, which is in agreement with the present study. Under conditions of nitrate and phosphate availability, the green algae (Chlorophyceae) are known to proliferate in freshwater environment [43]. Bacillariophyceae, the second most dominant algal group was primarily represented by 6 species of *Achnanthes*, 16 species of *Cymbella*, 18 species of *Navicula*, 11 species of *Gomphonema* and 8 species of *Synedra* (Table 2). Sunkad [44] reported the maximum population density of diatoms in summer and minimum in monsoon months. Patrick [45] concluded that many species of diatoms could tolerate a temperature up to 35°C. Zafar [46] has emphasized the importance of temperature in the distribution of diatoms. Temperature influences the production of diatoms as they seem to grow and colonise during the warmer periods and will have lean population in winter [22,47,48].

The Cyanophycean group as mainly dominated by *Oscillatoria* (14 species), *Anabaena* and *Aphanocapsa* (6 sp's each) (Table 2). The presence of these species indicates higher nutrient status. Wanganeo and Wanganeo [22] have emphasized that factors like alkalinity, nitrates and phosphates are responsible for the luxuriant growth of Cyanophyceae, apart from higher pH, temperature, and dissolved oxygen. The nutrient increase due to discharge of agricultural and organic effluents coupled with other anthropogenic activities in the catchment, a shift in biodiversity has probably impacted phytoplankton composition of the Bhoj wetland. Bowling [49], Wanganeo [50], and Bhat et al. [51] reported that the presence of *Anabaena* sp., *Oscillatoria* sp., and *Microcystis* sp., indicate nutrient enrichment as these genera commonly respond to increases in nutrients.

In this study significant relationship of Euglenophyceae with calcium hardness and total hardness could be attributed to the fact that calcium is an important part of plant tissue, increases the availability of other ions [52] and thus might have played a vital role in the growth of phytoplankton. Further, studies on the Euglena bloom in the present study, similar type of observation were reported by Bowling [49], and Duttagupta et al. [53] in flood plain wetlands of Assam, and another study on lake Manasbal of Kashmir valley by Khan and Bhat [54] emphasized the importance of calcium in stimulating the growth of *Euglena*. Euglenophyceae group is generally abundant in waters rich in organic matter [55], therefore presence of *Phacus* sp. in the present study is a direct indication of higher pollution load in the system, because this species is considered to be dominant genera of polluted waters [56]. Further, high nutrients and favourable physico-chemical characteristics recorded in the Bhoj wetland, may be contributing to the increased Euglenophyceae. Munawar [27] in his study indicated that more amount of CO_2, phosphate, nitrate and low content of dissolved oxygen favoured the growth of euglenoids. Singh [57] concluded that high organic load, low transparency, low dissolved oxygen, high (alkalinity, chlorides, total hardness, calcium and magnesium) favoured the rich growth of Euglenophyceae. Because of organic pollution, euglenoid members were often found in wetland. Species like *Euglena* and *Phacus* from euglenophyceae were dominant organisms (Table 2). It is reported that Euglenophycean members generally develop very well in waters which is rich in organic substances [58]. Abundance of this group, represented by single taxa, Euglena sp. can be attributed to the influx of domestic sewage from the urban catchment (Tables 3 and 4).

The decrease in taxa from dry season towards wet season during first year (Table 5) revealed a different situation during second year of investigation on account of acute drought conditions.

In the first year study though dominance value was in close proximity to zero for most of the groups indicating that the majority of the species are present with lesser dominance, yet Cyanophyceae group was exception which registered highest dominance values of 0.51 (during dry season) and 0.44 (during wet season). Similarly in the second year it was cyanophyceae and euglenophyceae which recorded high values (0.40 and 0.32) from cyanophyceae and euglenophyceae (0.47 and 0.33). It signifies that some taxa dominate the whole study period (Table 5).

Simpson's diversity index varied between the values of 0.95 to 0.49. The minimum value was recorded from the group cyanophyceae during dry season and a maximum value from the group chlorophyceae during wet season. While in the second year of study, the diversity varied between 0.95 to 0.54. The minimum value was found from the group euglenophyceae during dry season and a maximum value from

Indices	First Year							
	Chlorophyceae		Bacillariophyceae		Cyanophyceae		Euglenophyceae	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Taxa_S	91	87	63	52	31	26	15	13
Individuals	5325	5850	2634	1007	4260	3367	237	276
Dominance_D	0.07	0.05	0.12	0.06	0.51	0.44	0.13	0.21
Simpson_1-D	0.93	0.95	0.88	0.94	0.49	0.56	0.87	0.79
Shannon_H	3.43	3.5	2.99	3.33	1.4	1.54	2.33	1.89
Evenness_e^H/S	0.34	0.38	0.31	0.54	0.13	0.18	0.68	0.51
	Second Year							
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Taxa_S	65	97	44	40	13	24	19	17
Individuals	3030	3704	677	784	731	1648	1339	515
Dominance_D	0.11	0.05	0.07	0.09	0.4	0.32	0.47	0.33
Simpson_1-D	0.89	0.95	0.93	0.91	0.6	0.68	0.54	0.67
Shannon_H	3.02	3.55	3.08	2.93	1.37	1.79	1.41	1.65
Evenness_e^H/S	0.31	0.36	0.5	0.47	0.3	0.25	0.22	0.31

Table 5: Variation of phytoplankton diversity indices in Bhoj wetland.

chlorophyceae group during wet season (Table 5). Simpson's index of diversity showed that the index of diversity was significantly higher. The Simpson index (low value) indicates an increase in dominance of fewer species in Baigul water bodies [59]. The index value ranges from 0 and 1, the higher the index value, the higher the diversity.

In the present investigation of study period, Shannon -Wiener diversity index ranged between the values of 3.50 to 1.40 in the first year of period (2008-09). While in the second year the values varied between 3.55 to 1.37. The highest diversity index was found to be from the group chlorophyceae during wet season and a lowest value from the group cyanophyceae during dry season in both the years of the study (Table 5). In general the index reveals that wetland is more diverse. Wilhm and Dorris [60] found that the value of index decline sharply in polluted zones of the lake.

The evenness components of diversity values were found to range between 0.68 to 0.18. The lowest value was found from the group cyanophyceae during wet season and the highest value of 0.68 was found from euglenophyceae group during dry period (Table 5). While in the second year the values varied between 0.50 (bacillariophyceae) to 0.22 (euglenophyceae) during dry periods.

Conclusion

The encroachment of human settlement around the Bhoj wetland is having a negative impact on the aquatic environment; therefore, a number of interventions are required to halt the continued degradation of the wetland ecosystem. There should be strict legislation to protect the wetland from undue exploitation.

Phytoplankton communities are sensitive to changes in their environment and, therefore, many phytoplankton species are used as an indicator of water quality. It seems this wetland is under stress due to the high nutrient concentration and needs immediate attention for its conservation as it is one of the chief sources of potable water. Therefore, management strategies should be designed to restore wetland's water quality and biological communities that have been damaged by anthropogenic pressures.

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