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Original Research Paper

Influence of Water Quality on Composition and Seasonal Abundance of Phytoplankton Community in Thol Wetland, Gujarat, India

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ABSTRACT

The study deals with water quality parameters affecting the composition, seasonal abundance and dominance of phytoplankton in a wetland, Thol Bird Sanctuary, Central Gujarat, India. Hydrochemical parameters of water samples were analysed during September 2007 to August 2009. Monthly variation of water quality parameters like temperature, pH, dissolved oxygen, total dissolved solids, total alkalinity, total hardness, chloride, phosphate, sulphate and nitrate were investigated during the study period. Nutrients like chloride, phosphate, sulphate and nitrate were found higher during summer and lower during monsoon months in both the years. 102 phytoplankton taxa were identified of which Cyanophyta represented by 44 species, constituted the largest group, followed by Bacillariophyta by 25 species, Chlorophyta by 23 species and *Euglenophyta by* 10 species. Remarkable seasonal variation in mean density of Chlorophyta and Bacillariophyta was observed during the study period. Chlorophyta members were present in reasonable numbers throughout the study period, being most abundant in post monsoon and winters. Cyanophyta and Euglenophyta populations showed less seasonal variations except a noticeable increased in density of Euglenophyta in summer 2009. The interrelationship between the hydrochemical properties and phytoplankton assemblages and influence of water quality parameters were investigated by adopting statistical correlation coefficient analysis and linear curves. The hierarchical cluster analysis was used to define biologically distinct regions within the wetland based on the composition of phytoplankton.

INTRODUCTION

Phytoplankton are the main primary producers and they condition the structure and density of consumers as well as hydrochemical properties of water (Harold et al. 2007). The community varies widely in respect to taxonomic composition and cell size and their density increase with increasing nutrient status or trophic state (Senerpont 2007).

Phytoplankton are very suitable organisms for the determination of the impact of toxic substances on the aquatic environment because any effect on the lower level of the food chain will also have consequence on the higher level (Akbulut et al. 2001). Phytoplankton encountered in the water body reflect the average ecological condition and therefore, they may be used as indicator of water quality (Hakason et al. 2003). Several studies in India, have correlated phytoplankton composition in response to water parameters in wetlands and reservoirs under distinct trophic states. Chattopadhyay & Benerjee (2007) observed phytoplankton response immediately to the surrounding changes and hence, their standing crop alters due to indicated water quality. Knowledge of phytoplankton population dynamics is relevant because temporal and spatial fluctuations in composition and biomass may be efficient indicators of natural or anthropogenic alterations in the aquatic ecosystems (Prescot 2004, Olele 2008).

Studies on phytoplankton diversity and abundance in Gujarat are sparse and restricted to mere short term taxonomic observation reports. However, certain limnological studies were done by Nirmal Kumar et al. (2005) on assessment of eutrophication and weed growth of certain wetlands. Nirmal Kumar et al. (2006, 2007, 2008) examined the patterns of site-specific variation of waterfowl community, abundance and diversity in relation to seasons in Nal Wetland Bird Sanctuary. Nirmal Kumar (2008, 2009) assessed the variations in hydrochemical characters of wetlands of Gujarat. The present work assessed the composition and seasonal variation of phytoplankton in relation to hydrochemistry to understand the status of the wetland Thol Bird Sanctuary.

MATERIALS AND METHODS

Site description: Thol is a shallow wetland with maximum depth of 3 m, having an area of 6.99 sq. km and located 24 km from Ahmedabad city, district Mehsana (23°15’ to 23°30’ N and 72°30’ to 72°45’ E) of Gujarat. The wetland was declared as a bird sanctuary in November 1988, which inhabitate hundreds of bird species of which 30 bird species are migratory. Wetland Thol is characterised by alkaline nature of water and good oxygenation of surface water. For decades the wetland has been used for irrigation purposes and fishing (Fig. 1). Rural settlement is found towards the north east and north west direction of the wetland. As the wetland comes under the natural conservation area for birds of Gujarat, the anthropogenic activities such as washing, poaching, bathing, cattle wading and illegal entry are strictly restricted. Birds like Common coots, Shelduck, Common pochards, Flamingoes, Painted stork, Spoonbills, Ibis are dominant species throughout the investigated period and Spot Billed Duck, Eurasian Wigeon, Asian openbill are found mostly seasonal and appeared only during in winter season. *Ipomea aquatica, Polygonum glabrum, Typha angustata, T. domengensis, Eichhornia crassipes* and *Salvinia natans* are some marshy and floating aquatic macrophytic species providing food and shelter to these aquatic fowls.

Water sampling and analysis: Monthly surface water samples were collected for two years (September, 2007 to August, 2009) for physical and chemical analysis at two stations (Stations 1 and 2). Collection was made between 7:00 and 9:00 hours IST (Indian Standard Time). Samples for dissolved oxygen were collected just a few centimetres below the surface and fixed with Winkler's reagents. The collected samples were brought to the laboratory within 1h and stored in a refrigerator for further analysis. The physico-chemical analysis was made following the methods given by APHA (2000) and Trivedy & Goel (1987). The average of two samples was considered as one reading.

Phytoplankton sampling and identification: The phytoplankton samples were simultaneously collected by using 20 μ mesh size planktonic net along with the water samples, and fixed by addition of 1 mL of 4 % formalin solution. The camera lucida diagrams were drawn under light microscope and identification of phytoplankton was made by using various monographs, books and published literature (Desikachary 1959, Prescott 2004, Hadi et al. 1984).

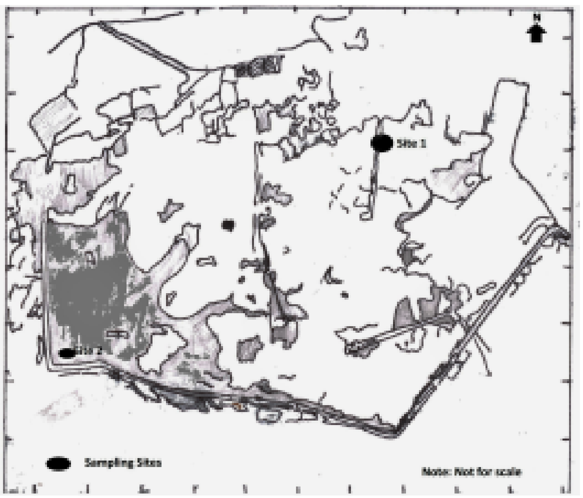

Fig. 1: Localisation of the study sites, Thol Bird Sanctuary.

RESULTS

The average hydrochemical properties of water are given in Table 1 for the two years, and Fig. 2 shows their annual variation. Water temperature varied from 14.8 to 29.6°C and the maximum water temperature was achieved in the summer season of second year, and the minimum in the winter season of the same year. Values of pH remained alkaline, and lowest value of 8.2 was observed in the monsoon season of the first year. The dissolved oxygen fluctuated between 4.5 and 7.9 mg/L, with minimum values in May, and maximum values (7.9 mg/L) in winters of the second year. Decomposition processes and sediment oxygen demand were sufficient to cause lower dissolved oxygen values. In the dry period Thol wetland had low dissolved oxygen, and high pH and temperature, when compared to rainy and winter seasons.

Total alkalinity values varied in a narrow range from 173 to 244 mg/L. In first year alkalinity was characterized by higher values than the second year. Chlorides attained their maximum in post monsoon season (154 mg/L) and found minimum in monsoon season (71 mg/L) of first year, whereas in the second year the values of chlorides ranged from 69 to 146 mg/L.

Nutrient analysis revealed the remarkable differences, observed in the concentration of nitrate and phosphate after monsoon season. Sulphate values ranged between 16 and 80 mg/L, and phosphate between 0.5 and 3.3 mg/L. The recorded high phosphate values are probably due to release of great amounts of runoff from the agriculture fields, and the lower values of phosphate could be attributed to vigorous uptake by plankton. The maximum value of nitrate was found in summer (1.2 mg/L), and minimum in winter (0.2 mg/L). The highest values of nitrate reflect the direct effect of the agriculture run off, while the lowest values are the indicator of phytoplankton uptake. On the other hand, phosphate content was recorded maximum in summer season (3.3 mg/L), and minimum in monsoon season (0.4 mg/L). Mean concentration of sodium (247 mg/L) and potassium (212 mg/L) were recorded maximum in second year.

The correlation analysis of the important parameters with the phytoplankton density showed a positive correlation of temperature with Cyanophyta (0.17), Bacillariophyta (0.05) and Euglenophyta (0.02), and DO with Cyanophyta (0.65). Further, sulphate and nitrate also showed a positive correlation with Cyanophyta (0.47) and Euglenophyta (0.49). Following a similar trend at site 2 also, DO correlated positively with Cyanophyta (0.39), Chlorophyta (0.61) and

Table 1: Hydrochemical characteristics of water in Thol Bird Sanctuary.

	First Year 2007-2008			Second Year 2008-2009		
	Mean	SD	SV	Mean	SD	SV
Temp.	21.9	4.63	21.41	22.3	4.73	22.4
pH	9.3	0.52	0.27	8.9	0.40	0.16
DO	5.6	1.12	1.25	6.4	1.09	1.20
Total alkalinity	213	15.70	246	211	19.65	386
Hardness	131	17.42	303	149	16.34	267
Chloride	122	28.02	785	110	25.5	651
SO_4	21.0	5.12	26.18	43	19.9	398
PO_4	0.99	0.57	0.32	1.8	0.89	0.8
NO_3	0.66	0.24	0.06	0.5	0.23	0.1
Na	167	49.30	2431	247	62	3817
K	133	26.70	713	212	30.04	902

All values are in mg/L except temperature (°C) and pH; Standard Deviation (SD); Standard Variance (SV)

Bacillariophyta (0.58). Nitrate also showed a positive correlation with Cyanophyta (0.76), Chlorophyta (0.58) and Bacillariophyta (0.58).

Phytoplankton: The phytoplankton consisted of total 102 taxa belonging to Cyanophyta (44), Bacillariophyta (25), Chlorophyta (23) and Euglenophyta (10) (Table 3). According to the percentage distribution of species diversity, the highest rich algal group was Cyanophyta (42.8%). In terms of the counting results, the total density of Bacillariophyta, Chlorophyta and Euglenophyta was 31.0%, 19.7% and 5.6% respectively (Table 3).

The diagram obtained from cluster analysis showed that the five different groups comprised in the water samples at 14% hierarchical level (Fig 4). The first important group within these was characterized by the dominance of *Coelastrum cambricum* and other group species *Cosmarium monomatum* and *Aphanocapsa elachista*. The second important group was characterised by the increase of the green algae. In this month *Scenedesmus* and *Pediastrum* from Chlorophyta were dominant species. The second group was characterized by the increase of the green algae together with beginning of spring and end of winter. The third group comprised with the decline of blue green algae, green algae and the increase of diatoms. *Cyclotella* and *Nitzschia* from the diatoms and also *Trachelomonas* from Euglenoids were prevalent species. The significant fourth and fifth group contained only spring samples. This group was characterized by the dominant green algae. *Merismopedia* and *Scenedesmus* species were water blooms. *Cocconeis*, *Navicula* and *Nitzschia* from diatoms and *Anabaena*, *Aphanocapsa*, *Gloeocapsa*, *Merismopedia* and *Microsystis* from Cyanophyta were prevalent species in the same group.

When the relative abundance of species in the samples of the two years was compared, the highest similarity was seen between the first and second year. According to the diagram obtained from cluster analysis, similar clusters were seen between different months of both the years (Fig. 4).

DISCUSSION

Wetlands exhibit different water quality status depending on the geological formation in the catchment and inflow includes wastewater (Bendell-Young et al. 2000). It is evident that the maintenance of healthy conditions in aquatic systems is dependent on the hydrochemical properties of water and biological diversity. The temperature of the water body is an important parameter influencing the water quality. In both the years temperature varied according to the seasonal fluctuations of atmospheric temperature with maximum during summers and minimum during winters (Nirmal Kumar et al. 2005). Dissolved oxygen is an important parameter of aquatic system, which is essential to the aerobic metabolism of all aquatic organisms (Wetzel 1975). In summer with the increase in water temperature, there was reduction in DO, whereas in winter months due to decrease in temperature, the level of DO increased. These results were in conformity with Ahmed Masood & Krishna Murthy (1990) and Srivastava et al. (2003). Comparatively low values of DO in the first year indicate an oxygen deficient condition, which could be due to the high respiratory activity of the biota present there (Alom & Zaman 2006). Low quantity of water level during spring, summer and pre monsoon may be the reason for the increase of the chloride concentration which corroborated with the study of Sukhija (2007). Higher values of hardness were observed during summer, which may be due to low water level and high rate of decomposition and evaporation thus concentrating the salts (Chatterjee & Raziuddin 2007).

High concentration of nutrients like phosphate, sulphate, chloride, nitrate and others was recorded in second year. High phosphate concentration indicates fertilizer runoff, domestic waste discharge and detergents. Similar observations were also made by Khare et al. (2007). The monthly variation of hydrochemical properties also indicated that concentration of nutrients was greater during warmer months in the wetland, which could be attributed to high atmospheric temperature, evaporation and high amount of entry of waste-discharge from surrounding villages corroborating with the findings of Ranjan et al. (2007).

In tropical regions, different algal groups were seen as if they followed typical succession model (Reynold 2004). It is thought that these successions cause the variations related to the use of the light and temperatures. According to the number of species, Chlorophyta and Bacillariophyta type of

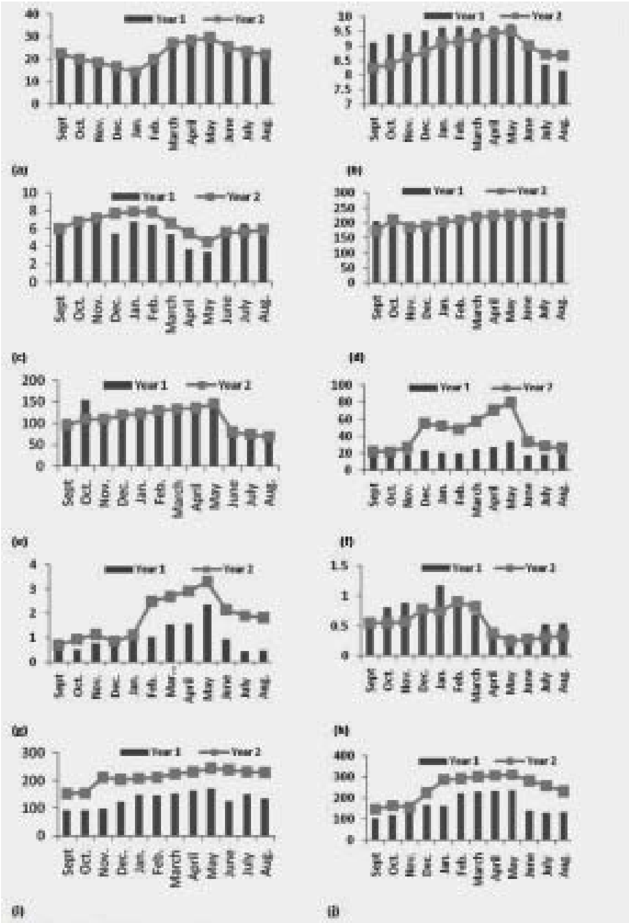

Fig. 2: Monthly variation in temperature, pH (a, b), DO, total alkalinity (c, d), chlorides, sulphate (e, f), phosphate, nitrate (g, h) and sodium, potassium (i, j) at Thol wetland from September 2007 to August 20. Values are in mg/L except temperature (°C) and pH.

phytoplankton existed in Wetland Thol. The wetland had a typical phytoplankton population of eutrophic wetlands, which represent members of Chlorophyta, Bacillariophyta and Cyanophyta along with harmful water blooms (Paerl et al. 2001). The seasonal succession of algae in Wetland Thol was Chlorophyta and diatoms in the spring, Chlorophyta in early summer, Cyanophyta in late summer and Diatoms in autumn and winter. Generally, it was a complicated succession, as it happens in many shallow tropical wetlands (Hutcinson 2007).

In the dendrograms obtained from cluster analysis, species making blooms encountered as densely composed groups. *Monoraphidium* sp., *Oocystis borgei*, *Pediastrum boryanum* and *Secenedesmus* sp. showed blooming sometimes. Round (2002) reported that some Chlorococcales members are quite abundant in tropical wetlands showing transition from oligotrophic condition to eutrophic one. In terms of Hutchinson (2007), these species are dominant

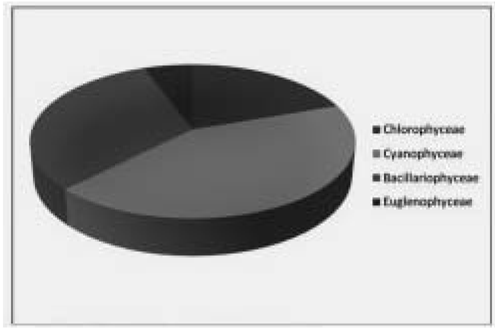

Fig. 3:Density in percentage of phytoplankton groups.

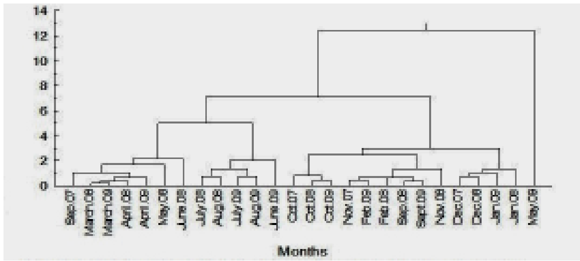

Fig. 4: Dendrograms for hierarchical clustering of the samples, months and phytoplankton groups in the Wetland Thol.

organisms in eutrophic waters. Wetland Thol is located in sensum environment; green algae are dominant and are responsible for making blooms in some months. Also, *Chroococcus* sp. from blue green algae and *Euglena gracilis* from euglenoids were prevalent species in the wetland having eutrophic properties in particular. Prescott (2004) reported that Cyanophyta members make blooms in the stagnant water of certain tropical wetlands. In the eutrophication of wetland ecosystems, the blooming of blue greens is a frequent event (Moss et al. 2006). Blue green algae are the most prevalent and harmful for people and limit the convenient use of water (Pitois et al. 2001).

When the phytoplankton dynamics expressed to seasons, blue green algae were found to make blooms in summer and early autumn. *Cryptomonas* genus is an indicator of eutrophic wetlands (Akbulut & Yildiz 2001). In these months, blue greens and green algae made blooming in phytoplankton. *Anabaena catenula*, *Microcystis aeruginosa*, *Nodularia spumigena* and *Pseudoanabaena limnetica* species were noticed important increases in summer and late autumn.

Because of organic pollution, Euglenoid members were often found in Wetland Thol. *Phacus* and *Trachelomonas* from Euglenophyta were dominant organisms in spring months. It is reported that Euglenophyta members generally develop very well in waters which is rich in organic substances (Round 2003).

Table 2: Hydrochemical correlation coefficient analysis of water, Thol Bird Sanctuary, year 2007-2009.

	Temp	pH	DO	Tl.alk	Cl	SO_4	PO_4	NO_3	Na	K	Chloro-phyta	Cyano phyta	Bacillario phyta	Eugleno phyta
Temp	1													
pH	0.16	1												
DO	-0.71	-0.32	1											
Tl.Alk	0.57^{NS}	0.42	-0.56	1										
Cl	0.08**	0.79	-0.16	0.07^{NS}	1									
SO_4	0.31	0.19	0.05*	0.26	0.29	1								
PO_4	0.64	0.37	-0.31	0.60	0.30	0.75	1							
NO_3	-0.67^{NS}	0.29	0.55^{NS}	-0.46	0.43	-0.20	-0.34	1						
Na	0.37	0.31	-0.06	0.57	0.22	0.82	0.86	-0.23	1					
K	0.29	-0.13	0.08*	0.41	-0.19	0.74	0.71	-0.44	0.83	1				
Chlorophyta	-0.87	0.06	0.65	-0.43	0.19	-0.04	-0.36	0.72	-0.12	-0.08	1			
Cyanophyta	0.17	0.17	-0.23	0.09	0.29	0.47	0.37	-0.18	0.24	0.20	-0.07	1		
Bacillariophyta	0.05*	-0.54	-0.10	0.16	-0.76	-0.22	-0.06	-0.41	-0.03	0.24	-0.30	-0.05	1	
Euglenophyta	0.02*	0.16	-0.05	0.03*	0.29	0.49	0.35	-0.04	0.30	0.25	0.10	0.93	-0.10	1

Level of significance: ** = ($P \leq 0.01$), * = ($P \leq 0.05$), ^{NS} = Non-significant ($P > 0.05$).

Table 3: Number of phytoplankton and mean density (units × 10^5 per litre) of the major taxonomic groups to total phytoplankton in Wetland Thol Bird Sanctuary in both the investigated years.

Group	Number of Species	Mean density Year		Total in Percent
		2008	2009	
Cyanophyta	44	4.1976	5.6848	42.8
Chlorophyta	25	1.826	2.7192	19.7
Bacillariophyta	23	2.86	4.5276	32.0
Euglenophyta	10	0.4796	0.8184	5.6
Total	102	9.3632	13.75	100

The results obtained from cluster analysis and the counting methods supported to each other regarding phytoplankton abundance. There was no difference between the phytoplankton composition and the seasonal dynamics except for some months. When the diagram was examined, the dominant species comprised groups in cluster analysis of both the years. It was reported that these taxa composed of groups in wetland with eutrophic characteristic (Hutchinson 2007).

Diversity of plankton population is fairly dependent on quality of water and climatic factors. Phytoplankton diversity and productivity are strongly related to water quality (Moss 2006) as well as to biotic factors (Kruk et al. 2002). The non-monsoon months recorded higher phytoplankton density when compared to the monsoon months as observed from the density values. The fall down of the phytoplankton community in monsoon months can be attributed to dilution of the phytoplankton biomass caused by runoff. The average values of the chemical parameters and the algal group densities for the first year and the second year depicted that sulphate and nitrate seem to be stimulating growth of the different algal groups as evident from the positive correlation coefficient values. Phosphate seems to limit the growth as depicted from the negative correlation coefficient values for both the years with Chlorophyta and Bacillariophyta density. Ersanli et al. (2003) stated that temperature, pH, alkalinity and phosphate have been emphasized to be limiting factors for controlling distribution of Cyanophyceae which also corroborated with the present study. Tripathy & Panday (1990) and Rana & Nirmal Kumar (1993, 2005) reported that high water temperature, phosphate, nitrate and low DO support the growth of Chlorophyceae. pH was found to be in the alkaline range (8.9 to 9.3) supporting a good population of the diatoms. Moreover, DO content was found to be considerably high in colder months. The plankton community, on which the whole aquatic population depends, is largely influenced by interaction of a number of limiting factors and number of hydrochemical and biological factors acting simultaneously must be taken into consideration in understanding the diversity of plankton population. The data obtained from this study indicated that the wetland is progressing to eutrophication stage.

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