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SEASONAL CHANGES IN PHYTOPLANKTON COMMUNITY OF LAKE SILISERH, INDIA

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ABSTRACT

The seasonality of phytoplankton density and species diversity of Lake Siliserh was studied together with physico-chemical factors for one year on the basis of monthly sampling. Correlation between various physico-chemical parameters, phytoplankton groups were also calculated according to Karl Pearson's formula. The phytoplankton community of the lake belonged to three major groups and according to their density these groups ranked Chlorophyceae > Cynophyceae > Bacillariophyceae. Ulothrix and Closterium were the main contributors in density of Chlorophyceae. Group Cynophyceae was dominated by Coelospharium while Nitzschia and Synedra were the most common genera of Bacillariophyceae. These dominant forms also exhibited a clear seasonal succession. The phytoplankton number represented by 27 species. The lake was found to be slightly eutrophic during monsoon months. Algal bloom was observed during September. At the same time biological oxygen demand (8.98 mgL^{-1}) and nutrients (Nitrate 5.78 mgL^{-1}) were also found higher. These results suggest that temperature and nutrients play a crucial role in the phytoplankton dynamics of Lake Siliserh. The value of Shannon diversity index shows that the water quality can be classified as moderately polluted to clean water.

Keywords: *Lake Siliserh, Phytoplankton, Nutrients, Seasonal succession, Algal Bloom.*

Introduction

Phyotplankton comprises extremely diverse, polyphyletic group of organisms, demonstrating a wide array of morphological, physiological, and behavioral traits (Litchman and Klausmeier 2008). Phytoplankton succession is a well investigated phenomenon in aquatic ecology and several studies have described the patterns and underlying mechanisms of the seasonal dynamics (Rothhaupt 2000, Soylu and Gonulol 2006). The phytoplanktons have been intimately connected, directly or indirectly, with human beings as a source of food, fodder and manure since time immemorial especially in densely populated countries. Besides being used as a potent source of food to combat the problems of rapidly growing world population they also act as a possible food source in space flight.

Rajasthan in spite of being a recognized state of arid condition is characterized by large number of water bodies both natural and manmade. These water bodies of arid and semi arid region are characterized by very low precipitation largely confined to the rainy season and extremely high temperature (Vashistha et al. 2016 b). Siliserh Lake is an important water body of Alwar, Rajasthan, India. It is also a source of aesthetic pleasure and holiday recreation for tourists and local people by providing boating facilities. The lake also attracts a lot of migratory birds. The judicious management and proper utilization of water of this lake require a systematic study of its ecology (Vashistha et al. 2016 a) Adequate information about the various physico-chemical components influencing parameters and the delicate dynamics sustained by them is of supreme importance to formulate appropriate environmental management strategies and to protect the lake from degradation.

So in the present study, an attempt was made to analysis the seasonal variation of phytoplankton community of this lake with special reference to physical and chemical parameters of lake water.

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Materials and Methods

Study Area

Siliserh Lake is situated nearly about 16km. away from Alwar city in southwest direction at 27°32'N latitude and 76° 9' E longitude at an elevation of 661 m above MSL. This Lake was formed by constructing a dam nearly 12.19 m high and 304 m long thrown across a tributary of the River Ruparel by Maharaja Vinay Singh. Besides being a source of potable water, this water body has economic application for fish breeding and irrigation. Some of the salient features of Siliserh Lake are presented in Table 1.

Sample collection and estimations

Limnological studies were carried out for a period of one year from July, 2010 to June, 2011. The water and plankton samples were collected during morning hours on monthly basis from five different locations (1-5) of Siliserh Lake in Alwar (Fig. 1). For physico-chemical studies, water samples were collected in 500 ml plastic bottles. The water temperature was recorded by mercury thermometer for each site under study. Dissolved oxygen (DO_2) was fixed on the spot in biological oxygen demand (BOD) bottles, brought to laboratory and analyzed by modified Winkler's method (APHA 2005). Various parameters like free carbon dioxide (free CO_2), alkalinity, salinity, hardness, total solids (TS), biological oxygen demand (BOD) and chemical oxygen demand (COD) were estimated according to APHA (2005). Nitrate (inorganic) and phosphate (ortho) were analyzed by the spectrophotometric method (Systronics 119).

For the study of phytoplankton, the water samples were transferred to 500 ml polyethylene bottles. Then, 5 ml Lugol's iodine solution and 10-15 ml 4% formalin were added to it for fixation and preservation of planktonic cells. The organisms were identified under a microscope using specialized literatures (Edmondson 1965; Needham and Needham 1978; APHA 2005). One ml of plankton sample was drawn and transferred to the Sedgwick Rafter counting cell for quantitative analysis. Each sample was counted five to eight times and average was taken for calculation. Density of plankton was calculated at each site, and expressed in No x 10^2 L^{-1}.The frequency of occurrence of different phytoplankton species is represented as: dominant (50% or more), common (between 10% and 50%) and rare (below 10%). Diversity index H' (Shannon and Weaver) was calculated for phytoplankton. The correlation of various physico-chemical parameters and phytoplankton groups were tested using Pearson Product- Moment Correlation.

Results and Discussion

The physico-chemical factors were varied from season to season as shown in Table 2. During the present study, water temperature varied between 11.0 and 36.0^{0}C. Salinity values varied from 82.0 to 421.0 mgL^{-1} and the pH ranged between 7.1 to 8.3. The maximum and minimum values for hardness were 56.8 mgL^{-1} and 148.6 mgL^{-1} respectively. Nitrate and phosphate content ranged between zero to 10.8 mg$L^{-1}$and 0.04 to 0.12 mgL^{-1}respectively. Water temperature, pH, alkalinity and total hardness showed maximum values during summer due to high temperature which enhanced evaporation of water resulting concentration of the salts (Nasar and Sharma 1980; Maheshwari et al. 2015). But total solids and nutrient concentration showed maximum values during monsoon. This may be due to inflow of soil and agriculture waste from the catchment area.

The phytoplankton community of the lake belonged to three major groups and ranked Chlorophyceae > Cyanophyceae > Bacillariophyceae during the study period. It is apparent from Table 2 that out of 27 species reported, 17 belonged to Chlorophyceae, 6 to Cyanophyceae and 4 to Bacillariophyceae. The total density of phytoplankton recorded varied between 2.68 cells x 10^2 L^{-1} in July 2010 and 24.02 cells x 10^2 L^{-1} in September 2010 as shown in Fig.2.

Regarding the relative dominance of different algal groups, Chlorophyceae population was found dominated followed by Cynophyceae and Bacillariophyceae in the present study, which could be a desirable feature from the fisheries point of view (Kanwal and Pathani 2012). Chlorophyceae was found dominant during summer and winter season whereas monsoon community was dominated by Cynophyceae. Bacillariophyceae was present in less number as compared to other groups throughout the year. Dominance of Chlorophyceae in summer may be due to high pH and water temperature along with bright sunshine (Rajagopal et al. 2010). These factors enhanced the growth of green algae with moderate quantity of phosphate and nitrate (Butcher 1946). Chlorophyceae flourish in water with high temperature and pH (Munawar 1970).

Observations on the seasonal distribution of different groups of phytoplankton with respect to their species number and density are presented in the Fig. 3. It is apparent from this figure that species diversity was maximum during winter and minimum during monsoon while maximum density was found during summer and minimum during winter.

The abundance of phytoplankton during the summer months is possibly due to good nutritional status of the lake (Tiwari 2017). Temperature showed positive correlation with total phytoplankton density during the study period. The enhanced growth of the algal flora was noticed in the present study during summer period which could be attributed to increased temperature, light and transparency and reduction in water current velocities during this season (Kopczynska 1980; Nabout et al. 2006).

Correlation between various physico-chemical parameters and different plankton groups of Siliserh Lake is shown in Table 4.

Total phytoplankton density showed positive correlation with temperature ($r = 0.58$; $p<0.05$), pH ($r = 0.76$; $p<0.01$), Mg hardness ($r = 0.66$; $p<0.05$), conductivity ($r = 0.66$; $p<0.05$) and nitrate ($r = 0.66$; $p<0.05$). High pH value promoted the growth of algae (George 1961; Verma and Mohanty 1984). It is known that during winter, low algal growth is due to low water temperature. Increasing illumination with the onset of summer followed by high availability of nutrients and water column turbulence strongly support the development of phytoplankton in summer months (Sreenivasan 1964).

Nutrients have a tendency to accumulate in deeper layers of water because of sinking of organic material through the water, followed by subsequent decay. Upwelling brings a rich supply of nutrients to the surface and allows high production. Nutrients play a special role in structuring phytoplankton and nutrient availability can vary seasonally, directly influenced by climate patterns (Naselli-Flores and Barone 2000; Figueredo et al. 2016)

Three peaks were observed in phytoplankton density in which the summer peak, recorded in May, was dominated by Chlorophyceae. The monsoon peak of September, however, was dominated by Cynophyceae while the winter peak, recorded in the month of December, was dominated by Chlorophyceae. The winter peak of Chlorophyceae was mainly composed of *Closterium acutum*, and *Ulothrix zonata* while the summer peak was dominated only by *Ulothrix zonata*. The monsoon peak of Cynophyceae was dominated by *Coelosphaerium sp.* The observation indicates that numerically Chlorophyceae dominated for whole year except September 2010 where Cynophyceae was dominated. Chlorophyceae was the dominant group and its contribution ranged between 28.47% in September and 97.25% in August 2010 of the total phytoplankton depending upon months. Highest density of Chlorophyceae was reported in summer months and minimum in monsoon months. Species composition of various phytoplankton groups of Siliserh Lake are presented in Table 3.

The dominant genera of Chlorophyceae were *Closterium* and *Ulothrix* whereas *Ankistrodesmus, Cladophora, Coelastrum, Desmidium, Gonatozygon, Mesotaenium, Ophiocytium, Pediastrum, Protococcus, Scenedesmus, Sphaeroplc, Tetraspora* and *Volvox* were comparatively lesser in number during the study period. Number of species in this group varied between 6 in July and 13 in November 2010. Maximum and minimum diversity of Chlorophyceae was noted during winter and monsoon respectively. Chlorophyceae had positive correlation with salinity ($r = 0.64$; $p<0.05$), total phytoplankton density ($r = 0.68$; $p<0.05$) and Bacillariophyceae ($r = 0.71$; $p<0.05$).

Cynophyceae ranked second in position contributing 1.86% in July to 59.90% in September 2010 of the total phytoplankton density with 6 genera. Species density and diversity were maximum in monsoon months. Number of species varied between 2 to 5 species. This group exhibited highest peak at all station during the month of September, the peak values ranging between 12.62 cells X 10^2 L^{-1} at site-4 and 16.29 cells X 10^2 L^{-1} at site-2. Cynophyceae peak observed in September was mainly contributed by two species namely *Coelosphaerium sp.* and *Microcystis sp*. contributing 39% and 26% respectively. Other genera of Cynophyceae were *Aphnocapsa, Anabaena, Microcystis, Nostoc, Synechocystis*. Density of Cynophyceae was positively correlated with nitrate.This group showed a direct correlation with temperature ($r = 0.77$; $p<0.01$), nitrate ($r= 0.79$; $p<0.01$), TSS ($r = 0.82$; $p<0.01$), total phytoplankton ($r = 0.85$; $p<0.01$) whereas an inverse correlation was found with Ca hardness ($r = -0.63$; $p<0.05$). Maximum values of nitrate were reported from site 1 and 2 in September month. Maximum density of Cynophyceae was also observed in the above site which clearly indicates the preference of Cynophyceae in nutrient rich water. The nutrients present in the aquatic system have positive influence on growth and distribution of members belonging to Cynophyceae (Kumar and Oomen 2009).

The contribution of Bacillariophyceae was varying between 1% in August 2010 and 26.88% in March 2011 of the total density. Summer months showed highest species density while monsoon months represented lowest species density of this group. Species diversity of this group was found maximum in summer months and minimum in winter months. In Bacillariophyceae *Nitzschia* and *Synedra* were the most common genera while *Cyclotella* and *Achnanthes* were comparatively lesser in number. Bacillariophyceae showed positive correlation with temperature (r = 0.77; p<0.01), alkalinity (r = 0.57; p<0.05), conductivity (r = 0.83; p<0.01), free CO2 (r = 0.61; p<0.05) and total phytoplankton (r = 0.75; p<0.01). A positive correlation between temperature and Bacillariophyceae showed that the high temperature of summer was favorable for the optimum growth of Bacillariophyceae. A number of factors can influence the distribution of diatoms in water body, such as change in water temperature (Descy et al. 2011) light and irradiance of water (Descy et al. 2011) and water current (Jones and Barrington 1985; Descy et al. 2011).

The dominant forms of three phytoplankton groups exhibited a clear seasonal succession. *Gonatozygon* was dominant during winter while *Ulothrix* during monsoon and summer. Among Cynophyceae, *Anabaena* dominated during late monsoon, *Coelosphaerium* during whole year except late monsoon. Out of the four genera of Bacillariophyceae, *Nitzschia* showed their maximum frequency during monsoon and late winter, *Cyclotella* during mid winter and *Synedra* during late summer. The time of appearance of different phytoplankton genera varied over the study period. Among Chlorophyceae, *Closterium, Pediastrum* and *Ulothrix* were found to be perennial genera. Two members of Cynophyceae, *Coelosphaerium, Nostoc* and two members of Bacillariophyceae *Cyclotella* and *Nitzschia* were recorded as perennial genera. Chlorophyceae was found dominant during summer and winter season whereas monsoon community was dominated by Cynophyceae. Bacillariophyceae was present in less number as compared to other groups throughout the year. Dominance of Chlorophyceae in summer may be due to high pH and water temperature along with bright sunshine (Rajagopal et al. 2010). These factors enhanced the growth of green algae with moderate quantity of phosphate and nitrate (Butcher 1946).

A plankton species which enters in to water bloom association thrive very successfully in warm water, particularly if an adequate supply of nitrate and phosphate are available (Davis 1955). Both *Coelosphaerium sp.* and *Microcystis sp.* can multiply rapidly in water and less affected by water currents. Moreover these species produce toxins harmful to other phytoplankton and zooplankton (Sen and Sonmez 2006).

Dissolved oxygen concentration was found minimum in October just after the bloom of *Coelosphaerium sp.* and *Microcystis sp.. Coelosphaerium sp*. completely disappeared from the water during October whereas the number of *Microcystis sp*. decreased considerably. This showed that bloom causing species of phytoplankton can rapidly increase in numbers in bloom condition and can suddenly die out (Marshall 1933).The effect of both light and temperature on seasonal succession of diatoms is a clear proof of temperature tolerence of various species of diatoms (Wallace 1955). The nutrients, organic matter, dissolved oxygen, pH and other physical factors play an important role in the ecological distribution of Bacillariophyceae (Hulyal and Kaliwal 2008).

While applying the Shannon-weaver index in the present study, the value varied from 1.10 to 3.2 for phytoplankton (Table 5). Shannon diversity index values of phytoplankton communities can be used to indicate water pollution status (Modoosoodun et al. 2010). Values less than 1 are interpreted as heavily polluted, between 1-3 as moderately polluted and more than 3 as clean water (Whitton 1975). The Shannon diversity index of Siliserh Lake varied from 1.10 to 3.2, suggest that the water quality can be classified as moderately polluted to clean water but Rahmati et al. (2011) placed a water body containing Shannon diversity index between 1.7 and 3.21 in mesotrophic to slightly eutrophic condition.

The lake was found to be slightly eutrophic during monsoon months (Vashistha et al. 2016 a). Early recognition of differences in the quality and quantity of plankton is the basis of the origin of the trophic system of lake classification. High nutrient levels during monsoon months enhanced growth of toxic algae and produced eutrophic condition in the lake (Cano et al. 2016). Monsoon community of plankton was dominated by Cynophyceae, especially with a bloom in September. In monsoon season the plankton were dominated by eutrophic species whereas summer and winter seasons were dominated by oligotrophic species. During monsoon various species of phytoplankton such as *Microcystis sp., Coelosphaerium sp., Anabeana sp.,* were found in good numbers. Bloom was enriched by *Coelosphaerium sp.* and *Microcystis sp.* Several authors have reported *Microcystis sp., Coelosphaerium sp., Anabeana sp.* as indicators of eutrophic condition in various water bodies of the world (Baruah and Das 2001; Gulati and Donk 2002; Shashi Shekhar et al. 2008; Mukherjee et al. 2010; Claps et al. 2011).

The Lake was found to be oligotropic during summer and winter months and eutrophic during monsoon months. Chlorophyceae were observed to be dominant phytoplankton groups in summer and winter months. Notable plankton species observed during these seasons were *Diaptomus sp, Gonatozygon sp., Pediastrum simplex, Closterium sp., Cyclotella sp., Scenedesmus sp.* These planktonic species to be the dominant communities in oligotrophic lakes (Jeppesen et al. 2000; Kaufman et al. 2010).

Conclusion

The study validates the fact that this freshwater lake remains oligotrophic during summer and winter but becomes loaded with nutrients during monsoon reaching eutrophic condition. The surface runoff from adjoining agricultural lands is the major cause of nutrient enrichment of the lake. Unchecked use of fertilizers has augmented the process.

A major source of drinking water to the inhabitants may become unsuitable for potability unless definite remedial measures are taken immediately. It is clear from the present studies that the lake requires proper management strategies to minimize further degradation from the present status. For a sustainable use of the water, further anthropogenic activities in and around the lake should be controlled otherwise the lake will turn into complete eutrophic condition.

The sustainability of Siliserh Lake ecosystem will depend upon managing the nearby agricultural setups as well as other disturbing factors. Moreover, recreational activities especially boating in the lake should be regulated. Governments must take a serious eye over the issue as it is just the beginning of the deterioration of the ecosystem.

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Table 1: Salient Features of Siliserh Lake

1.	River basin	Ruparail
2.	Catchment area	11.25 sq Km
3.	Average annual rainfall	675.30 mm
4.	Gross command area	10.34 sq Km
5.	Culturable command area (CCA)	7.2 sq Km
7.	Design maximum flood	475.72m^3/s
8.	Top bank level (TBL)	10.03 m
9.	Maximum water level (MWL)	9.75 m
10.	Full tank Level (FTL)	9.29 m
11.	Full reservoir level	13.93 MCM
12.	Type of dam	Earthen
13.	Length of dam	304 m
14.	Length of overflow portion	30 m
15.	Free boards	0.92 m
16.	Dead storage	0.78 m
17.	Year of construction	1845

Table 2: Mean Monthly values of Various Physico-Chemical Parameters at Five Stations in Siliserh Lake.

Parameters	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Air Temperature (^{0}C)	35.0±0.01	32.0±0.02	31.0±0.02	30.0±0.01	28.0±0.01	20.0±0.01	11.0±0.01	15.0±0.11	21.0±0.09	30.0±0.11	33.0±0.34	36.0±0.03
Water Temperature (^{0}C)	30.0±0.06	28.0±0.01	29.0±0.07	28.0±0.07	22.0±0.01	13.0±0.08	9.0±0.01	11.0±0.61	17.0±0.01	24.0±0.01	30.0±0.08	31.0±0.03
Transparency (m)	0.15±0.03	0.36±0.06	0.55±0.03	1.05±0.04	2.33±0.06	0.95±0.01	1.04±0.02	1.55±0.14	0.92±0.03	1.33±0.02	0.80±0.018	0.58±0.002
pH	8.09±0.03	7.68±0.12	7.63±0.16	7.11±0.22	7.24±0.10	7.78±0.06	8.02±0.12	8.26±0.06	8.10±0.04	8.16±0.12	8.28±0.12	8.37±0.13

Conductivity (µ mhos cm^{-1})	180.2±0.01	158.6±0.03	388.4±0.33	127±0.03	142±0.03	164.6±0.07	196.2±0.06	182±0.02	251.2±0.24	454.2±0.15	337±0.09	267.4±0.03
Water Level (m)	3.96±0.64	4.78±0.63	7.19±0.62	6.97±0.69	6.87±0.63	6.81±0.68	6.73±0.67	6.18±0.75	5.72±0.62	5.44±0.62	3.76±0.67	3.22±0.62
Dissolved O_2 (mgL^{-1})	6.0±0.33	10.08±.08	7.76±0.92	4.56±0.69	10.08±1.50	10.32±0.96	11.5±0.69	12.56±0.79	11.68±0.74	10.9±1.21	9.76±0.10	10.46±0.16
Free CO_2(mgL^{-1})	3.52±0.88	4.4±1.07	8.07±0.09	10.56±1.07	5.28±0.88	8.8±0.0	3.08±0.54	6.16±1.07	8.8±0.0	12.32±0.48	8.8±0.0	4.4±0.0
Alkalinity(mgL^{-1})	70.0±5.09	107.0±5.56	97.2±3.72	104.0±5.09	88.0±12.0	144.0±6.0	75.0±2.73	153.0±3.0	118.0±4.89	128.0±7.34	161.6±1.43	143.6±1.4
Acidity(mgL^{-1})	30.0±2.2	41.0±5.78	41.0±6.78	68.0±16.62	47.0±12.80	22.0±2.0	24.0±4.0	18.0±1.1	12.4±1.93	31.6±1.02	47.8±2.74	55.4±1.28
Total hardness(mgL^{-1})s	97.6±2.71	115.0±6.32	64.6±1.63	56.8±1.85	60.4±4.11	91.6±2.71	95.6±0.97	112.8±3.61	108.4±1.83	144.6±11.86	148.6±1.91	135.8±0.86
Ca hardness(mgL^{-1})	68.04±1.70	63.82±3.07	45.6±1.6	50.4±1.75	50.5±1.82	74.78±0.84	77.7±1.15	82.6±0.67	79.2±2.63	80.72±4.24	77.8±1.53	75.3±0.86
Mg hardness(mgL^{-1})	7.18±0.81	12.42±0.79	4.71±0.12	1.16±0.51	2.40±0.89	4.09±0.46	4.34±0.36	7.48±0.68	7.09±0.24	15.52±1.96	18.11±1.06	14.56±0.26
Salinity(mgL^{-1})	1.11±0.0	.94±2.44	2.51±0.06	.82±0.02	4.21±0.14	3.26±0.06	2.92±1.02	2.51±0.01	1.40±0.0	2.55±0.10	3.12±0.01	3.02±0.24

BOD(mgL^{-1})	2.96±0.52	5.4±0.43	8.98±1.11	2.82±0.46	2.02±0.41	4.08±0.71	3.98±0.59	4.06±0.41	8.60±0.27	8.35±0.90	2.44±0.15	3.14±0.11
COD(mgL^{-1})	5.6±0.04	5.7±0.03	6.64±0.12	4.72±0.18	9.08±1.81	6.22±0.32	4.4±0.12	6.89±0.08	7.45±0.23	8.5±0.43	6.38±0.12	7.2±0.05
TDS(mgL^{-1})	782.2±8.21	708.8±15.76	625.6±20.82	558.2±14.48	702.2±17.95	394.0±9.79	206.0±2.44	169.2±4.82	127.4±2.73	151.2±10.64	222.2±2.72	241.39±0.81
TSS(mgL^{-1})	144.0±16.33	114.0±6.22	371.2±35.63	159.4±20.06	199.2±6.87	51.8±7.22	50.2±5.60	49.8±3.46	24.0±0.94	34.4±5.15	53.8±0.97	71.0±0.86
TS(mgL^{-1})	916.2±30.18	822.8±11.06	996.8±19.29	717.6±19.29	901.4±20.22	445.1±9.09	276.2±3.66	213.7±2.54	151.4±2.73	185.6±13.76	276.0±3.39	313.2±0.86
Nitrate(mgL^{-1})	3.3±0.43	2.38±0.41	5.78±1.45	3.54±1.23	2.42±0.56	1.42±0.05	1.0±0.0	1.38±0.15	2.76±0.26	3.16±0.12	2.96±0.11	2.62±0.02
Phosphate(mgL^{-1})	0.022±0.0	0.005±0.0	0.015±0.0	0.005±0.0	0.004±0.0	0.005±0.0	0.010±0.0	0.009±0.0	0.008±0.0	0.009±0.0	0.012±0.0	0.016±0.0
Sulphate(mgL^{-1})	18.0±1.48	21.0±1.18	14.6±0.51	11.8±0.91	7.1±0.50	4.86±0.08	4.18±0.18	4.16±0.18	4.14±0.14	4.96±0.04	4.14±0.06	3.9±0.05

Table 3: Species Composition of Various Phytoplankton Groups at Siliserh Lake

Name of Species	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Bacillariophyceae												
Nitzschia palea	++	++	++	++	++	++	+	+	+	+	+	+
Cyclotella sp.	+	++	+	+	+	+	+	+	+	+	+	+
Synedra ulna	-	-	-	-	-	++	++	++	+	+	+	+
Achnanthes sp.	-	-	+	+	-	-	-	-	-	-	-	-
CHLOROPHYCEAE												
Ulothrix zonata	+	+	+	+	++	++	++	++	+++	+++	+++	+++
Closterium setaceum	+	+	+	+	++	++	++	++	++	++	++	++
Closterium acutum	+	+	+	+	+	+	+	+	+	+	+	+
Closterium acerosum	+	+	+	+	+	+	+	+	+	+	+	+

Gonatozygon sp.	+	+	+	+	+	++	++	++	++	++	++	++
Pediastrum simplex	++	++	-	-	++	++	++	++	++	++	++	++
Ankistrodesmus sp.	+	+	+	+	+	+	+	+	+	-	-	-
Cladophora glomerata	-	-	+	+	+	+	+	+	+	+	-	-
Scenedesmus sp.	-	-	-	-	+	+	+	+	+	+	+	+
Coelastrum sp.	-	-	-	-	-	+	+	+	+	-	-	-
Tetraspora sp.	-	-	-	-	+	+	+	+	-	-	-	-
Protococcus sp.	-	-	-	-	+	+	+	+	+	+	+	+
Ophiocytium sp.	-	-	-	-	+	+	+	-	-	-	-	-
Volvox sp.	-	-	+	+	+	+	-	-	-	-	-	-
Spharoplac sp.	-	-	-	-	+	+	-	-	-	-	-	-
Desmidium sp.	-	-	-	-	+	+	-	-	-	-	-	-
Mesotaenium sp.	-	-	-	-	+	+	-	-	-	-	-	-
Cynophyceae												
Coelosphaerium sp.	+++	+++	+++	-	-	++	++	++	++	++	++	++
Microcystis sp.	++	++	++	++	++	+	+	+	+	+	+	+
Anabaena sp.	++	++	++	++	++	+	+	+	+	+	+	+
Nostoc sp.	+	+	+	+	+	+	+	+	+	+	+	+
Aphanocapsa sp.	-	+	+	-	-	-	+	+	+	-	-	+
Synechocystis	-	-	+	+	+	-	-	-	-	-	-	-

+++ = Dominant
++ = Common
+ = Rare
_ = Absent

Table 4: Correlation matrix (r) between various physico-Chemical Parameters and Phytoplanktonplankton Groups at Siliserh Lake

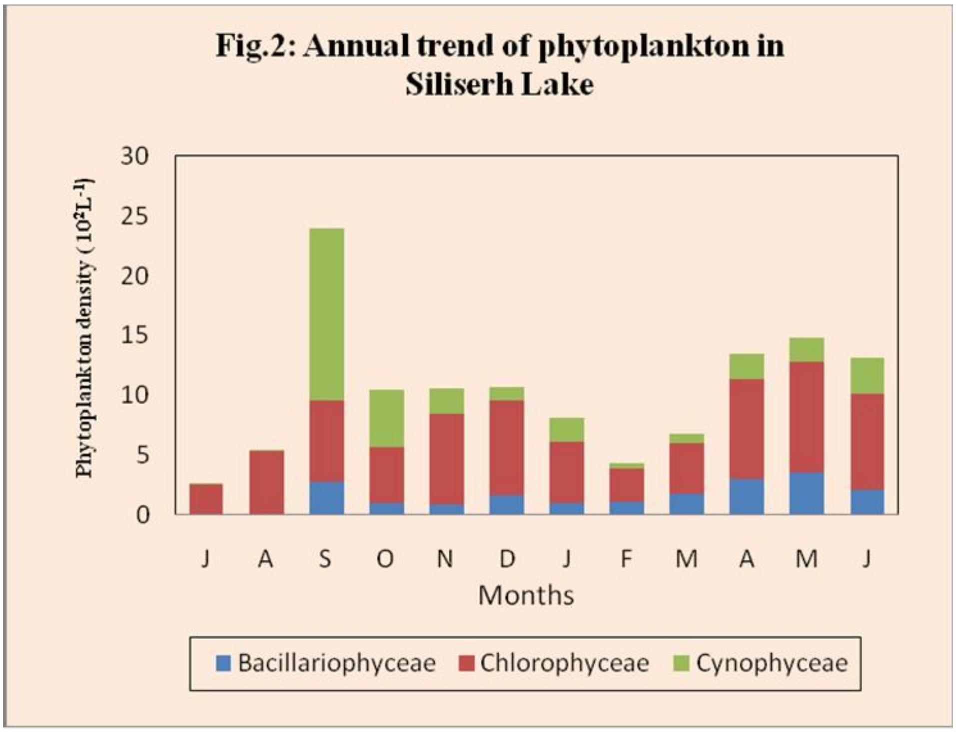
Water level	Air tem.	Water tem.	pH	Salinity	Conductivity	TSS	TDS	TS	Alkalinity	Acidity	COD	BOD	Total hardness	Ca hardness	Mg hardness	Nitrate	Phosphate	Sulphate	DO	Free CO_2	Turbidity	Parameters
0.20	0.58	0.58	-0.76	0.39	0.66*	0.55	-0.03	0.14	0.16	0.38	0.22	-0.07	-0.10	-0.40	0.66	0.66*	0.10	-0.11	0.14	0.42	-0.01	Total phytoplankton
-0.11	0.78	0.77	0.29	0.17	0.83**	-0.02	-0.55	-0.42	0.57	0.08	0.37	0.06	0.43	0.20	0.50	0.36	0.12	0.53	0.20	0.61*	0.06	Bacillariophyceae
-0.11	0.30	0.25	-0.01	0.64*	0.51	0.01	-0.18	-0.13	0.41	0.36	0.43	-0.20	0.29	-0.02	0.43	0.13	-0.17	-0.36	0.16	0.36	0.17	Chlorophyceae
0.39	0.20	0.30	-0.47	0.07	0.44	0.82**	0.22	0.42	-0.16	0.33	-0.03	-0.01	-0.44	-0.63	-0.23	0.79	0.21	0.19	-0.37	0.23	-0.13	Cynophyceae

(* indicates significance at p<0.05 and ** indicates significance at p <0.01 level).

Table 5: Shannon Diversity Index for Phytoplankton

Diversity Index	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Shannon diversity index (H)	1.10	1.42	1.21	2.22	2.24	3.2	2.18	2.13	2.15	2.23	2.01	2.11

Figure 1. Satellite map of Lake Siliserh showing all five sites studied.



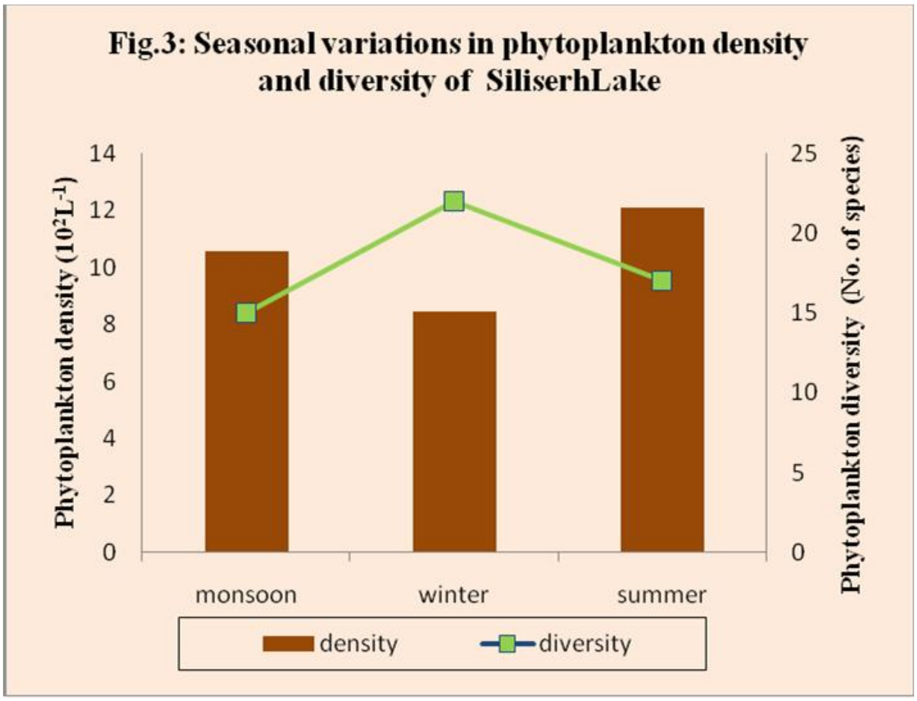


Fig.3: Seasonal variations in phytoplankton density and diversity of SiliserhLake
Phytoplankton density (10²L⁻¹)
14
12
10
8
6
4
2
0
25
20
15
10
5
0
Phytoplankton diversity (No. of species)
monsoon
winter
summer
density
diversity

1. .

❖◆❖