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RESEARCH ARTICLE

SEASONAL VARIATION IN ZOOPLANKTON DYNAMICS OF LAKE SILISERH, INDIA

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ABSTRACT

Siliserh Lake is an important water body of Rajasthan state. In Siliserh Lake, zooplankton community composed mainly of Crustaceans (particularly Copepoda and Cladocera) and Rotifers. Other plankton groups were also observed at low density and frequency, such as Protozoa, Ostracoda and Insecta. Plankton samples were collected by means of horizontal haul, using plankton net (No.25) with a mesh size of 55 µm. In the present study. The correlation between various physico-chemical parameters and zooplankton groups were tested using Pearson-Moment Correlation. Zooplankton population was observed to be composed of 37 species belonging to 29 genera. Out of 37 species, 16 represented Rotifera, 6 Copepoda, 7 Cladocera, 3 Protozoa, 3 Ostracoda and 2 Insecta. The total density of zooplankton varied between 12.44 x 10^1 L^{-1} and 144.84 x 10^1 L^{-1} during the study period. Minimum species density was recorded in the monsoon season, while the summer season was characterized by maximum zooplankton density. Total zooplankton density was found positively correlated with total hardness, Mg hardness, and free CO_2 and negatively correlated with conductivity, TS, TDS of water. Copepoda was the dominant group both in winter and summer season. So the present study validates the fact that this freshwater lake remains oligotrophic during summer and winter season but becomes loaded with nutrients during monsoon season reaching eutrophic condition.

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INTRODUCTION

Zooplankton community structure is potentially affected by both "natural" lake water chemistry and lake morphology, and by anthropogenic changes in lakes and watersheds (Allan, 1976; Brooks and Dodson, 1965). They provide an important food source for larval fish and shrimp in natural waters and in aquaculture ponds. Zooplankton are highly sensitive to environmental variation, as a result of which any change in their abundance, species diversity or community composition can provide important indication of environmental change or disturbance which could act as forewarning, when pollution affects food chain (Mahajan *et al.*, 1981). Due to their short life cycle, these communities often respond quickly to environmental change. Zooplankton are major trophic link in food chain and being heterotrophic organisms they play a key role in cycling of organic materials in aquatic ecosystem. They play an integral role in transferring energy to the consumers; hence they form the next higher trophic level in the energy flow after phytoplankton. Therefore in view of importance of studies related to their distribution, ecological requirement and mode of reproduction, zooplankton have attracted the attention of several workers throughout the world. Siliserh Lake is an important water body of Rajasthan state. This Lake is a major source of potable water for the population of Alwar city of Rajasthan. Every year, about 4.814 MCM of water is discharged from the lake for irrigation and used in culturable command area of 7.2 km^2. Besides, this lake also has appreciable fish productivity potential. Total catch of fish from this lake was 1363.3 MT in the year 2010-11 in 2.7 km^2 of productive area. 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. But there is no report available on the zooplankton diversity of this Lake. The analysis of zooplankton dynamics can be used to infer the environmental conditions of this lake. By characterizing the zooplankton dynamics of this reservoir, the ecological or trophic status of the system can be assessed. This will allow an appropriate treatment plan be devised if adverse conditions are indicated. The study will reveal the present condition of the lake water, its feasibility for irrigation, as well as drinking purpose. So, the present study is a step forward for taping the full potentiality of the water body. In the present study, an attempt was made to examine the seasonal variation of zooplankton community of Lake Siliserh.

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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. He named the new Lake Siliserh in honour of his wife Seela and also built a beautiful lake palace overlooking the water in 1845 AD. Water spread area of the lake is 10.5 km^2. Storage capacity is 13.93 MCM. It has an average depth of 8.71m. Catchment area of this Lake is about 11.25 km^2 of the Aravali hill range. The dam of lake is composite earthen dam consisting of earthen embankment with masonry face wall. The catchment area drains mostly the Aravalli hill ranges. 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). Zooplankton samples were collected by means of horizontal haul, using plankton net (No.25) with a mesh size of 55 µm. For the study of zooplankton, the water samples were transferred to 500 ml polyethylene bottles. Then, 5ml Lugol's iodine solution and 10-15 ml 4% formalin were added to it for fixation and preservation of planktonic cells. Zooplankton was preserved in 5% formalin and brought to laboratory. Plankton samples were identified with the help of Edmondson (1965), Needham & Needham (1978), Battish (1992) and 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 10^1 L^{-1}.The frequency of occurrence of different zooplankton species is represented as: dominant (50% or more), common (between 10% and 50%) and rare (below 10%).

The Correlation between various physico-chemical parameters were tested using Karl Pearson's Correlation formula (Pearson Product Moment Correlation Coefficient) as follows:

$$r = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{N\sum X^2 - (\sum X)^2}\sqrt{N\sum Y^2 - (\sum Y)^2}}$$

Where,
N= Number of observation
X= Variables of series X
Y= Variables of series Y
The statistical calculations were based on Ipsen & Feigl (1970) method.

$$\text{Student test (t)} \quad \frac{r}{1-r^2} \times \sqrt{n-2}$$

Where,
n = Number of observation
r = Correlation coefficient
Degree of freedom (df) = n-2

Significance: -'t' values were signified by Ipsen and Feigl (1970) formula for significance test. The probability 'p' for obtaining 't' value for a given degree of freedom was determined by comparing the 't' values with probability for a given degree of freedom. Then 'p' values are signified according to the following conventions- (Significant level for Correlation(r) value)

$p < 0.01$; Highly significant
$p < 0.05$; Significant
$p > 0.05$; Non-significant

Diversity index H' (Shannon and Weaver, 1949) was calculated for zooplankton. The results are statistically analyzed and presented graphically.

RESULTS AND DISCUSSION

Zooplankton play an integral role in transforming energy to the consumers; hence, they form the next higher trophic level in the energy flow after phytoplankton and have often been used as indicators of the trophic status of water bodies (Verma and Datta Munshi, 1987). The density of zooplankton varied between 12.44 cells X 10^1 L^{-1} and 144.84 cells X 10^1 L^{-1} depending upon season to season. It is apparent from the data that the maximum density of zooplankton was recorded during the summer season and minimum during rainy season (Fig.2, Fig.3). The average zooplankton count of all the sites taken together showed a peak in each season: monsoon (July), winter (December) and summer (April), but the summer peak was more prominent than the other two. Summer peak was coincided with a peak of phytoplankton also (Sarma *et al.*, 2011). The net zooplankton species increased in abundance during summer, probably corresponding to water quality, decaying vegetation, increased levels of organic matter in the lake during this time (Jacoby and Greenwood, 1989; Srivastava *et al.*, 1990; Coman *et al.*, 2003). Zooplankton density was found positively correlated to temperature, total hardness, Mg hardness and free CO_2 whereas negatively correlated with conductivity, TS and TDS of water. Correlation between various physico-chemical factors and zooplankton groups is shown in Table 2. The density and diversity of zooplankton are controlled by several physico-chemical factors of water (Quasim, 1979; Nair *et al.*, 1983). Among these factors temperature exhibited the greatest influence on the periodicity of zooplankton (Battish and Kumari, 1986). At high temperature the multiplication, reproduction and metabolic activities of zooplankton increased resulting in their abundant growth (Morales-Baquero *et al.*, 2006). High organic matter, hardness, conductivity and increase in alkalinity also played important roles, directly or indirectly to control zooplankton growth (Byars, 1960). Though water temperature was high during monsoon, yet the zooplankton density was minimum during this season. This may be due to high water level in monsoon as compared to summer which minimized the density of organisms (Takamura *et al.*, 1989).

The zooplankton community of Siliserh Lake was represented by six groups i.e. Rotifera, Copepoda, Cladocera, Protozoa, Ostracoda and Insecta. In the present study zooplankton population was observed to be composed of 37 species belonging to 29 genera. Out of 37 species 16 represented Rotifera, 6 Copepoda, 7 Cladocera, 3 Protozoa, 3 Ostracoda and 2 Insecta as depicted in Table 4. Total zooplankton diversity was 11 in Febrauary 2011 and 20 in November 2010. In Siliserh Lake, zooplankton community composed mainly of Crustaceans (particularly Copepoda and Cladocera) and Rotifers. Other plankton groups were also observed at low density and frequency, such as Protozoa, Ostracoda and Insecta. In terms of percentage, Copepoda was the most dominant form followed by Rotifera, Cladocera, Protozoa, Ostracoda and Insecta on yearly basis. It is apparent from the result that numerically Copepoda was dominant for 8 months from November to June while Rotifera was dominated during August to October. Copepoda was represented by 6 species belonging to 5 different genera, its contribution varied between 10.49% in October 10 and 79.14% in June 11 towards the total density of zooplankton. Copepoda was found to be the most dominant group in the Siliserh Lake during both summer and winter season (from November to June). It shows that Copepoda favours more stable environment and generally regarded as pollution sensitive taxa as they disappear in polluted waters Das *et al.* (1996). This group exhibited highest peak at all station during the month of April, the peak values ranging between 2.74 cells X 10^1 L^{-1} and 102.14 cells X 10^1 L^{-1}. In many other Indian water bodies, Copepoda was found dominant during summer (Shyam, 1991; Varghese and Naik, 1992). It may probably be due the presence of certain carotenoids in the body of Copepoda which provided them protection against sunlight (Hairston, 1976). Other studies have indicated carotenoids as a source of stored energy in Copepoda (Ringelberg, 1980; Dussart and Defaye, 1995). Copepoda cannot synthesize carotenoids, but obtain them by eating algae or other zooplankton (Hairston, 1976). A large fraction of Copepoda population of Siliserh Lake consisted of Calanoid, mainly *Diaptomus kenai* and *Limnocalanus sp.* followed by Harpacticoida as *Canthocamptus sp.* but Cyclopoida were found in lesser number. Even though phytoplankton density was low in winter season, Calanoid Copepoda was in good numbers as compared to Cyclopoida. It may be due to the tendency of Calanoid to remain dominant during low food concentration and are highly resistant to starvation relative to Cyclopoida (DeMott, 1989). *Diaptomus sp.* was dominant among Copepoda in Siliserh Lake during the study period except September and October. The lake was slightly in eutrophic condition during September due to nutrients enrichment followed by Cynophycean bloom. *Diaptomus sp.* was reported to be highly sensitive to pollution (Mahajan *et. al.* 1981). One of the possible reasons for the dominance of *Diaptomus sp.* may be due to the omnivorous nature of this species and put effects on herbivorous zooplankton and phytoplankton (Brett *et al.*, 1994).

Copepoda was directly correlated with pH ($r = 0.65$; $p<0.05$), conductivity ($r = 0.68$; $p<0.05$), total hardness ($r = 0.77$; $p<0.01$), Ca hardness ($r = 0.62$; $p<0.05$), Mg hardness ($r = 0.72$; $p<0.01$) and inversely correlated with TDS ($r = -0.66$; $p<0.05$) and TS ($r = -0.67$; $p<0.05$). Correlation between various phytoplankton and zooplankton groups is shown in Table 3. It is apparent from this table that Copepoda also had a positive correlation with total zooplankton density ($r = 0.98$; $p<0.01$), Cladocera ($r = 0.76$; $p<0.01$) and Bacillariophyceae ($r = 0.70$; $p<0.05$). In the present study, Copepoda showed direct correlation with Cladocera population and Bacillariophyceae. Copepoda are filter feeders and consume Diatoms and Dinoflagellates whereas Cladocera consumes Chlorophyceae (Malej and Harris, 1993).This result indicated their differential food preference in the reservoir. Thus abundant population density of Copepods in Siliserh Lake is favorable for pisciculture practices (Pai *et al.*, 2001). Next to the Copepoda, Cladocera was found to be the second dominant group in Siliserh Lake. The maximum number of Cladocera was reported in summer months and minimum in monsoon months (Kaushik and Sharma, 1994). Cladocera was represented by 7 species out of which 2 species *(Bosmina longirostris* and *Ceriodaphnia reticulata*) were found to be perennial. In terms of density of zooplankton, the percentage contribution of this group was found between 9.99% in February 2011 and 45.35% in November 2010. Lowest Cladocera density was reported in monsoon months and highest in summer months. The results of the present study indicate that the density of Cladocera was regulated by two factors: food availability and fish predation. It has also been reported that the density of Cladocera was primarily dominated by food supply (Wright, 1954). Predation was another reason for seasonal dynamics of Cladocera in Siliserh Lake, because the density of most sensitive and dominant species declined during the study period when larval fish displayed their maximum density in the lake water. The present water body is also used for pisciculture. Every year lakhs of fry and fingerlings of major carp like *Catla catla, Cirrhina mrigala and Labeo rohita* are released (from September to October) into the lake. Cladocerans are the preferred food of major carps (Kamal, 1967). Reduced number of Cladocera in the lake water during this period may be due to feeding activities of these fishes. When given a choice, the predator most consistently choose the largest food morses available (Brooks and Dodson, 1965). Cladocera community was dominated by *Ceriodaphnia reticulata* followed by *Bosmina longirostris*. But in monsoon period *Coelosphaerium* and *Microcystis* species was maximum in number whereas *Ceriodaphnia reticulata* was very less. *Coelosphaerium sp.* and *Microcystis sp.* produce microtoxins which may be harmful to *Ceridodaphnia reticulata.* This may be the reason for their reduction in number (Lampert, 1987; Carmichael, 1989). *Bosmina longirostris* was in good number in monsoon. *Bosmina longirostris* was dominant because it is a specialist feeder, avoiding toxic phytoplankton (DeMott and Kerfoot, 1982). *Bosmina longirostris* has been shown to exhibit strong selectivity for green algae and diatoms. (Mason and Abdul-Hussein, 1991), thus it may have utilized high volume of Chlorophyceae.

Bosmina longirostris was dominant during monsoon whereas *Ceriodaphnia reticulata* was dominated in winter and summer. Genera Daphnia remained subdominant while *Diaphanosoma*, *Moina, Sida* and *Simocephalus* appeared only during monsoon. Other factors which appear to influence the Cladoceran distribution are Bacillariophyceae, Chlorophyceae and total zooplankton density. In the present study Cladocera was found negatively correlated to Cynophyceae. In monsoon *Coelosphaerium sp.* and *Microcystis sp.* were dominant species of Cynophyceae. But the bloom of *Coelosphaerium sp.* and *Microcystis sp.* reduced the number of other Cladocera population because they produced microcystins harmful to Cladocera (Lehman *et al.*, 2009 and Cerbin *et al.*, 2010). Cladocera obtained a positive correlation with Bacillariophyceae ($r = 0.57$; $p<0.05$), Chlorophyceae ($r = 0.66$; $p<0.05$), Rotifera ($r = 0.61$; $p<0.05$) and total zooplankton ($r = 0.85$; $p<0.01$). In the present study Rotifera was found to be the third major group of zooplankton in Siliserh Lake.

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. Correlation matrix (r) between various physico-chemical parameters and zoplankton 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
-0.36	0.83	0.81	0.52	0.20	0.70*	-0.48	-0.62*	-0.62*	0.46	-0.08	0.45	0.21	0.68*	0.51	0.66*	0.05	0.02	-0.50	0.29	0.60*	0.12	Total zooplankton
0.85	0.33	0.41	-0.13	-0.09	0.71**	0.16	-0.18	-0.09	0.17	0.34	0.20	0.14	0.16	-0.16	0.32	0.60	-0.10	-0.05	-0.22	0.80**	0.06	Rotifera
-0.47	0.15	0.11	0.65	0.15	0.68*	-0.56	-0.66*	-0.67*	0.49	-0.17	0.41	0.25	0.77**	0.62	0.72	0.01	0.12	-0.53	0.35	0.51	0.01	Copepoda
-0.07	0.10	0.05	0.16	0.43	0.50	-0.32	-0.36	-0.37	0.25	0.05	0.55	0.01	0.38	0.24	0.40	-0.03	-0.26	-0.48	0.22	0.56	0.47	Cladocera
0.45	0.68	0.67	-0.68*	-0.03	0.19	0.97**	0.57	0.73**	-0.40	0.33	-0.01	-0.03	-0.65*	-0.85**	-0.41	-0.80**	0.02	0.48	-0.51	0.08	0.09	Ostracoda
0.28	-0.39	-0.37	-0.11	0.43	-0.39	-0.25	-0.31	-0.31	0.24	0.21	0.08	-0.36	-0.17	0.04	-0.26	-0.45	-0.50	-0.61*	0.17	0.07	0.73**	Protozoa
0.41	-0.18	-0.29	-0.37	0.30	-0.34	0.01	0.20	0.16	0.13	-0.10	0.06	-0.13	-0.36	-0.13	-0.42	-0.22	-0.38	-0.10	-0.07	0.18	0.14	Insecta

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

Table 3. Correlation matrix (r) of various plankton groups at Siliserh Lake

1	2	3	4	5	6	7	8	9	10	11	Parameters
1	0.75**	0.68*	0.85**	0.24	0.60*	0.15	0.24	0.64*	-0.11	0.06	1.Total phytoplankton
	1	0.71**	0.41	0.74**	0.67*	0.70*	0.57	0.10	0.03	-0.07	2. Bacillariophyceae
		1	0.22	0.54	0.45	0.46	0.66*	0.02	0.09	0.26	3.Chlorophyceae
			1	-0.17	0.43	-0.24	-0.17	0.90**	-0.22	-0.03	4.Cynophyceae
				1	0.64*	0.98**	0.85**	-0.40	0.02	-0.19	5.Total zooplankton
					1	0.53	0.61*	0.28	-0.07	-0.26	6.Rotifera
						1	0.76**	-0.47	-0.04	-0.24	7.Copepoda
							1	0.29	0.22	0.01	8.Cladocera
								1	-0.26	0.01	9.Ostracoda
									1	0.01	10.Protozoa
										1	11.Insecta

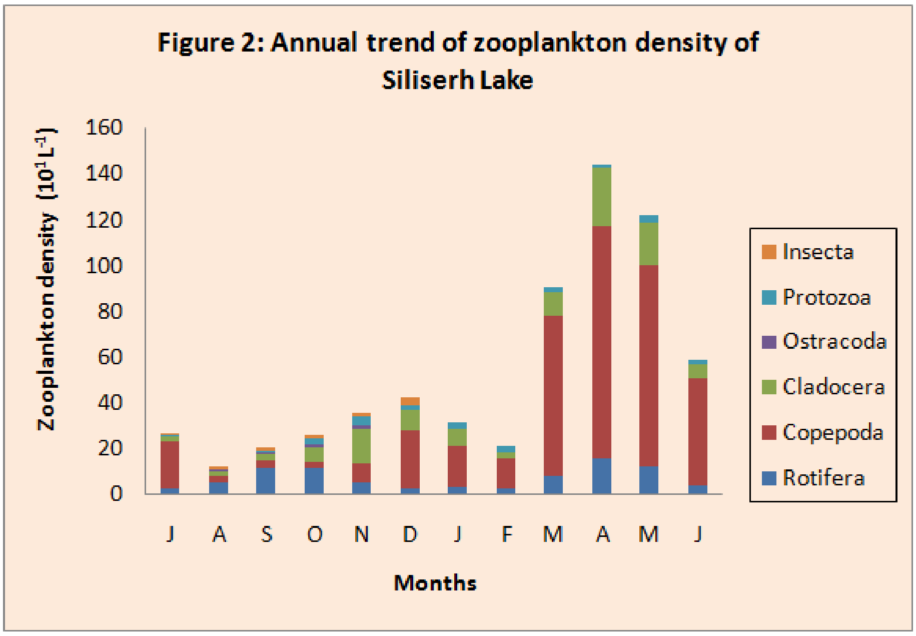
(* indicates significance at p<0.05 and ** indicates significance at p <0.01 level).

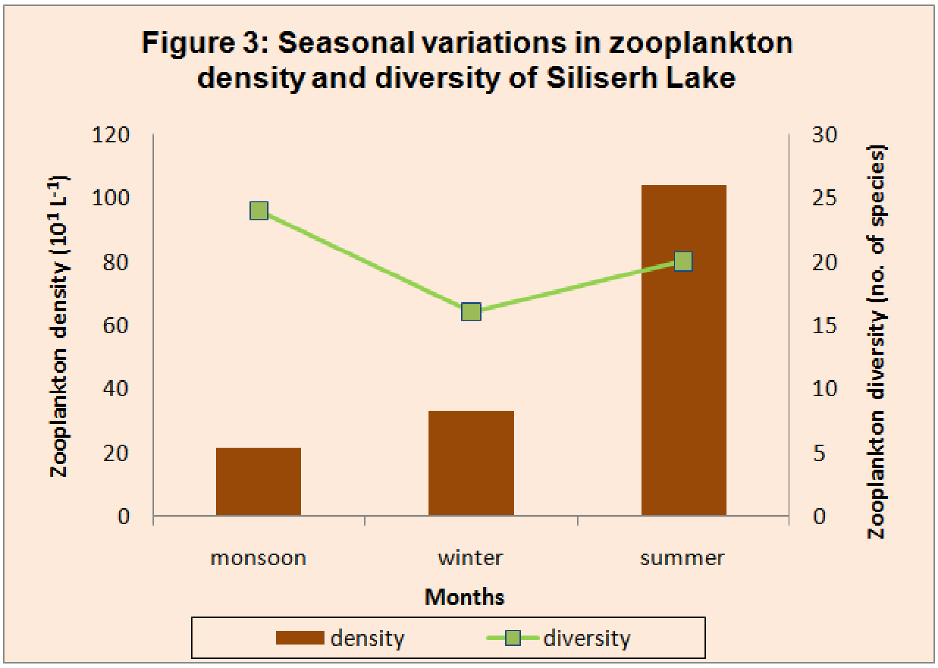
Table 4. Species composition of various zooplankton groups at Siliserh Lake

Name of species	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
ROTIFERA												
Asplanchna priodonta	++	++	++	-	++	+++	+++	+++	+++	+++	+++	+++
Brachionus bidentata	++	++	++	++	+	+	+	+	+	+	+	+
B. forficula	+	+	+	+	-	-	-	-	+	+	+	+
B. calyciflorus	+++	+++	+++	+++	+	+	-	-	-	-	-	-
B. caudatus	++	++	++	++	+	+	+	-	-	-	-	-
B.quadridentata	-	-	-	-	-	+	+	+	+	+	+	+
Filina longiseta	++	++	++	++	-	-	-	-	-	-	-	-
F. opoliensis	++	++	++	++	-	-	-	-	-	-	-	-
Keratella tropica	++	++	++	++	++	-	-	-	-	++	++	++
K. quadrata	+	+	-	-	-	-	+	+	-	-	+	+
K. cochlearis	+	+	+	+	-	-	-	-	+	+	+	+
Gastropus sp.	-	-	-	-	+	+	+	+	+	+	+	+
Lecane luna	+	+	-	-	-	-	-	-	-	-	+	+
Rotaria sp.	-	+	+	+	-	-	-	+	+	+	+	+
Cupelopagus sp.	+	+	-	-	-	-	-	-	-	-	-	-
Notholca sp.	-	-	-	-	+	+	+	-	-	-	-	-
COPEPODA												
Diaptomus kenai	+	+	+	+	+++	+++	+++	+++	+++	+++	+++	+++
D. sp.	-	-	-	-	-	-	-	+	+	+	+	+
Canthocamptus sp.	-	-	-	-	-	+	+	+	+	+	++	++
Limnocalanus sp.	-	-	+	+	++	++	++	++	++	++	++	++
Cyclops sp.	+	+	+	+	++	++	++	++	++	++	++	++
Nauplius sp.	-	-	-	-	-	-	-	+	+	+	+	+
CLADOCERA												
Ceriodaphnia reticulata	+	+	+	+	++	++	++	++	++	++	++	++
Bosmina longirostris	+++	+++	+++	+++	+	+	+	+	+	+	+	+
Moina sp.	+	+	+	+	-	-	-	-	-	-	-	-
Sida sp.	+	+	+	+	-	-	-	-	-	-	-	-
Daphnia sp.	++	++	++	++	++	++	++	++	++	++	++	++
Diaphanosoma sp.	+	+	+	+	-	-	-	-	-	-	-	-
Simocephalus sp.	+	+	+	+	-	-	-	-	-	-	-	-
OSTRACODA												
Physicocypris sp.	-	+	+	-	-	-	-	-	-	-	-	-
Cypris sp.	+	-	-	+	+	-	-	-	-	-	-	-
Stenocypris sp.	+	+	-	-	-	-	-	-	-	-	-	-
PROTOZOA												
Cretium sp.	+	+	+	+	+	+	+	+	+	+	+	+
Astramoeba sp.	-	-	-	-	-	-	-	-	+	+	+	+
Difflugia sp.	-	-	-	-	-	-	-	-	+	+	+	+
INSECTA												
Larvae of Odonata	-	-	-	-	+	-	-	-	-	-	-	-
Larvae of Diptera	+	+	+	+	+	-	-	-	-	-	-	-

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

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





Rotifera was the dominant group during monsoon. Rotifera was represented by 16 species belonging to 9 genera, none of which was found to be perennial. The contribution of Rotifera was varying from 6.94% in June 2011 to 55.6% in September 2010 of the total zooplankton density. Rotifera was dominated during monsoon over the other groups. On seasonal basis, density of Rotifera was maximum in summer months and minimum in winter months. Highest diversity of this group was noted during summer months and lowest diversity was found during monsoon months. A positive correlation between temperature and Rotifera population was also observed in the present study. It has been observed that high temperature, long duration of day, intensity of sunlight during summer and accelerating phytoplankton, are some favorable factors for the growth and abundance of Rotifers (Kaushik and Sharma, 1994). Rotifera was found positively correlated with Conductivity ($r = 0.71$; $p<0.01$), free CO_2 ($r = 0.80$; $p<0.01$), temperature ($r=0.81$; $p<0.01$) and nitrate ($r = 0.60$; $p<0.05$). Rotifera also showed positive correlation with Bacillariophyceae ($r = 0.67$; $p<0.05$), total phytoplankton ($r = 0.60$; $p<0.05$) and total zooplankton ($r = 0.64$; $p<0.05$). Different genera of Rotifera showed different periodicity of occurrence. *Filina* genera was present during monsoon, *Asplanchna priodonta* was reported whole year except October. *B. calyciflorus* and *Keratella tropica* were found in maximum number during monsoon. *Brachionus caudatus* and *Keratella chochleris* were found frequent while *B. quadridentata, Cupelopegus sp., Gastropus sp., K. qvadrata, Lecane luna, Notholca* sp. and *Rotaria* were rarely observed. The most dominant species of Rotifera were *Asplanchna priodonta, Brachionus calyciflorus* and *Brachionus forficula* Rotifera also showed a positive correlation with nitrate content and free CO_2 of lake water. Nitrate contents were maximum during monsoon. High temperature and nitrate content might have increased the multiplication, reproduction and metabolic rates of Rotifera resulting in their abundant growth (Branco *et al.*, 2002). The most dominant species among. The dominant nature of *B. calyciflorus* during the monsoon month coincided with the abundance of *Coelosphaerium* and *Microcystis* of Cynophyceae. *B. calyciflorus* having great ability to utilize colonial Cynophyceae as food, exhibit a greater tolerance to their blooms (Fulton and Paerl, 1987). On the other hand, through differential inhibition of population growth and filtering rates of Cladocera, *Microcystis* has the potential to alter the zooplankton community structure by favoring Rotifera (Smith and Gilbert, 1995). The density of Protozoa varied between 0.318 cells $X10^1$ L^{-1} in month of July 2010 and 3.99 cells X 10^1 L^{-1} in the month of November 2010. Maximum and minimum Protozoa density was observed in winter and monsoon months respectively. But highest diversity of Protozoa was reported in summer months and lowest in winter months. *Cretium sp.* was found to be perennial while *Astramobea sp. and Difflugia sp.* were found rare. Protozoa contributed 0.78% in April 10 and 13.97% in October 10 of total zooplankton density. Protozoa was negatively correlated with sulphate ($r = -0.61$; $p<0.05$). The Ostracoda was represented by 3 genera namely *Cypris, Physocypria* and *Stenocypris*. None of 3 species representing this group was found to be perennial. *Cypris* was reported in July, October and November, *Physocypria* in August and September whereas *Stenocypris* was available only in July and August. Species density of this group ranged between 0.318 cells X 10^1 L^{-1} and 1.98 cells X 10^1 L^{-1}. The contribution of this group varied between 0% and 7.08% of total zooplankton population. The maximum species diversity of Ostracoda was reported during rainy season. This genera was totally absent from December 2010 to June 2011. Ostracoda showed positive correlation with TSS, TDS and TS and negative correlation with pH, hardness, nitrate and total phytoplankton. The performance of Protozoan was almost equal in winter and summer and was poorest during rainy season. Insecta was represented by larvae of Diptera and Odonata comprising from 0.77% to 7.08% of total zooplankton population on monthly basis. Maximum species density was found in monsoon months and this group was absent during January to June 2011. Larva of Diptera was presented in November while larva of Odonata was found from July to November. Insecta did not show any definite seasonal pattern.

Conclusion

From the above discussion, it can be concluded that the species composition and abundance of zooplankton community are influenced by a number of physical, chemical and biological factors. In general, factors such as temperature (Edmondson, 1965), salinity (Egborge, 1994), pH (Sprules, 1975) and EC (Pinto-Coelho *et al.*, 1998) can affect this community with regards to both composition and population density. The size of the water bodies (Patalas, 1971), their trophic status (Gannon and Stemberger, 1978) and the successional stage (Hutchinson, 1967) also greatly influence the species composition of zooplankton. However, the most important factors recognized in the present study are temperature, nitrate, TDS, quality and availability of food, competition and predation. In natural environments these factors act simultaneously and may also interact to different degrees, modifying the zooplankton structure and abundance in different ways. While applying the Shannon-weaver index in the present study, the value varied from 1.0 to 3.4 for zooplankton. Shannon diversity index values of phytoplankton communities can be used to indicate water pollution status. 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 1.0 to 3.4, suggest that the water quality can be classified as moderately polluted to clean water. The lake was found to be slightly eutrophic during monsoon months. Early recognition of differences in the quality and quantity of zooplankton 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. Monsoon community of plankton was dominated by Rotifera and Cynophyceae, especially with a bloom in September. In monsoon season the zooplankton were dominated by eutrophic species whereas summer and winter seasons were dominated by oligotrophic species. During monsoon various species of zooplankton such as *Bosmina longirostris, Brachionus calyciflorus, Keratella tropica, Filina longiseta,* were found in good numbers. Several authors have reported *Bosmina longirostris, Brachionus calyciflorus, Keratella tropica, Filina longiseta,* 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; El-karim, 2009; Haroon *et al.*, 2010, Mukherjee *et al.*, 2010; Claps *et al.*, 2011, Rahmati *et al.*, 2011). The Lake was found to be oligotropic during summer and winter months and eutrophic during monsoon months. Copepoda was observed to be dominant zooplankton groups in summer and winter months. Notable zooplankton species observed during these seasons were *Ceriodaphnia sp, Limnocalanus sp.* (Jeppesen *et al.*, 2000; Tolotti, 2001; Kaufman *et al.*, 2010). 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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REFERENCES

Allan, J.D. 1976. Life history patterns in zooplankton. Am. Nat., 110: 165-180.

APHA, 2005. Standard methods for the examination of the water and waste water. 21st ed. American Public Health Association Inc., Washington DC.

Baruah, B.K. and Das, M. 2001. Study on plankton as indicator and index of pollution in aquatic ecosystem receiving paper mill effluent. *Ind. J. Environ. Sci*., 5(1): 41-46.

Battish, S.K. 1992. Fresh water zooplankton of India. Oxford & IBH Publishing Co. New Delhi, Bombay, Calcutta. 233pp.

Battish, S.K. and Kumari, P. 1986. Effect of physico-chemical factors on the seasonal abundance of Cladocera in typical pond at village of Raqba, Ludhiana. *Ind. Economic*, 13(1):146-151.

Branco, C.W.C., Roacha, M.A., Pinto, G.F.S., Gomara, G.A. and Filippo, R.D. 2002. Limnological features of Funil Reservoir (R.J., Brazil) and indicator properties of Rotifers and Cladocerans of the zooplankton community. Lake. *Reserv. Res. Manage*., 7(2): 87-92.

Brett, M., Wiackowksi, K., Lubnow, F.S., Mueller-Solger, A., Elser, J.J. and Goldman, C.R. 1994. Species-dependent effects of zooplankton on planktonic ecosystem processes in Castle Lake, California. *Ecol*., 75(8): 2243-2254.

Brooks, J.L. and Dodson, S.I. 1965. Predation, body size, and composition of plankton. *Sci*., 150: 28-35.

Byars, J.A. 1960. A fresh water pond in New Zealand. *Aus. J. Mar. Freshwat. Res*., 11: 220-240.

Carmichael, W.W. 1989. Cynobacteria secondary metabolites-The cyanotoxins. *J. Appl. Bacteriol*., 35: 634-639.

Cerbin, S., Kraak, M.H.S., Voogt, P., Visser, P.M. and Van Donk, E. 2010. Combined and single effects of pesticide carbaryl and toxic *Microcystis aeruginosa* on the life history of *Daphnia pulicaria. Hydrobiol*., 643: 129-138.

Claps, M.C., Gabellone, N.A. and Benitez, H.H. 2011. Seasonal changes in the vertical distribution of Rotifers in a eutrophic shallow lake with contrasting states of clear and turbid water. *Zool. Studies*, 50(4): 454-465.

Coman, F.E., Connolly, R.M. and Preston, N.P. 2003. Zooplankton and epibenthic in shrimp ponds: factors influencing assemblage dynamics. *Aquac. Res*., 34: 359-371.

Das, P.K., Michael, R.G. and Gupta, A. 1996. Zooplankton community in Lake Tasek a tectonic lake in Garo Hills, India. *Trop. Ecol*., 37: 257-263.

DeMott, W.R. 1989. The role of competition in zooplankton succession. In Sommer, U.(ed.), Plankton Ecology

Succession in Plankton Communities. Springer-Verlag, Berlin, Heidelberg, New York: 195-252.

DeMott, W.R. and Kerfoot, K.C. 1982. Competition among Cladocerns: Nature of the interaction between *Bosmina* and *Daphnia*. *Ecol*., 63:1949-1966.

Dussart, B.H. and Defaye, D. 1995. Introduction to the Copepoda. In Dumont, H.J.F. (ed.), Guides to the identification of the Macroinvertibrates of the Continental Waters of the World. Academic Publisher, Amsterdam: 277 pp.

Edmondson, W. T. (ed). 1965. Freshwater Biology. John Wiley & Sons, Inc. New York. 1248 pp.

Egborge, A.B.M. 1994. Salinity and the distribution of Rotifers in the Lagos Harbour-Badagry Creek system, Nigeria. *Hydrobiol*., 272: 95-104.

El-Karim, M.S.A. 2009. Present and long-term changes of phytoplankton communities in hypertrophic Mediterranean Lagoon, Lake Manzala, Egypt. *American-Eurasian J. Agric. Environ. Sci*., 5(2): 171-178.

Fulton, R S. and Paerl, H.W. 1987. Effects of colonial morphology on zooplankton utilization of algal (*Microcystis aeruginosa*) blooms. Limnol. Oceanogr., 32(3): 634-644.

Gannon, J.E. and Stemberger, R.S. 1978. Zooplankton (especially Crustaceans and Rotifers) as indicators of water quality. *Trans. Am. Micro. Soc*., 97(1): 16-35.

Gulati, R.D. and Donk, E.V. 2002. Lakes in the Netherlands, their origin, eutrophication and restoration: state of the art review. *Hydrobiol*., 478: 73-106.

Hairston, N.G. 1976. Photoprotection by carotenoid pigments in the Copepod. *Diaptomus nevadensis*. Proc. Nat. Acad. Sci. U.S.A., 73:971-974.

Haroon, G., Khoiyangbam, R.S., Ahmad, S. and Zuber, S.M. 2010. Limnological assessment of Antiya Tal, Jhansi to assess its water quality. *Int. J. Lake. River*., 3(1): 79-85.

Hutchinson, G.E. 1967. A treatise on Limnology- Introduction to lake biology and the limnoplankton. Vol.II, John Wiley & Sons, New York, 1115 pp.

Jacoby, C.A. and Greenwood, J.G. 1989. Emergent zooplankton in Moreton Bay, Queensland, Australia: seasonal, lunar and diel patterns in emergence and distribution with respect to substrat. *Mar. Ecol. Prog. Ser*., 51: 131-154.

Jeppesen, E., Lauridsen, T.L., Mitchell, S.F., Christoffersen, K. and Burns, C.W. 2000. Trophic structure in the pelagial of 25 shallow New Zealand lakes: changes along nutrient and fish gradients. *J. Plankton Res*., 22(5): 951–968.

Kamal, M. Y. 1967. Studies on the food and alimentary canal of Indian major carps. I. Food consumed and differentiation of the alimentary canal and associated structures in *Catla catla* (Ham.). *Ind. J. Fish*., 11(1): 449-464.

Kaufman, D.S., Anderson, R.S., Hu, F.S., Berg, E. and Werner, A. 2010. Evidence for a variable and wet Younger Dryas in Southern Alaska. *Quarternary Sci. Rev*., 29:1445-1452.

Kaushik, S. and Sharma, N. 1994. Physico-chemical characteristics and zooplankton population of a perennial tank, Matsya Sarowar, Gwalior. *Environ. Ecol*., 12(2): 429-434.

Lampert, W. 1987. Laboratory studies on zooplankton-cynobacteria interactions. *NZ. J. Mar. Freshwat. Res*., 21: 483-490.

Lehman, P.W., Teh, S.J., Boyer, G.L., Norbriga, M.L., Bass, E. and Hogle, C. 2009. Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food web in the San Francisco Estuary. *Hydrobiol*., 637:229-248.

Mahajan, C. L., Sharma, S., Sharma, S. and Arora, N.K. 1981. Changes in zooplankton populations in a wetland ecosystem due to drought. *Int. J. Ecol. Environ. Sci*., 7: 139-143.

Mason, C.E. and Abdul-Hussein, M.M. 1991. Population dynamics and production of *Daphnia hyaline* and *Bosmina longirostris* in a shallow eutrophic reservoir. *Freshwat. Biol*., 25:243-260.

Morales-Baquero, R., Carrillo, P.,Barea-Arco, J., Perez-Martinez, C. and Villar-Argaiz, M. 2006. Climate-driven changes on phytoplankton-zooplankton coupling and nutrient availability in high mountain lakes of Southern Europe. *Freshwat. Biol*., 51: 989-998.

Mukherjee, B., Nivedita, M. and Mukherjee, D. 2010. Plankton diversity and dynamics in a polluted eutrophic lake, Ranchi. *J. Environ. Biol*., 31(5):827-839.

Nair, N.B., Dharmaraj, K., Abdul Aziz, P.K., Arunchalam, M., Krishna Kumar, K. and Balasubramaniam, N.B. 1983. Nature of primary production in a tropical backwater of southwest coast of India. *Proc. Nat. Acad. Sci. Ind*., 49(B):581-597.

Needham, J.G. and Needham, P.R. 1978. A guide to study of freshwater biology. Holden Day Inc. San Francisco.

Pai, S.C., Tsau, Y.J. and Yang, T.I., 2001. pH and buffering capacity problems involved in the determination of ammonia in saline water using the indophenol blue spectrophotometric method. *Anal. Chemi. Acta*., 434:209-216.

Patalas, K., 1971. Crustacean plankton communities in forty-five lakes in the Experimental Lakes Area, Northwestern Ontario. *J. Fish. Res. Bd. Can*., 28: 231-244.

Pinto-Coelho, R.M. 1998. Effects of eutrophication on seasonal patterns of mesozooplankton in a tropical reservoir: A 4-year study in Pampulha Lake, Brazil. *Freshwat. Biol*., 40:159-173.

Quasim, S.Z. 1979. Primary production in some tropical environment. In J. Duhbar (ed), Marine production mechanisms, London: Cambridge University Press, 31-69.

Rahmati, R., Pourgholam, R., Najafpour, S.H. and Doustdar, M. 2011. Tropical status of a shallow lake (North of Iran) based on the water quality and the phytoplankton community. *World Appli. Sci. J*., 14:112-120.

Ringelberg, J. 1980. Aspects of red pigmentation in zooplankton, especially Copepods. In Kerfoot, W.C. (ed.), Evolution and Ecology of Zooplankton Communities Special Symposium. University Press of New England, 91-97.

Sarma, S.S.S., Osnaya-Espinosa, L.R., Aguilar-Acosta, C.R. and Nandini, S. 2011. Seasonal variations in zooplankton abundances in Iturbid Reservoir (Isidro Fabela, State of Mexico, Mexico). *J. Environ. Biol*., 32:473-480.

Shashi Shekhar, T.R., Kiran, B.R., Puttaiah, E.T., Shivaraj, Y. and Mahadevan, K.M. 2008. Phytoplankton as index of water quality with reference to industrial pollution. *J. Environ. Biol*., 29: 233-236.

Shyam, R. 1991. Comparative dynamics of zooplankton in tropical freshwater swamp and in newly constructed pond in swampy area. *J. Appl. Zool. Res*., 2(2): 80-84.

Smith, A.D. and Gilbert, J.J. 1995. Relative susceptibilities of Rotifers and Cladocerans to *Microcystis aeruginosa*. *Arch. Hydrobiol*., 132: 309-336.

Sprules, W. G. 1975. Zooplankton in acid-stressed lakes. *J.Fish. Res. Bd. Can*., 32(3): 390-395.

Srivastava, K.N., Srivastava, P. and Sinha, A.K. 1990. Zooplankton studies of Ganga River between Kalkanker (Pratapgarh) and Phaphamau (Allahabad) (Uttar Pradesh). *Recent Trends in Limnology*, 1-4: 129-133.

Takamura, K. Y, Sugaya, Y., Takamura, N., Hanazato, T., Yasuno, M. and Iwakuna, T. 1989. Primary production of phytoplankton and standing crops of zooplankton and zoobenthos in hypertrophic Lake Teganuma. *Hydrobiol*., 17:173-184.

Tolotti, M. 2001. Phytoplankton and littoral epilithic diatoms in high mountain lakes of the Adamello-Brenta Regional Park (Trentino, Italy) and their relation to trophic status and acidification risk. *J. Limnol*., 60 (2): 171-188.

Varghese, M.and Naik, L.P. 1992. Hydrobiological studies of a domestically polluted tropical pond. II. Biological characteristics. *Poll. Res*., 11(2):101-105.

Verma, P.K. and Datta Munshi, J.S. 1987. Plankton community structure of Badua Reservoir, Bhagalpur (Bihar). *Trop. Ecol*., 28:200-207.

Whitton, B. A. 1975. River ecology. Blackwell scientific publications. London.

Wright, J.C. 1954. The Hydrobiology of Atwood Lake-A flood control reservoir. *Ecol*., 35(3): 306-316.

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