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Seasonal Variation in Primary productivity of Lake Siliserh, India

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ABSTRACT
The productivity can be grouped into two categories: the first is the gross primary productivity (GPP) and the second is net primary productivity (NPP). The GPP is total production which includes chemical energy used in respiration. Siliserh Lake is an important water body of Rajasthan state. Phytoplankton productivity (Gross and Net) was measured following the dark and light bottle method. Gross production was ranging between 1.30 gC m^{-3} h^{-1} in July and 1.99 gC m^{-3} h^{-1} in September 2010. The value of NPP ranged between 0.59 gC m^{-3} $h^{-1}$and 1.06 gC m^{-3} h^{-1}. NPP and GPP showed positive correlation with electric conductivity (EC), salinity and total phytoplankton density. Highest productivity in summer may be due to lower water level corresponding to high pH, alkalinity, EC, nutrients and plankton density. In the present study primary productivity was found positively correlated to Chlorophyceae. This freshwater lake remains oligotrophic during summer and winter but becomes loaded with nutrients during monsoon reaching eutrophic condition.
Key words*. Net primary productivity, Gross primary productivity, Chlorophyceae Oligotrophic, Eutrophic*

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INTRODUCTION

Primary productivity is the rate at which the sun's radiant energy is stored by photosynthetic and chemosynthetic activities of producers (phytoplankton, algae and macrophytes in water) in the form of organic substances [1]. The importance of study of primary productivity of an aquatic ecosystem lies in the fact that, firstly it gives valuable information on the productive nature of water body and secondly, the productivity values also serve as an index of pollution status of water body [2]. The measurement of primary productivity of aquatic ecosystem is required to forecast fishery potential of an area. The rate of gross primary productivity is important for assessing the fisheries yield [3].
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 primary productivity of lake. The judicious management and proper utilization of water of this lake require a systematic study of its ecology. Adequate information about the various 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, the present study is a step forward for taping the full potentiality of the water body.

MATERIAL AND METHODS

Siliserh Lake is situated nearly 16 km. 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. 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.

Limnological investigation on the lake was carried out for a period of one year, from July 2010 to June 2011. Samples were collected during morning hours from five different sites including areas of maximum and minimum human activities at monthly intervals. These sites were referred to as site 1, site 2, site 3, site 4, and site 5 as shown in Fig 1. The productivity can be grouped into two categories: the first is the gross primary productivity (GPP) and the second is net primary productivity (NPP). The GPP is total production which includes chemical energy used in respiration. The NPP is the stored organic matter in the plants in excess of that lost in respiration (Thus NPP: GPP - respiration). In the present investigation, productivity was measured at sites 1, 3 and 5.

Phytoplankton productivity (Gross and Net) was measured following the dark and light bottle method [4]. For this study 250 ml corning glass bottles were employed. The dark bottles were painted and further covered with cloth bag of black colour to prevent entry of sun light. Bottles used for incubation were suspended horizontally in the surface water for three hours. Before and after the incubation the dissolved oxygen was fixed in the field itself and estimated by the Winkler's method [5]. These oxygen values were converted to carbon values by multiplying with the factor of 0.375 (6). The results were computed in gC m^{-3} h^{-1} for gross primary production (GPP), net primary production (NPP) and respiration.

The Correlation between various 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 method.

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

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

Significance: -'t' values were signified by Ipsen and Feigl 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

Results and discussion

The primary productivity of a water body is the manifestation of its biological production. It is an ultimate outcome of photosynthesis that forms the basis of ecosystem functioning since it makes the chemical energy and organic matter available to entire biological community. Observations on the monthly gross, net primary production and respiration in phytoplankton community at Siliserh Lake are presented in the

Table 2 and Fig. 2. It is evident from the data that gross production was ranging between 1.30 gC m^{-3} h^{-1} in July and 1.99 gC m^{-3} h^{-1} in September 2010. With respect to the different seasons, the maximum and minimum values for GPP were observed in summer and monsoon seasons respectively. GPP showed a positive correlation with salinity ($r=0.70$; $p<0.01$), conductivity ($r=0.70$; $p<0.01$), total phytoplankton density ($r=0.76$; $p<0.01$), NPP ($r=0.98$; $p<0.01$), Bacillariophyceae ($r=0.74$; $p<0.01$) and Chlorophyceae ($r=0.76$; $p<0.01$).

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 primary productivity (gCm^{-3} h^{-1}) of Siliserh Lake.

Productivity	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
NPP	0.64	0.69	1.06	0.59	0.85	0.89	0.83	0.67	0.71	0.97	1.01	0.82
GPP	1.30	1.34	1.99	1.07	1.67	1.68	1.61	1.32	1.39	1.77	1.87	1.59
RV	0.66	0.65	0.93	0.48	0.82	0.79	0.73	0.65	0.68	0.80	0.86	0.77

Table 3. Correlation (r) matrix between various physico-chemical parameters and primary productivity of Siliserh Lake.

Physicochemical Parameters	NPP	GPP
Water level	0.05	0.03
Air temperature	0.10	0.08
Water temperature	0.10	0.07
pH	0.06	0.09
Salinity	0.65*	0.70**
Conductivity	0.74**	0.70**
TSS	0.23	0.24
TDS	-0.21	-0.18
TS	-0.08	-0.05
Alkalinity	0.24	0.19
Acidity	0.01	-0.04
COD	0.38	0.41
BOD	-0.03	-0.02
Total hardness	0.21	0.20
Ca hardness	-0.01	-0.01
Mg hardness	0.33	0.31
Nitrate	0.32	0.28
Phosphate	0.10	0.15
Sulphate	-0.30	-0.29
DO	0.23	0.28
Free CO_2	0.30	0.17

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

Table 4. Correlation (r) matrix between various phytoplankton groups and primary productivity of Siliserh lake.

NPP	GPP	Parameters
0.81**	0.76**	Total phytoplankton
0.80**	0.76**	Chlorophyceae
0.50	0.47	Cynophyceae
0.80**	0.74**	Bacillariophyceae

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

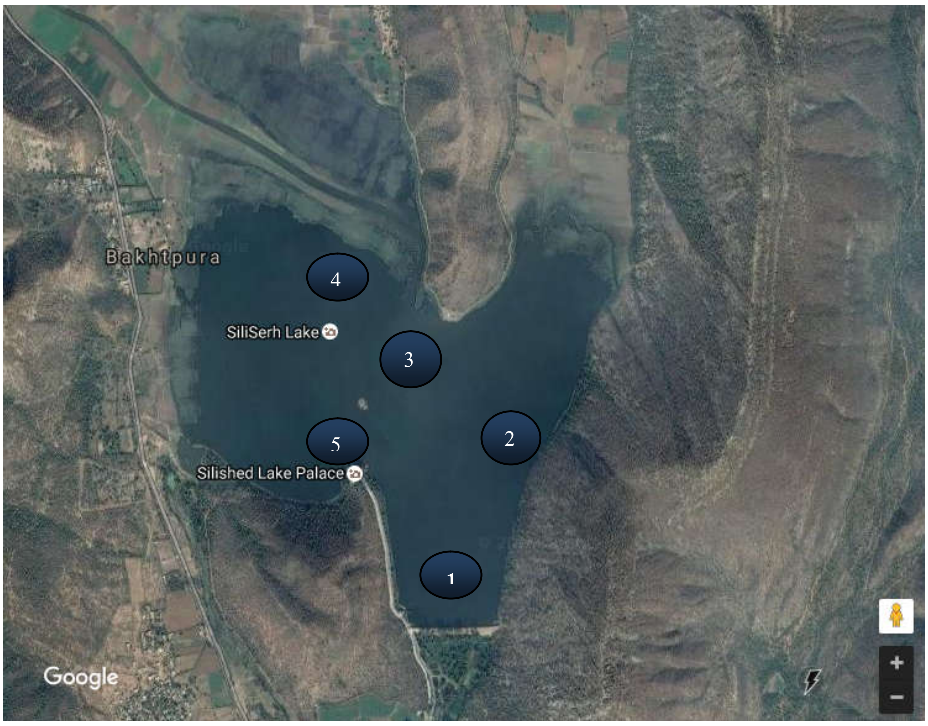
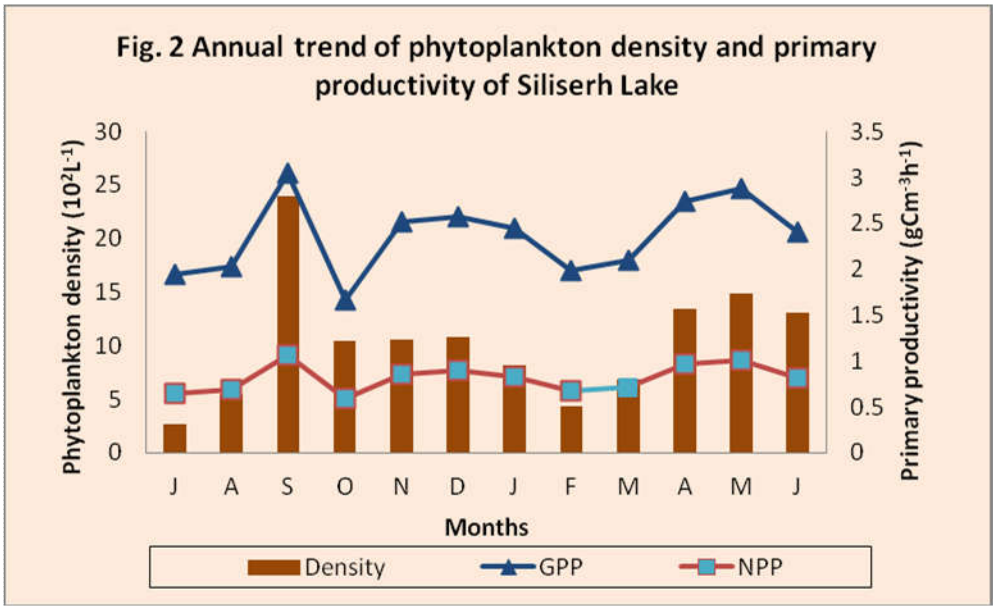


Figure 1. Satellite map of Lake Siliserh showing all five sites studied.



The value for NPP was lowest in October and highest in September 2010. The value of NPP ranged between 0.59 gC m^{-3} $h^{-1}$and 1.06 gC m^{-3} h^{-1}. Seasonal values of NPP showed to follow a trend similar to that of GPP. The respiratory rate was found to be maximum (0.93 gC m^{-3} h^{-1}) and minimum (0.48 gC m^{-3} h^{-1}) during the month of September and October 2010 respectively.

Correlation between different limnological parameters on productivity is depicted in Table 3 and 4. NPP had a positive correlation with salinity ($r=0.65$; $p<0.05$), conductivity ($r=0.74$; $p<0.01$), total phytoplankton density ($r=0.81$; $p<0.01$), Bacillariophyceae ($r=0.80$; $p<0.01$) and Chlorophyceae ($r=0.80$; $p<0.01$). In the present study, the gross primary productivity (GPP) and net primary productivity (NPP) were recorded high during summer and minimum during monsoon season (7)(8)(9)(10).

Washing, bathing, dumping of waste as well as other anthropogenic activities and surface water runoff into the lake water during monsoon months enormously deposit organic matter to the lake sediments increasing the nutrient load. These nutrients are least available to green algae and diatoms for their growth and development during low light intensity. These are probably responsible for comparative lower values of primary productivity in monsoon months. However, in summer, the rise in temperature enhances the releases of nutrients from sediments through bacterial decomposition. The excessive amount of nutrient along with higher temperature favors the growth of aquatic flora, which ultimately increases the primary productivity.

NPP and GPP showed positive correlation with EC, salinity and total phytoplankton density. Highest productivity in summer may be due to lower water level corresponding to high pH, alkalinity, EC, nutrients and plankton density (11)(12). Net productivity is considered to be directly correlated to the net rate of CO2 fixation and the rate of respiration. These two metabolic activities are highly dependent on temperature. Thus, temperature is a key factor in controlling primary production. Another important factor is chlorophyll content (13).

In the present study primary productivity was found positively correlated to Chlorophyceae. In summer Chlorophyceae was dominant coinciding higher productivity and this may be due to presence of both Chlorophyll a and b in this group (14)(15). Chlorophyceae might have transferred an additional amount of light energy for primary photochemical reactions (16). Thus, it plays a major role in primary production.

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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