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Primary Productivity in Nachiketa Tal, a high altitude lake of Garhwal Himalayas (India)

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Abstract:

Present study deals with the primary productivity of high altitude Lake Nachiketa Tal of Garhwal Himalaya. During the study period the Gross primary productivity varied between 18.77 g C/m^3/hr and 281.52 g C/m^3/hr, while the respiration between 11.26 g C/m^3/hr and 281.52 g C/m^3/hr, and the Net Primary Productivity between -150.10 g C/m^3/hr and 262.75 g C/m^3/hr. GPP (r= -0.005, p<0.05 in I year; r= -0.075, p<0.05 in II year) and NPP (r= -0.334, p<0.05 in I year; r= -0.460, p<0.05 in II year) was negatively correlated with water temperature. However the respiration was positively correlated with water temperature (r= 0.275, p<0.05 in I year; r= 0.559, p<0.05 in II year). Primary Productivity was higher in winter and springs whereas, it was lower in monsoon and summer.

Key words: Primary productivity, GPP, NPP, CR, Lake

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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 in the form of organic substances (Odum, 1971). Phytoplankton being the important primary producers in lake ecosystems, its estimation shows the nature of ecosystem, its trophic level and availability of energy for secondary producers (Patil, 2012). The knowledge of phytoplankton spatial variations of primary production, nutrient concentration and community structure is fundamental to the understanding of ecosystem dynamics (Bootsma and Hecky, 1993). Moreover, phytoplanktonic organisms are sensitive organisims, as their growth rate and variability are subject to cyclic changes: fluctuation and succession (Reynolds, 1987; Arhonditsis et al, 2004). The rate of primary production is the amount of biomass produced over some interval of time. Estimation of primary productivity is essential to understand food chain and food web (Chinnaiah and Madhu, 2010), water quality (Wetzel and Linkens 2000) and pollution study (Prabhakar et al. 2009).

In Indian context, some of the studies on productivity of lakes and ponds have been carried out by Sreenivasan (1965), Vijayraghavan (1971), Nasar and Munshi (1975), Nair and Prabhoo (1980), Datta et al. (1984), Khan et al. (1988), Adholia and Dave (1991), Sharma and Sarang (2004), Hujare and Mule (2007), Bhosale et al. (2010), Patil and Chavan (2010), Meera and Nandan (2010), Ajayan and Naik (2014), Gajanan et al. (2014), Barupal and Gehlot (2014) and Kumar et al. (2015). Similar studies in Himalayan region have been done by Khan and Zutshi (1979), Sarwar and Wazir (1981), Kaul (1985), Yadava et al. (1987), Pande and Singh (1978), Kumar (2001), Negi et al. (2004) and Laskar and Gupta (2009). The present study is first attempt to analyse to the productivity of high altitude Lake Nachiketa Tal located in the Uttarkashi District of Uttarakhand (India).

MATERIALS AND METHODS

Study Area:

In Uttarakhand about100 lakes have been documented (Uttarakhand Year book, 2011), while in the Garhwal region alone, 56 lakes have been enlisted (Rawat et al., 2007). Lake Nachiketa Tal is located in the northern-western part of Indian Himalaya and south-east to Uttarkashi township. Nachiketa Tal, situated at an altitude of 2475m asl lies between 30°22'-31°25'N latitude and 75°51'-79°27'E longitude. It is small, somewhat oval shaped lake with an approximate length of 200m, width of 90m and depth of 3m (Plate 1). With a catchment area of about 600 square meters, it receives water from precipitation and melting of snow. The lake, as such, has no inlet or outlet. The lake is approached by road about 27 Km from Uttarkashi up to Chaurangikhal, and thereafter a trek of 3 Km through dense mixed forest of *Rhododendron*, *Cedrus, Abies, Taxus, Quercus* and *Myrica.*

Sampling for ascertaining the productivity of Lake Nachiketa Tal was conducted at four sampling sites i.e., S1, S2, S3 and S4, respectively at north-west, north-east, south-east and south-west part of the lake. Each sampling site was situated at a distance of about 100 meters so as to cover the whole area of the lake. During the present study due to low water level at sample site S3, productivity was measured only at surface level. Similarly, the measurement of primary production at bottom could not be made at all sites in June and July during the II year due to scanty rainfall and the resultant low water level.

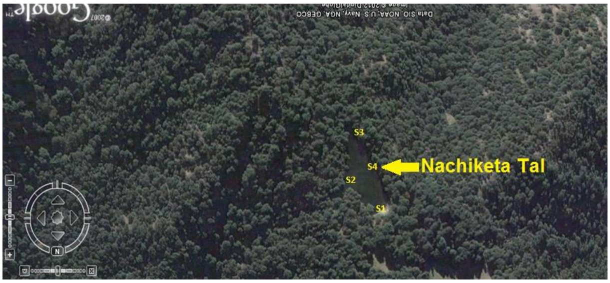

Photo 1. Arial view of Lake Nachiketa Tal (*Source: Google maps).*

Analysis of Primary Productivity:

The primary production was measured monthly with light and dark bottle method (Gaarder and Gran, 1927). The primary production was calculated as follows (Trivedy and Goel, 1986):

$$\text{Net primary production, } O_2 \text{ mg/l/hr} = \frac{\text{Dl} - \text{Di}}{\text{h}}$$

$$\text{Gross primary production, } O_2 \text{ mg/l/hr} = \frac{\text{Dl} - \text{Dd}}{\text{h}}$$

$$\text{Community respiration, } O_2 \text{mg/l/hr} = \frac{\text{Di} - \text{Dd}}{\text{h}}$$

Where,

Di = Dissolved oxygen in the initial bottle in mg/l.
Dl = Dissolved oxygen in the light bottle in mg/l.
Dd = Dissolved oxygen in the dark bottle in mg/l.
h = Duration of exposure in hours.

The value can be converted to carbon by using following formula (Strickland and Persons, 1968):

GPP, NPP or CR, gC/m^3/hr= GPP, NPP or CR, in mg O_2/l/hr x 375

RESULTS

To ascertain the primary production in Nachiketa Tal measurements of gross primary production (GPP), respiration (CR) and net primary production (NPP) were made at the surface and bottom of the lake at different sites during 2008-2010. The value of GPP, R and NPP calculated in mg l^{-1} of oxygen/hr were subsequently converted into g C/m^3/hr as per the convention and has been followed subsequently in the description.

Gross Primary Productivity (GPP)

Surface: The mean monthly GPP at the surface of Nachiketa Tal ranged between 4.753±45.291 g C/m^3/hr (November, I year) and 185.803±91.255 g C/m^3/hr (December, I year) (Fig. 1 & 2). Seasonally, the GPP measured was lowest at surface (24.40 g C/m^3/hr) during Autumn 2008 (S1) and Monsoon 2009 (S4), while the it was highest (206.45 g C/m^3/hr) during Spring 2008 at S4 (Table 1 & 2).

Bottom: The mean monthly GPP at bottom of the lake ranged between 22.523±6.501 g C/m^3/hr (February, II year) and 162.657±106.720 g C/m^3/hr (March, I year) (Fig. 1 & 2). Seasonally, the GPP at the bottom varied between 37.53 g C/m^3/hr (Autumn 2009) at S1 and 206.45 g C/m^3/hr (Spring 2008) at S4 (Table 1 & 2).

Respiration (R)

Surface: The mean monthly respiration recorded at the surface of the lake varied from 15.015±4.336 g C/m^3/hr (September, II year) to 145.453±107.677 g C/m^3/hr (March, I year) (Fig. 1 & 2). Also, the respiration recorded seasonally at the surface of the lake ranged from 5.63 g C/m^3/hr (Autumn 2008) to 197.06 g C/m^3/hr (Spring 2008) at S1 & S4, respectively (Table 1 & 2).

Bottom: The mean respiration recorded at the bottom of lake ranged from 13.763±4.336 g C/m^3/hr (February, II year) to 125.120±138.341 g C/m^3/hr (March, I year) (Fig 1 & 2). Seasonally in bottom, the respiration recorded at bottom in Nachiketa Tal seasonally varied from 15.01 g C/m^3/hr (Autumn

2009) to 197.06 g C/m^3/hr (Spring 2008) at S1 and S4, respectively (Table 1 & 2).

Net Primary Productivity (NPP)

Surface: At surface of the Lake Nachiketa Tal, the mean monthly NPP varied from (-42.218±72.464 g C/m^3/hr) in June II year to 143.575±104.084 g C/m^3/hr (December, I year) (Fig. 1 & 2). Seasonal variation in the NPP of the lake surface was observed to vary from -18.76 g C/m^3/hr (Monsoon 2009) to 101.34 g C/m^3/hr (Winter 2008) both at S2 (Table 1 & 2).

Bottom: The mean monthly NPP recorded at the bottom level ranged from 8.760±9.447 g C/m^3/hr (February, II year) to 93.840±146.581 g C/m^3/hr (December, I year) (Fig. 1 & 2). Also, seasonally, the NPP fluctuated between 7.51 g C/m^3/hr (Summer 2009) and 93.84 g C/m^3/hr (Winter 2008) at S1 and S2, respectively (Table 1 & 2).

DISCUSSION

In most of the lakes phytoplankton are the main primary producers. Phytoplankton productivity change spatially and seasonally, as physical, chemical and biological conditions in the water body changes (Wetzel, 1983). It has been noticed that the primary production in tropical lakes is generally three times higher than in temperate lakes (Limoalle, 1981; Amarasinghe and Vijverberg, 2002). High light intensity during the day and the much higher temperature contribute to the large difference in primary productivity between tropical and temperate aquatic systems (Lewis, 1987). Primary production is often affected by nutrient availability in tropical lakes (Talling and Lemoalle, 1998). Rain induced high primary productivity has been observed in some African lakes (Melack, 1979; Thomas et al., 2000).

In Nachiketa Tal primary productivity was higher during winter and spring whereas, lower in monsoon and summer. Higher primary productivity in winter and spring in Nachiketa Tal was may be, due to higher phytoplankton density in these seasons (Singh, 2012). The effect of phytoplankton population to productivity has been reported by Edmondson and Edmondson (1946), therefore phytoplankton abundance and primary productivity were correlated significantly (Kalff, 1967). Similarly, Arvola (1983) has noted spring maximum and a rapid decline in primary production in June. Roy et al. (2011) also observed that months with colder weather had higher primary productivity in Santragachi Lake. Similarly, Radwan (2005) reported maximum productivity in winter season.

On monthly basis GPP was observes to vary between 18.77 g C/m^3/hr and 281.52 g C/m^3/hr, while the respiration between 11.26 g C/m^3/hr and 281.52 g C/m^3/hr, and the NPP between -150.10 g C/m^3/hr and 262.75 g C/m^3/hr. As a consequence, negative NPP was observed at all sampling sites in the month of July and at site S1 and S3 in June during the II year. The low productivity recorded during the present study suggests that Nachiketa Tal has characteristic of an oligotrophic system. In Lake Borringesjon, Blindow et al. (2006) found NPP value between +19 to -61 g C m^{-2} and concluded that this low net productivity is most probably caused by low light availability due to self-shading. According to Krishnan (2008), in non-polluted water, production usually exceeds respiration but in polluted system, respiration exceeds production and no oxygen is left available for the normal aerobic bioactivity of the system leading to the impairment of the system. The S1 and S3 sites in Nachiketa Tal is heavy shaded by *Rhododendron* trees and has a thick accumulation of litter at ground which eventually fill in to the lake. Also, the level of the lake at site S1 and S3 decreases considerably during Summer.

The NPP values are more important ecologically as they represent the energy available to other trophic levels. However, the basic problem in determining net primary productivity is the issue of respiration since respiration measured is always whole community respiration. Due to this, model estimates of net primary production taken as a difference between gross primary production and respiration tend to show negative value on some days due to high community respiration (Oduor and Schagerl, 2007). Further, the high oxygen demand may be attributed to the high community respiration especially from the huge microbial biomass as suggested by Kilham (1981) and Yasindi et al. (2002).

In Nachiketa Tal, the increased levels of free CO_2 and turbid condition of water during monsoon results in low/negative primary productivity. However, clear water permitted more light to penetrate and thus accounted for the higher value of primary productivity during winter. As Grobbelaar (1983) observed that the lower productivities in turbid waters are due to the absorption of nutrients on the suspended clay particles. In monsoon primary production was probably limited by reduced duration and intensity of sunlight and high concentration of silt reducing water transparency. Similarly, Ali and Khan (1978) and Khan et al. (1988) observed a decline in production when turbidity was high. Also, Nair and Pandey (1986) noted low productivity in four fresh water bodies in Rajkot due to increased turbidity.

The primary production in lakes in controlled by an interaction of many factors, the temperature being primary one Findenegg (1965). Also, Goldman and Wetzel (1963) believed that temperature is important in determining seasonal productivity. Suijo and Kawashima (1964) have pointed out that productivity was low in spite of high concentration of nutrients and plenty of incident radiation. Qasim et al. (1969) did not find any relationship between temperature and primary production. In Nachiketa Tal the gross primary production was negatively correlated water temperature ($r= -0.005$, $p<0.05$ in I year; $r= -0.075$, $p<0.05$ in II year). Similarly, the NPP was negatively correlated with water temperature (r= -0.334, $p<0.05$ in I year; r= -0.460, $p<0.05$ in II year). Conversely, the respiration was positively correlated with water temperature (r= 0.275, $p<0.05$ in I year; r= 0.559, $p<0.05$ in II year).

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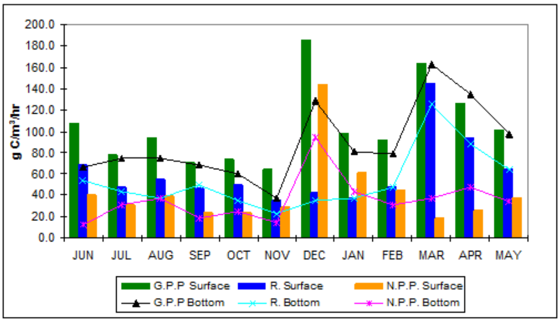

Fig. 1. Monthly average fluctuation of GPP, R, NPP (Surface and Bottom) of Lake Nachiketa Tal during I year (June 2008–May 2009).

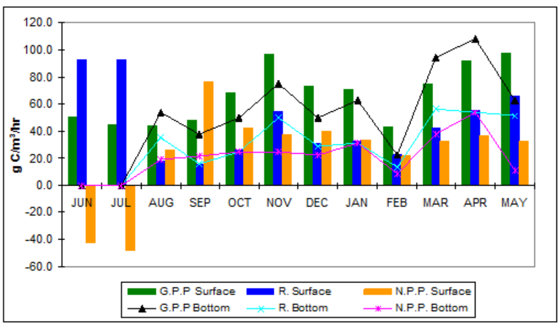

Fig. 2. Monthly average fluctuation of GPP, R, NPP (Surface and Bottom) of Lake Nachiketa Tal during II year (June 2009–May 2010).

G.P.P. = Gross primary production
R. = Respiration and
N.P.P. = Net primary production.

Table 1. Seasonal variation in primary production of Lake Nachiketa Tal at sampling site S1, S2, S3 and S4 during I year (June 2008–May 2009)
(gC/m³/hr).

	S1			S2			S3			S4		
Seasons	**G.P.P.**	**R.**	**N.P.P.**	**G.P.P.**	**R.**	**N.P.P.**	**G.P.P.**	**R.**	**N.P.P.**	**G.P.P.**	**R.**	**N.P.P.**
SURFACE												
SU	140.760	93.840	46.920	108.855	58.180	52.550	103.225	65.685	37.540	65.685	46.920	18.770
MO	84.455	75.070	9.385	84.455	48.795	37.535	103.225	46.920	56.305	71.320	33.785	37.535
AU	24.400	5.630	18.770	84.455	75.070	9.385	93.840	46.920	46.920	84.460	65.690	18.770
WI	120.118	46.920	73.195	129.500	28.155	101.348	103.223	40.353	63.813	88.210	47.858	40.350
SP	140.760	121.995	16.890	84.455	33.785	52.550	150.140	127.620	11.260	206.450	197.065	9.385
BOTTOM												
SU	93.840	75.070	18.770	86.335	48.795	37.535	-	-	-	65.685	52.545	13.140
MO	75.070	37.540	37.540	84.455	56.305	28.155	-	-	-	65.690	28.155	37.535
AU	43.165	33.780	9.385	75.070	37.540	37.540	-	-	-	75.070	56.300	18.770
WI	46.923	32.845	14.078	115.423	21.585	93.840	-	-	-	82.580	52.548	30.030
SP	140.760	84.455	56.300	99.470	37.535	61.930	-	-	-	206.450	197.065	9.385

Table 2. Seasonal variation in primary production of Lake Nachiketa Tal at sampling site S1, S2, S3 and S4 during II year (June 2009–May 2010)
($gC/m^3/hr$).

	S1			S2			S3			S4		
Seasons	**G.P.P.**	**R.**	**N.P.P.**	**G.P.P.**	**R.**	**N.P.P.**	**G.P.P.**	**R.**	**N.P.P.**	**G.P.P.**	**R.**	**N.P.P.**
SURFACE												
SU	80.705	137.005	-56.280	88.210	61.935	28.150	84.455	84.455	0.000	43.165	33.785	9.385
MO	58.180	48.795	9.385	43.170	61.935	-18.765	52.550	93.840	-41.290	24.400	16.890	7.510
AU	37.540	18.770	18.770	65.685	15.015	52.550	90.085	33.780	56.300	39.415	15.015	24.400
WI	68.503	40.353	24.398	82.580	40.353	38.475	71.320	38.473	32.845	60.995	21.585	37.538
SP	103.225	84.455	16.890	84.455	33.785	52.550	61.935	24.400	37.540	84.455	52.550	32.285
BOTTOM												
SU	56.300	48.790	7.510	75.070	56.300	18.770	-	-	-	56.300	48.790	7.510
MO	48.800	30.030	18.770	37.540	18.770	18.770	-	-	-	75.070	56.300	18.770
AU	37.530	15.015	22.525	56.300	28.155	28.155	-	-	-	37.540	18.770	18.770
WI	60.995	35.660	25.338	59.120	33.783	26.275	-	-	-	37.538	23.463	14.078
SP	112.605	65.685	46.920	118.240	56.300	61.930	-	-	-	71.320	43.165	28.155

SU= Summer, MO= Monsoon, AU= Autumn, WI = Winter, SP= Spring, G.P.P. = Gross primary production, R. = Respiration and N.P.P. = Net primary production.