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Water Temperature and Primary Production in the Euphotic Zone of a Tropical Shallow Freshwater Lake

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Abstract : Changes in the primary production in relation to changes in water temperature in the euphotic zone of the Krishnasayer, a tropical shallow freshwater lake at Burdwan (23°16′N, 87°54′E) were measured over January-December 2005. Water temperature was maximum (34°C) in May and minimum (20°C) in December. The gross primary production (GPP) was maximum (0.82 ± 0.01 $gcm^{-3}h^{-1}$) in April and minimum (0.48 ± 0.01 $g\ c\ m^{-3}\ h^{-1}$) in December. In contrast, the net primary production (NPP) was maximum (0.38 ± 0.05 $gcm^{-3}\ h^{-1}$) in May and minimum (0.23 ± 0.01 $gcm^{-3}h^{-1}$) in December, and the community respiration (CR) was maximum (0.51 ± 0.02 $gcm^{-3}h^{-1}$) in April and minimum (0.17 ± 0.01 $gcm^{-3}h^{-1}$) in September. Seasonal changes in GPP and NPP demonstrated linear and significant ($P \leq 0.01$) relationships with water temperature, whilst seasonal changes in CR demonstrated linear but insignificant ($P > 0.01$) relationships with water temperature.

Key words : Water temperature, primary production, euphotic zone, tropical lake, Krishnasayer.

Introduction

The primary production by phytoplankton in the euphotic zone of an aquatic ecosystem refers to maximum utilization of the photosynthetically active radiation by the photoautotrophs present in the illuminated water column (Odum, 1971; Amarsinghe and Vijverberg, 2002; Dodds, 2006). Although extensive studies on primary production have been carried out in many temperate and tropical regions of the world (Talling and Lemoalle, 1998), few studies have been conducted in a man-made shallow freshwater lake of south-east Asia. This study is an attempt to examine seasonal changes in the primary production by phytoplankton in the euphotic zone of a tropical and shallow freshwater lake in relation to seasonal changes in water temperature.

Materials and Methods

Study area

The present investigation was carried out in the limnetic-euphotic zone of the Krishnasayer, an ancient (> 300 years), shallow (8-10 m) and man-made freshwater lake (8-10 depth) with 13.5 ha water area at Burdwan (23°16′ N, 87°54′ E) over January-December 2005.

Sampling and estimation of primary productions

Weekly samples were collected from the water column (1 m depth) of two sites in the limnetic-euphotic zone with the help of a paddle boat and between 11.00 and 12.30 h IST (Indian Standard Time) over January-December 2005. The "light and dark bottle" technique (Garden and Gran, 1927; Odum,

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1971) was used for the measurement of primary production in this zone. Water samples were collected in 2 sets of 3 Winklers bottles (100 mL each) from the euphotic water column of both sites which were spaced out 100 m apart from each other at the middle of the lake. Soon after collection, water in the initial bottles (IB) was fixed by Winkler's reagent for future analysis in the laboratory. The dark bottles (DB) were wrapped in aluminum foils to prevent any light penetration from the euphotic water column. The light and dark bottles containing lake water were suspended by two metal wire frames having attached ropes, at 1 m depth in the euphotic water column for 1 h incubation. These bottles in the metal frame were hung vertically from the surface, and a distance of 30 cm was always maintained between them to prevent any self-shading effects on the LB. The bottles were hauled up after 1 h incubation and the contents fixed immediately with Winkler's reagents. The water so fixed in these bottles was acidified and titrated in the laboratory for oxygen measurements (Dowdeswell, 1967; Odum, 1971).

Calculation of gross and net photosynthetic rates and community respiration were based on the changes in the oxygen content in the light and dark bottles, and the initial oxygen concentration (Vollenweider, 1974). The productions were calculated by using the following formulae :

Where LB and DB = dissolved oxygen contents in the light and dark bottles, respectively, IB = dissolved oxygen content's in the initial bottle, time of exposure = 1h 0.375 = conversion factor and PQ (Photosynthetic Quotient) = 1. For precision, all production data (e.g. mg $cm^{-3}h^{-1}$) are transformed and presented as $gcmm^{-3}h^{-1}$.

On every occasion the euphotic (1 m depth water column) temperature of both sites was measured *in situ* of sampling by a certified mercury-filled Celsius thermometer (Dimples, Japan) having the scale reading of 1/10 div. The calibrated thermometer was slowly immersed into the water column and the prevailing intensity of heat was instantly recorded.

Data analysis

Means were followed by standard errors throughout. One-way analysis of variance

$$\text{Gross Primary Productivity (GPP)} = \frac{\text{LB - DB}}{\text{Time of exposure}} \times \frac{0.375}{\text{PQ}} \times 1000 \ \text{mg c m}^{-3}\ \text{h}^{-1}$$

$$\text{Net Primary Productivity (NPP)} = \frac{\text{LB - IB}}{\text{Time of exposure}} \times \frac{0.375}{\text{PQ}} \times 1000 \ \text{mg c m}^{-3}\ \text{h}^{-1}$$

$$\text{Community Respiration (CR)} = \frac{\text{IB - DB}}{\text{Time of exposure}} \times \frac{0.375}{\text{PQ}} \times 1000 \ \text{mg c m}^{-3}\ \text{h}^{-1}$$

$$\text{Net Production Efficiency (\%)} = \frac{\text{NPP}}{\text{GPP}} \times 100$$

(ANOVA) was performed to test differences of values obtained between months for all variables considered. Coefficients of correlation (r) between dependent and independent variables were calculated following the procedure outlined by Zar (1996). Scattergrams, resulting from plotting seasonal changes in the dependent variables (primary productions) against corresponding changes in the independent variable (water temperature), and fitted regression lines (y=a+bx) were computed to predict any change in relationships between these variables.

Results

Water temperature at the euphotic water column of the Krishnasayer differed from season to season (Table 1). This ranged from 20 to 34°C, and the maximum temperature was recorded in May and minimum in December. The lake being a shallow and clear one, was always exposed to sunlight and wind, and thermal variations in the euphotic water column were significant ($P \leq 0.05$) between March and April, April and May, and May and June.

Furthermore, the gross primary production (GPP) in the euphotic water column of the Krishnasayer differed from season to season, and this was maximum (0.82 ± 0.03 g $cm^{-3}h^{-1}$) in April and minimum (0.48 ± 0.01 g $cm^{-3}h^{-1}$) in December (Table-I). In contrast, the net primary production (NPP) was maximum (0.38 ± 0.05 g$cm^{-3}h^{-1}$) in May and minimum (0.23 ± 0.01 g $cm^{-3}h^{-1}$) in December. The community respiration (CR) was maximum (0.51 ± 0.02 g $cm^{-3}h^{-1}$) in April and minimum (0.17 ± 0.01 g $cm^{-3}h^{-1}$) in September, whilst, the net production efficiency was maximum (67.9%) in September and minimum (37.8%) in April.

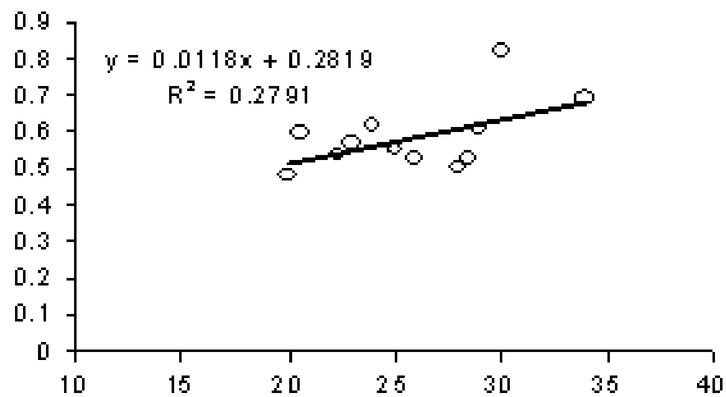
Table 1 : Seasonal changes in water temperature, gross primary production (GPP) net primary production (NPP), community respiration (CR) and net production efficiency (NPE) in the euphotic zone of the Krishnasayer over January-December 2005 (N = 52; ± 1SE)

Month	Water Temp. (0°C)	GPP (g $cm^{-3}h^{-1}$)	NPP (g $cm^{-3}h^{-1}$)	CR (g $cm^{-3}h^{-1}$)	NPE (%)
January	20.5 ± 0.6^a	0.6 ± 0.02^a	0.32 ± 0.02^a	0.28 ± 0.01^a	55.33
February	23 ± 1.2^a	0.57 ± 0.01^a	0.32 ± 0.03^a	0.25 ± 0.02^a	54.14
March	25 ± 1.2^a	0.55 ± 0.02^a	0.25 ± 0.03^a	0.30 ± 0.02^b	45.45
April	30 ± 1.2^b	0.82 ± 0.03^b	0.31 ± 0.02^b	0.51 ± 0.02^c	37.80
May	34 ± 1.4^c	0.69 ± 0.01c	0.38 ± 0.05^c	0.31 ± 0.01^b	52.20
June	29 ± 1^d	0.61 ± 0.01c	0.28 ± 0.03^d	0.33 ± 0.04^b	45.90
July	28 ± 1^d	0.50 ± 0.01^a	0.30 ± 0.01^d	0.20 ± 0.01^a	60
August	28.5 ± 1^d	0.53 ± 0.01^a	0.32 ± 0.02^d	0.21 ± 0.05^a	60.30
September	26 ± 1^a	0.53 ± 0.03^a	0.36 ± 0.01^e	0.17 ± 0.01^a	67.90
October	24 ± 0.6^d	0.62 ± 0.01^b	0.34 ± 0.03^a	0.26 ± 0.01^a	58
November	22.3 ± 0.7^a	0.54 ± 0.01^a	0.26 ± 0.01^a	0.28 ± 0.01^b	48.15
December	20 ± 1^a	0.48 ± 0.01^a	0.23 ± 0.01^a	0.25 ± 0.01^b	47.90

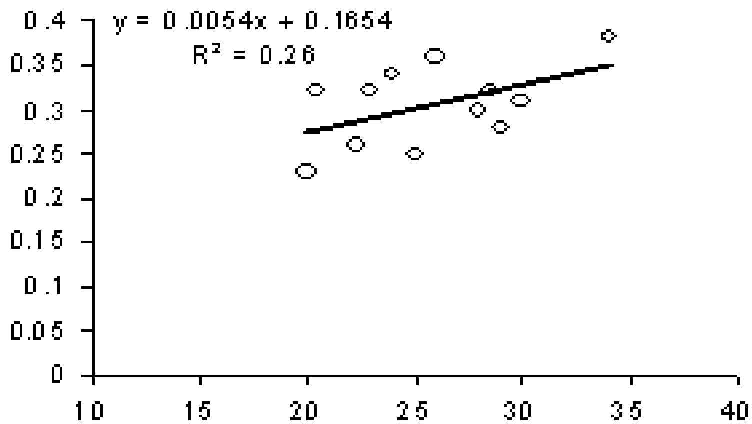
Discussion

The lake Krishnasayer demonstrated a clear annual temperature cycle with moderately high temperatures in April-June (Table 1). The air temperatures during these moths were high, and gusty winds induced higher evaporations from the surface water, and thereby affecting cooling of the water mass in the euphotic water column. In additions, low incident radiation due to frequent development of clouds during early south-west monsoon months also reduced water temperature of this lake. Because of the shallowness of this lake, occasionally the temperature of the euphotic water were occasionally slightly higher or lower than those restricting maximum photosynthetic activities of the phytoplankton (Lemoalle, 1981; Amarsinghe and Vijverberg, 2002).

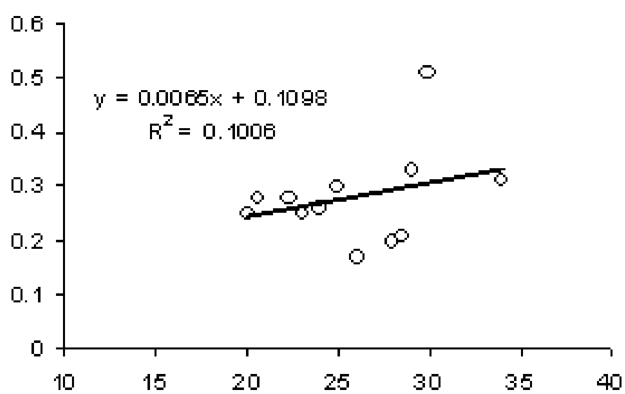
The factors that most frequently limit primary production in the tropical aquatic environment are the light (Begon *et al*., 2006), Secchi transparency (Amarsinghe and Vijverberg. 2002) and water temperature (Lemoalle, 1981). In this study, the scattergrams with fitted regression lines demonstrated linear and significant ($P \leq 0.01$) relationships between water temperature and gross primary production, and water temperature and net primary production; but a linear and insignificant ($P > 0.01$) relationship between water temperature and community respiration (Fig. 1). These are in contrast with other tropical lakes where primary production is often affected by nutrient availability (Talling and Lemoalle, 1998). In south-east Asian regions, like ours, a few showers in April-May with high nutrient inputs and moderately high water temperature prevailing during these months might have induced high primary production in the Krishnasayer. This is in agreement with the opinion put forward by Lewis (1987) who maintained that lower and higher water temperatures might produce a large difference in the primary productivity between temperate and tropical aquatic ecosystems.



(a)



(b)



(c)

Figure 1. Scatter diagrams with fitted regression lines show relationships between water temperature and gross primary production (a), water temperature and net primary production (b), and water temperature and community respiration (c) in the euphotic zone of the Krishnasayer over January-December 2005.

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