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SECONDARY PRODUCTION AND BIOMASS OF ZOOPLANKTON AND THEIR RELATIONSHIP TO TROPHIC STATUS OF A TROPICAL ARTIFICIAL LAKE

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ABSTRACT

Biomass, secondary production and P/B ratio of crustacean zooplankton have been studied in a tropical artificial lake for 2 years (October 1976-September 1978). Mean daily biomass varied between 363.75 mg dw/m^3 and 547.00 mg dw/m^3 and daily production between 31.20 mg dw/m^3-day and 52.10 mg dw/m^3-day in 1976-77 and 1977-78, respectively. The mean daily P/B ratio of both years were very close to each other (0.0858 in 1976-77 and 0.0952 in 1977-78). Copepod formed the bulk of total crustacean zooplankton biomass (78.50% in 1976-77 and 61.42% in 1977-78) and production (79.83% and 48.38% for the two years respectively). Cladoceran contributed little to biomass but their production was high as compared to biomass. The ratio of secondary production to primary production (energy transfer efficiency) varied between 0.078 in 1976-77 to 0.083 in 1977-78. No significant relationship was found between mean daily P/B and mean daily temperature revealing the insignificant role of temperature in production process of the lake.

On the basis of P/B and energy transfer efficiency, the lake appears to be eutrophic, but results loosely supported Patalas (1970) hypothesis. However, good support was found for Hillbricht-Ilkowska (1972) hypothesis that energy transfer efficiency is less in eutrophic waterbodies.

INTRODUCTION

Eversince Lindeman (1942) proposed his well known trophic dynamic model of ecosystem, the quantitative assessment of organic production and flow of energy at various trophic levels have been central points of investigations in the researches pertaining to the dynamics of aquatic ecosystem. A number of pioneer workers have attempted from various angles (Juday 1940, Odum 1957, Teal 1957, Slobodkin 1962) and the concept has somewhat been refined but the progress in this direction has been slow. Although works on primary production of phytoplankton and macrovegetation in freshwaters have started much earlier and sufficient amount of knowledge has been gathered regarding the rate and amount of solar energy fixed, respired and produced by plants in various freshwater bodies, the knowledge of secondary production of Zooplankton and bottom fauna, which are integral components of the food chain and occupy almost middle position in channelisation of energy, is still preliminary. This is because of difficult and less developed techniques and owing to complex life histories of these invertebrates often involving metamorphosis and long period of more or less continuous reproduction (Mann 1969).

Though the work on quantitative assessment of the rate of secondary production of zooplankton and bottom fauna started a little earlier in Russia (Greze and Baldina 1964, Petrovich *et al*, 1964, Pechan and Sushkina 1964, Klekowsky and Sushkina 1966) where techniques have been developed, it came in the knowledge of general aquatic ecologists of the world only, when IBP took initiative and published its hand book on secondary production (Edmondson & Winberg 1971) and when translations of some important Russian works specially that of Winberg (1971) were made available. Some serious attempts have been made during recent years and secondary productivity of some freshwaters in quantitative terms has been worked out (Hall *et al.* 1970, Patalas 1970, Hillbricht-Ilkowska 1972, Schindler 1972, Schindler and Noven 1971 and Pederson *et al.* 1976).

In India work has yet not been started on the secondary production of freshwater zooplankton. The present work has been carried out in order to determine production and energy flow at various trophic levels in some freshwater impoundment of this region of the country. In an earlier paper (Khan 1979), the primary productivity and trophic status of two impoundments have been discussed. The present communication deals with the zooplankton biomass, secondary production, P/B ratio and ratio of secondary production to primary production *i.e.*, efficiency of energy transfer in an artificial lake of Calcutta (Dhakuria lake). The trophic status of the lake has also been discussed based on secondary production, P/B ratio and energy transfer efficiency.

Materials and Method

The study was conducted for a period of two years (October 1976 to September 1978) in an artificial lake, Dhakuria lake of Calcutta, which has already been described (Khan 1979). Zooplankton samples were collected generally at fortnightly intervals, excepting, when detailed study on daily changes in the population composition and developmental duration of various life history stages of some important species was carried out. Sampling was done at 3 different stations of the lake with the help of a standard plankton net of No. 21 cloth. Two replicate vertical hauls were made from 3 meter depth at each station at a speed of 30 cm./sec. approximately. Samples of all the three stations were mixed so as to obtain only two replicate samples of a particular sampling day and screened through several cloths of varying mesh sizes in order to facilitate species or sizewise separation. Since rotifers constituted always less than 5% of the total biomass and involved great difficulty in biomass determination only crustacean, which constituted the rest of the zooplankton biomass, were taken into consideration. Samples were preserved in 4% formalin.

Identification, enumeration, size measurement and further separation were done simultaneously under a binocular with the aid of an ocular micrometer and varying magnification objectives after suitably diluting the samples and expressed in terms of cubic meter.

Copepods were divided into 7 groups *viz.*, eggs, nauplii I-III, nauplii IV-VI, copepodite I-III, copepodite IV-V, adult females and males. Similarly, Cladoceran were divided into 5 groups *viz.*, eggs, neonates, juveniles, adult I and adult II. Biomass was determined by multiplying the number of animals in each group to the mean dry weight of an individual of that group (W). The mean individual dry weight was determined as follows : Approximately 300 adults of each group were dried at 50° C for 2 days and weighed on an electrical microbalance and mean weight of one individual was calculated. Two or three replicate samples were weighed and a mean was obtained.

For the calculation of production of the population data were required on composition of various age or size group (N) in the population at a given time, developmental duration of each group (T), and standing crop biomass (B) at frequent intervals. Mean number (N) of each group of each species was determined by the analysis of samples throughout the period. Duration of development was determined in laboratory as well as by the field data by observing time lag either between the maxima (Comita, 1972) or between the first appearance of two subsequent groups (Gehrs and Robertson, 1975). The growth increment in weight of each group was determined by calculating the differences between the average mean weight of two subsequent groups.

Production was calculated by the following equation based on Petrovich *et al*, (1964) and Ivonova's result given in Edmondson and Winberg (1971).

$$P=\frac{N_i W_i}{T_i}+\frac{N_{ii} W_{ii}}{T_{ii}}+\frac{N_n W_n}{T_n}$$

where P is the production in weight per day, N_i, N_{ii}, N_{ii} are the mean number of respective groups in the simple. W_i, W_{ii}, W_n are weight increment during particular stage, T_i, T_{ii}, T_n are duration of development in days of respective groups. This gives daily production rate and production for longer periods was calculated as follows :

$$P=\frac{P_1+P_2}{2}(t_2-t_1)+\frac{P_2+P_3}{2}(t_3-t_2) + \ldots\frac{P_{n-1}+P_n}{2}(t_n-t_{n-1})$$

where P is summation of production from time t-t_n.

Besides this, primary production measurements and physicochemical analysis of the water were carried out as a routine by the methods already described (Khan, 1979). Energy transfer efficiency has been determined by working out the ratio of secondary production to primary production as follows :

$$e=\frac{\textit{Secondary production}}{\textit{Primary production}}$$

this e is same as ecological efficiency of Slobodkin (1962) expressed in terms of percentage. Coefficient of correlation (r) between mean daily P/B and mean daily temperature was worked out by least squares method. The dry weight was converted into carbon values.

RESULTS

Mean daily biomass of total crustacean zooplankton was quite high throughout the period of study, though it varied greatly between the two years (October 1976—September 1977, October 1977—September 1978). It ranged from 169.70 mg dw/m^3 to 797.50 mg dw/m^3 with a mean of 363.75 mg dw/m^3 in 1976-77 and 120.00 mg dw/m^3 to 800.00 mg dw/m^3 with a mean of 547.00 mg dw/m^3 in 1977-78 (Table 1). Inspite of great variation in mean daily accummulation of biomass during the two years, the seasonal pattern almost followed the similar trend. Three distinct peaks, first in November, second in March and third in June were noticed in both years (Fig. 1).

TABLE—1. Zooplankton, Mean daily and Annual Biomass, Productivity, P/B and percentage composition of Copepoda and Cladocera.

	Mean Daily Biomass (B) mg dw/m^3	Mean Daily Productivity mg dw/m^3-day	Daily P/B	Percent B	Percent P	Total Annual Production mg dw/m^3
1976-77						
Cladocera	78.45 (16.40-241.50)	6.300 (1.12-28.90)	0.0802 (0.004-0.175)	21.50	20.17	2300
Copepoda	285.30 (122.00-700.80)	24.90 (4.35-57.00)	0.0873 (0.02-0.167)	78.50	79.83	9100
Total	363.75 (169.70-797.50)	31.20 (4.52-61.00)	0.0858 (0.02-0.1713)			11400
1977-78						
Cladocera	211.00 (40.00-878.00)	26.15 (0.90-64.20)	0.1239 (0.021-0.142)	38.58	61.62	9565
Copepoda	336.00 (24.00-888.00)	25.95 (1.02-55.20)	0.0772 (0.0127-0.136)	61.42	48.38	9400
Total	547.00 (120.00-800.00)	52.10 (1.92-179.70)	0.0952 (0.016-0.1406)			18965

The daily production of total crustacean zooplankton was also high and ranged from 4.52 mg dw/m^3-day to 61.00mg dw/m^3-day with a mean of 31.20 mg dw/m^3-day in 1976-77 and 1.92 mg dw/m^3-day to 179.70 mg dw/m^3-day with a mean of 52.10 mg dw/m^3-day in 1977-78. The annual production varied from 11400 mg dw/m^3-year in 1976-77 to 18965 mg dw/m^3-year in 1977-78 (Table 1). Trend of seasonal pattern closely followed the biomass pattern except that the third peak in 1976-77 occurred one month earlier, *i.e.*, in May (Fig. 1). While there were great fluctuations in production and biomass from year to year, the average daily P/B ratio of total crustacean zooplankton (Table 1) differed very little. These values ranged from 0.0200-0.1713 (mean 0.0858) in 1976-77 and 0.0160-0.1406 (mean 0.0952) in 1977-78. Four distinct peaks were observed in both years but during different months (Fig. 1). The biomass and productivity of copepods were higher than cladocerans. Cladocerans biomass ranged from 16.40-241.50 (mean 78.45) mg dw/m^3 in 1976-77 and 40.00-878.00 (mean 211.00) mg dw/m^3 in 1977-78. The biomass of copepods ranged between 122.00 and 700.80 (mean 285.30) mg dw/m^3 and between 24.00 and 888.00 (mean 336.00) mg dw/m^3 in 1976-77 and 1977-78 respectively. The mean daily production of cladocera was 6.3 mg dw/m^3-day (range 1.12-28. 90) in 1976-77 and 26.15 mg dw/m^3-day (range 0.9-64.2) in 1977-78, while that for copepods were 24.90 (range 4.35-57.00) and 25.95 (range 1.02-55.20) mg dw/m^3-day for 1976-77 and 1977-78, respectively. The mean P/B ratio for cladocera were 0.0802 and 0.1239 and for copepods 0.0873 and 0.0772 for 1976-77 and 1977-78 respectively.

While cladoceran contributed less to total zooplankton biomass (38%). In 1977-78, their production was sufficiently high and was almost equal to copepods production (Table 1). In 1976-77 its contribution to biomass was almost proportionate to its production (mean daily biomass 21. 5% and mean daily production 20.17%). However, the bulk of biomass was produced by copepods during both years (78% and 61.4% during two years respectively). The daily P/B ratio was almost equal in 1976-77 but cladoceran got an edge over copepods in 1977-78.

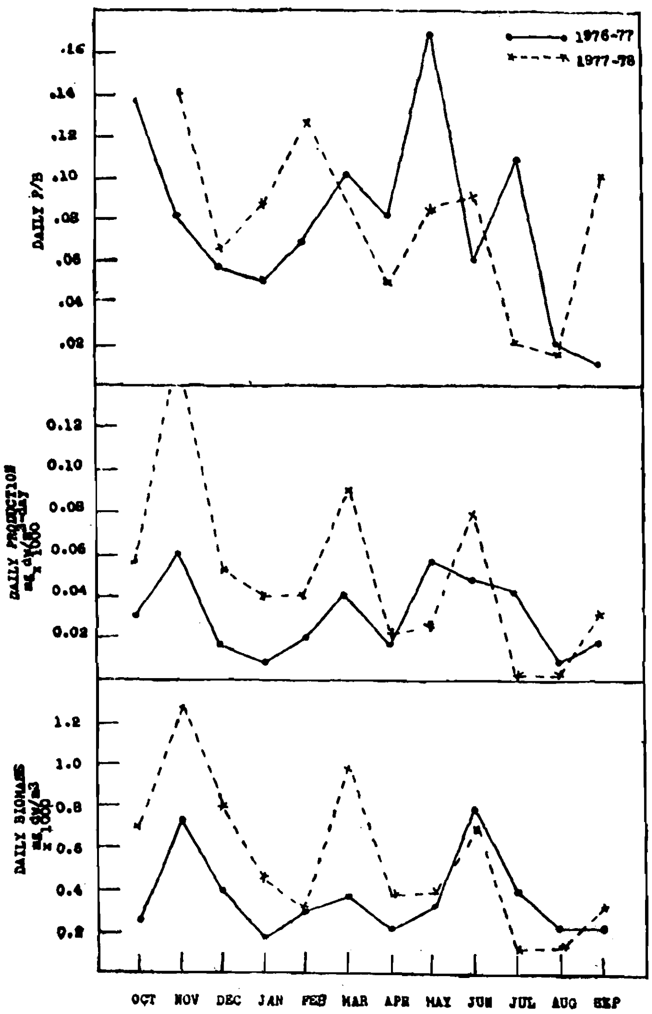

Fig. 1. Seasonal variations in mean daily biomass, production and P/B of total crustacean zooplankton.

Figure 2 and 3 display the seasonal pattern of mean daily biomass, production and P/B ratio of cladocerans and copepods respectively while Fig. 4 depicts the variation in percentage composition of the two groups. It is clear that during 1976-77 the November peak of total zooplankton biomass was due to the abundance of copepods while March and June peaks were due to both cladocerans and copepods. In 1977-78 November peak was due to cladocera, when a condition resembling to swarming or bloom formation of *Ceriodaphnia cornuta* occurred between November 1977-January 1978. Another peak of cladoceran abundance, this time contribution by another species, *Daphnia carinata*, combined with sufficient abundance of cyclopoid *Mesocyclops leuckarti* resulted in high daily biomass production of total zooplankton in June, while March peak was mainly due to copepods. As far as cladoceran production is concerned, in 1976-77 only one peak was observed, *i.e.*, in May 1977 due to the presence

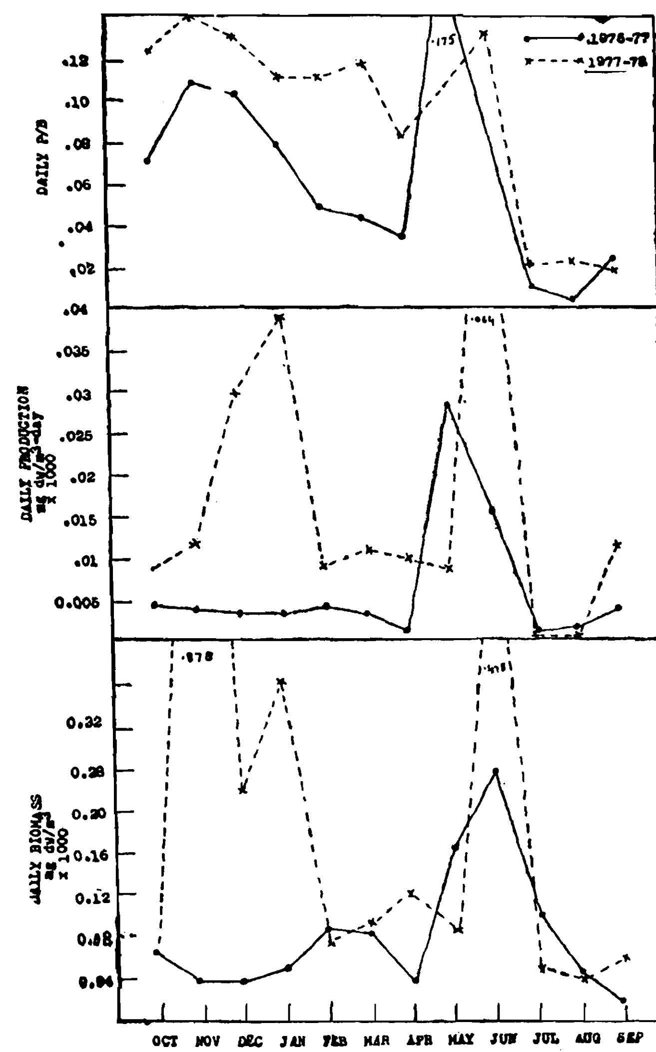

Fig. 2. Seasonal variations in mean daily biomass, production and P/B of cladocerans.

of sufficient number of youngs of *Daphnia carinata* in the population which resulted in high biomass during subsequent months when adult dominated. In 1977-78 peaks of production were noticed in January 1978 following abundance of *C. cornuta* and in June when *D. carinata* reproduced excessively resulting in bloom formation. In copepod temporary bloom formation was never noticed even though biomass and production were high in

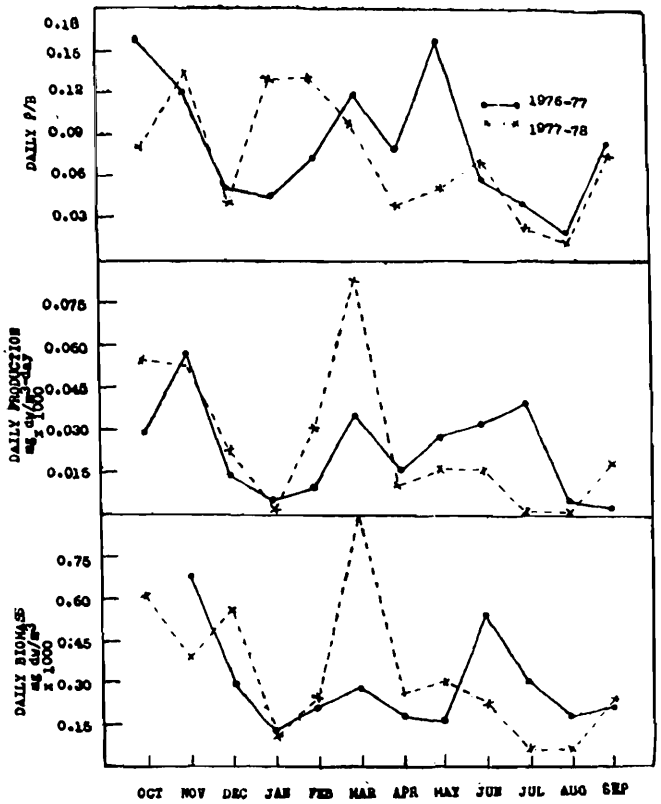

Fig. 3. Seasonal variations in mean daily biomass production and P/B of copepods.

both years (Figs. 3 & 4) with three peaks in 1976-77 (November, March and July) and only two distinct peaks, (October and March) in 1977-78.

The mean daily primary production rate for the two years were 176.00 mg C/m^3-day and 275.00 mg C/m^3-day for 1976-77 and 1977-78 respectively. When efficiency of energy transfer was calculated it varied between 0.078 or 7.8% in 1976-77 to 0.083 or 8.3% in 1977-78.

When the relationship between mean daily P/B of total zooplankton and mean daily temperature was worked out, a highly insignificant relationship were observed during both years (r=0.25, DF 11 in 1976-77 and r=0.35, DF 11 in 1977-78).

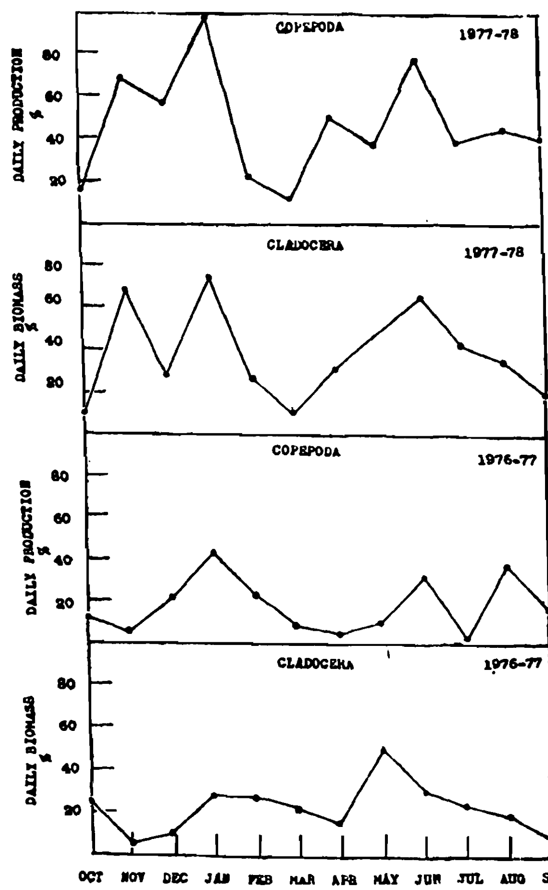

Fig. 4. Percentage composition of cladocera and copepoda in total zooplankton biomass, production and P/B.

Discussion

The standing crop biomass as well as production of crustacean zooplankton in Dhakuria lake were quite high throughout the year, as compared to freshwaters of temperate regions reported in literature (Patalas 1970, Schindler 1972, Pederson *et al.* 1976). This is quite expected as production is a continuously active process throughout the year in tropical water bodies unlike to temperate freshwaters where active production occurs only during ice free growing season.

Copepod played an important role in the biomass as well as production of total crustacean zooplankton of Dhakuria lake during both years. In 1976-77 more than three-fourth and in 1977-78 about two-third of the biomass of total zooplankton was formed by them. Similarly their production was also higher than cladoceran in both years. This revealed the stability of copepod in the production dynamics of the lake.

It is interesting to note that the bulk of biomass as well as production of total zooplankton was formed by only few species. Two species of copepods, one calanoid, *Haliodiaptomus contortus* and one cyclopoid, *Mesocyclops leuckarti* and two species of cladocera, *Daphnia carinata* and *Ceriodaphnia cornuta* were responsible for all the peak of biomass and production, though each species of cladocera and calanoida dominated during different period. It is further interesting to note that during the period when calanoida dominated, the contribution of cladoceran was at lowest ebb and vice versa. However, during the abundance of cyclopoids, cladocerans were not affected. This is probably due to the fact that both cladocera and calanoida were filter feeder and involved in active competition which either entirely eliminated one group or suppressed considerably its activities. Since cyclopoid, *M. leuckarti* was a seizer and mainly carnivore, it did not compete with cladocera.

The relationship between secondary production specially P/B and trophic status of the lakes has been discussed by many workers during recent years. Patalas (1970), after comparing an eutrophic lake receiving thermal effluent with a similar eutrophic lake as a control alongwith studies on some other lakes, put forward a hypothesis that P/B of crustacean zooplankton tended to increase in proportion to the productivity of the lake hence its eutrophiation. Pederson *et al.* (1976) working on the lakes of Lake Washington watershed could not confirm Patalas's hypothesis. Values of crustacean zooplankton P/B in Dhakuria lake were close to the values obtained by him for eutrophic lakes but being a highly eutrophic water body as revealed by primary poductivity, a very high P/B was expected from Patalas standard which was not so. Since no other information is available from tropical freshwaters, no comparison could be made and hence Patalas's hypothesis can not be definitely confirmed.

Another hypothesis regarding the relationship of secondary production to trophic status of freshwaters has been put forward by Hillbricht-Ilkowska (1972). She postulated that the zooplankton food supply in lakes is used less efficiently as the trophic status moves towards eutrophy, hence the ratio of primary production to secondary production decreases as the trophic status increases. This phenomenon has been attributed to the greater percentage of blue green algae in the richer lakes. These algae are either too large to be efficiently grazed or they pass through the alimentary canal of the grazers without being digested. Results of Hall *et al.* (1970) in experimental ponds and Pederson *et al.* (1976) support this hypothesis. This seems to be quite true in Dhakuria lake where efficiency of energy transfer was only 0.08 or 8%, close to the values reported for high nutrient experimental ponds by Hall *et al.* (1970). Like any other tropical eutrophic water body, the blue green algae formed sizeable proportion of phytoplankton biomass in Dhakuria lake which might have resulted in low transfer efficiency.

One of the very important findings of the present studies is that production process was not at all related to temperature as revealed by insignificant relationship between mean daily water temperature and mean daily P/B in Dhakuria lake. P/B fluctuated throughout the year irrespective of temperature. This is in contrast of majority of the earlier works in temperate waters (Hall *et al.* 1970, Patalas 1975, Duncan 1975, Janieki and De Costa 1977). In fact temperature in tropical freshwaters specially in this region of the country did not fluctuate much from season to season (Dhakuria lake mean daily water temperature 29+4°C, except for very very brief period) and consequently it did not play any important role. Similar insignificant relationship between phytoplankton primary production and temperature has already been reported (Khan 1979).

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