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PRIMARY PRODUCTIVITY AND TROPHIC STATUS OF TWO TROPICAL WATER BODIES OF CALCUTTA, INDIA

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ABSTRACT

The primary productivity of an artificial lake (Dhakuria lake) and a small polluted pond (Monohar Das pond) of Calcutta, India has been studied by classical light and dark bottle technique. With gross primary production rate 1800—(3733)—5600 mg C/m^2- day and annual production of 1364.544 mg C/m^2—year in Dhakuria lake and 7600—(9116)—12000 mg C/m^2—day with annual production of 3509 mg C/m^2—year in Monohar Das pond, both these water bodies have been classified as highly eutrophic. Respiration comprised 46.23% (24—83%) of the total gross production of Dhakuria lake while it was considerably high in the pond 75.15% (42—100%). Productivity was fairly uniform throughout the year with little oscilation except during monsoon months. Significant relationships were observed in case of transparency, pH, conductivity, phytoplankton and zooplankton density in both water bodies. However relationships with alkalinity and hardness were only significant in Dhakuria lake.

INTRODUCTION

Considerable work has been carried out during recent years on the primary productivity of freshwater ecosystems of temperate and arctic regions in order to assess the turnover rate at primary tropic level, community energetics, production capacity, trophic status and impact of human activities upon these water bodies, but such works on tropical waters, is comparatively lesser and scattered. In India Sreenivasan (1964 *a*, 1964 *b*, 1965, 1976), Ganapati and Sreenivasan (1970) and Vijayraghavan (1971) have studied the primary productivity of a number of ponds and reservoirs of Southern India but North Indian water bodies have received little attentions.

The present report, which is a part of the detailed investigations on the production ecology of some freshwater impoundments of this region of the country, deals with primary production, its seasonal variations and relationship with some of the physicochemical and biological factors of two impoundments, one being a large artificial lake (Dhakuria lake) and other a small polluted pond (Monohar Das pond) of Calcutta, India (Latitude 22°30′ N and longitude 88°30′ E).

DESCRIPTION OF THE STUDY AREA

Dhakuria lake is an artifical lake constructed by Calcutta Improvement Trust, 50 years ago. The main lake which is elongated in

shape covers an aproximate area of 72 acres. The maximum length is about 1770 metres, while its width at the broadest point is 282 metres. The perimeter is about 18,000 Rft. Mean depth varies from 10.5 to 9.3 metres. The lake is mainly fed by rain water and is mainly used for recreational purposes. Monohar Das pond is small (*c.* 9050 sq. metre in area and 3.2 metre average depth) and situated in the densely populated area of the city. It is also connected with a sewage drain and used for a variety of purposes, making it highly polluted water body.

Materials And Methods

Plankton primary productivity and respiration were determined by the classical light and dark bottle technique (Garder and Gran 1927). The operation was carried out *in Situ* filling the bottle pairs with water and incubating for 6 hours (9 A.M. to 3 P.M.) at fortnightly or monthly intervals during the period October 1975 to September 1976 in Dhakuria lake and December 1976 to November 1977 in Monohar Das pond. Oxygen was determined by modified Winkler's method and gross photosynthesis was calculated from the differences in oxygen concentration in light and dark bottles while community respiration was calculated from decrease in the oxygen contents in dark bottle as compared to initial reading. Integrating oxygen production/m^3 at various depth, yield/m^2 was determined. Data obtained were converted to terms of carbon using conversion factor of 0.375 and values were expressed as mg C/m^2—day taking the photoperiod of the region (from sun rise to sun set for the respective months) as a day. Surface temperature, pH, Secchi disc transparency, alkalinity, hardness and electrical conductivity were also determined. Physical parameter were evaluated by the techniques of Welch (1948) and chemical analysis followed Standard Methods (APHA 1965). Phytoplankton samples were collected by concentrating 1 litre of water and were preserved by Lugol's solution and counting was done with the help of a Sedgwick Rafter counter under a microscope.

Zooplankton samples were collected with the help of a standard net of No. 21 cloth both by filtering 120 litres of water and by towing from a boat moving at a speed of 3 km. per hour in lake and from the shore in pond. The latter samples were collected only for relative distribution studies. Samples were preserved in 4% formalin. After suitably diluting, the identification and enumeration were done simultaneously by taking three 1 ml. sub-samples in a rectangular glass chamber under a binocular and a mean was obtained.

Results

The gross primary productivity of both the water bodies was considerably high and varied between 1800 and 5600 mg C/m^2 — day with a mean of 3733 mg C/m^2 — day in Dhakuria lake and between 7600 and 12000 mg C/m^2 — day with a mean of 3509.8 mg C/m^2 — day in Monohar Das pond, corresponding to annual yields of 1354.545 gm C/m^2 — year and 3509.840 gm C/m^2—year respectively. The magnitude of primary productivity was about 2.5 times higher in the pond as compared to Dhakuria lake (Table 1).

Definite trend of seasonal variations in gross primary productivity rate were observed in Dhakuria lake and a bimodal pattern of increased producitivity was noticed. The first peak appeared during March and second during November. Relatively low values were noticed during peak monsoon months (July—September) when production rate declined significantly (Fig. 1). Though the production rate in Monohar Das pond was fairly high and consistent during most of the months, a decline in productivity during monsoon months was noticed (Fig. 2). Except these months

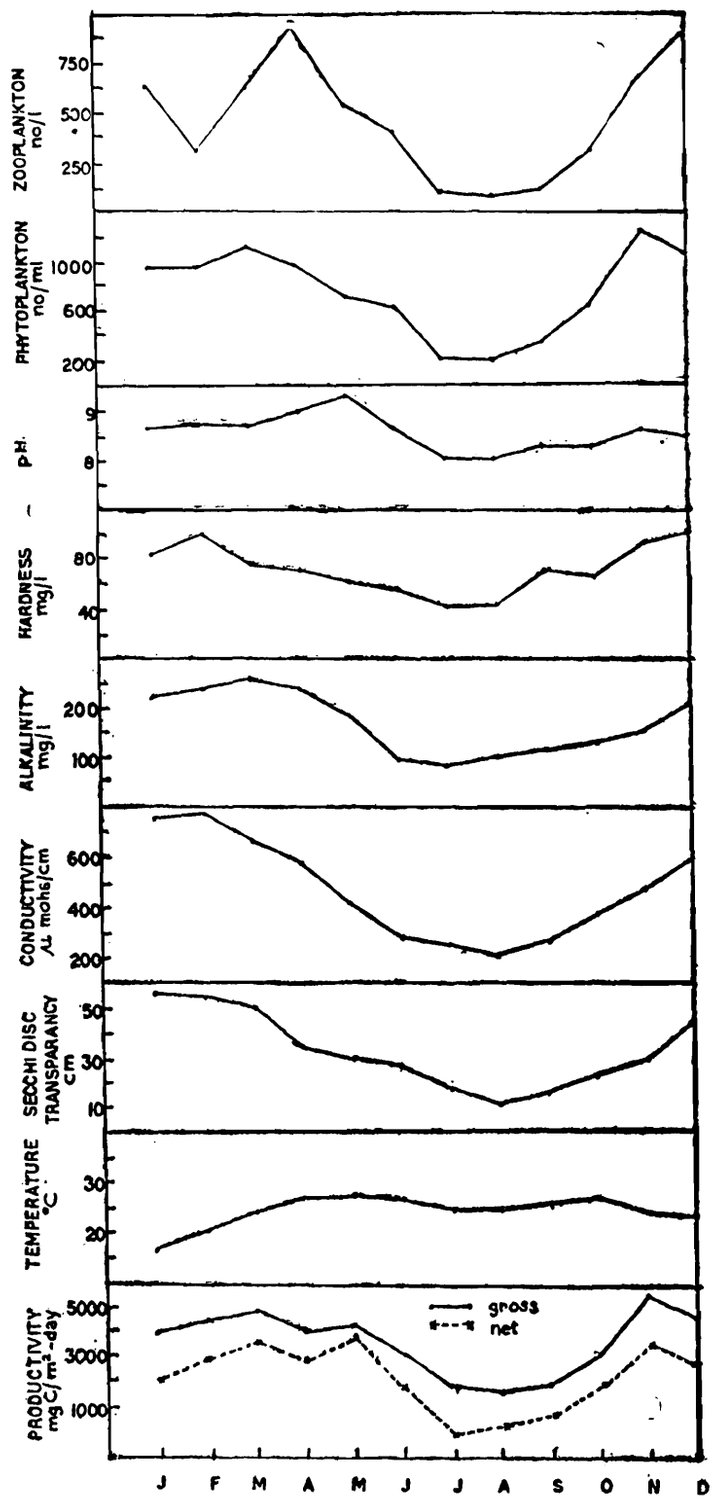

Fig. 1. Seasonal variations in primary productivity and various physicochemical and biological factors in Dhakuria lake.

the productivity was almost uniform throughout the year. Inspite of seasonal variation in the productivity the rate did not fluctuate too much in both the water bodies and maxi-

mum values were only 3 and 1.5 times higher than the minimum values in Dhakuria lake and the pond respectively (Table 1 & 2).

Respiration comprised about 46.23% of the gross production in Dhakuria lake and varied between 24% and 83%. The maximum respiration rate was noticed during peak monsoon months (August) and minimum during March when the gross production was relatively high. Consequently the ratio of net productivity to gross productivity ranged from 0.17 to 0.69. The average annual yield of the net productivity was found to be 568.607 gm C/m²-year. In pond respiration rate was considerably high throughout the year and varied between 40.25% (December) to 100% (July-August). The ratio of the net productivity to the gross productivity ranged from 0.00 to 0.60 with a mean value of 0.24 and annual yield of net productivity was 1000.465 gm C/m²-year.

The seasonal variations in various physicochemical factors in relation to productivity have been shown in Fig. 1. (Dhakuria lake) and Fig. 2 (Monohar Das pond). It is apparent that the Secchi disc transparancy was lower in the pond, total alkalinity, conductivity, hardness and pH were significantly higher as compared to Dhakuria lake. Each of the above-mentioned factors showed clear pattern of seasonal fluctuation in Dhakuria Lake. the values being low during monsoon months (June-September) and high during the period November-April. Almost similar pattern was also noticed in the pond in all the factors execpt in alkalinity and hardness which showed irregular trends. Fluctuations in water temperature in the both water bodies closely followed the air temperature which was governed by the season.

The marked seasonal fluctuations were noticed in the occurrence and density of phytoplankton and zooplankton of both the water bodies, the pattern of fluctuation being somewhat similar to most of the physicochemical factors. The phytoplankton and zooplankton concentration were considerably high in the pond as compared to Dhakuria Lake. The phytoplankton composition of Dhakuria Lake was dominated by green algae (40%) followed by diatoms (34%), while the share of blue green algae was only (20%). In pond the composition was dominated by blue green algae (55%) and a permanent bloom of *Microcystis aeruginosa* was observed. Green algae consituted only (20%) and diatoms 18%. The zooplankton concentration in the pond was fairly high and dominated by only few species of Cladocera and Copepoda. Two cladoceran speeies *Ceriodaphnia cornuta* and *Daphnia carinata* were found to be dominant species of zooplankton and a condition resembling to the swarming of these two species were observed during different periods of the year. In Dhakuria Lake the zooplankton were thinly distributed as compared to the pond.

The relationships between various physicochemical and biological factors and gross primary productivity (by computing the coefficient of correlation) (Table 1), was found to be significant in Dhakuria Lake in relation to Secchi dise transparency (r=0.727), pH r=0.578), conductivity (r= 0.765), alkalinity (r=0.887), pH (r=0.578), phytoplankton (r = 0.972) and zooplankton (r=0.903). The relationship between gross primary productivity and temperature was highly insignificant (r=0.080). In pond while the productivity was significantly related to transparency (r=0.621), conductivity (r=0.980), pH (r= 0.672), phytoplankton (r=0.846) and zooplankton (r=0.900), the relationships with alkalinity (r=0.377) and hardness (r=0.547 were not significant. The relationship with temperature was also highly insignificant (r=0.080).

Discussion

The classification of the trophic status of

TABLE 1. Seasonal variation in Primary Productivity of Dhakuria lake & Monohar Das pond.

Months	Dhakuria lake					Monohar Das pond				
	Gross Primary productivity mg C/m^2-day	Community Respiration mg C/m^2-day (24 hrs.)	net productivity mg C/m^2-day	Respiration as % of gross	net gross ratio	Gross primary productivity mgC/m^2-day	Community Respiration mgC/m^2-day (24 hrs.)	net production mg C/m^2-day	Respiration as % of	net gross ratio
Jan.	4000	1900	2100	47.56	0.52	12000	7500	4500	62.50	0.37
Feb.	4600	1700	2900	37.00	0.63	12000	6200	5800	51.66	0.41
Mar.	5000	1300	3700	24.00	0.76	10300	7800	3000	70.87	0.29
Apr.	4200	1300	2900	31.00	3.69	9500	8000	1500	84.21	0.16
May,	4400	1600	3800	36.33	0.64	9000	7900	1200	80.66	0.19
Jun,	3200	1400	1800	43.75	0.56	8300	8300	0000	100.00	0.00
Jul.	2000	1500	500	75.00	0.25	8000	8000	0000	100.00	0.00
Aug.	1800	1500	300	83.30	0.17	7600	7600	0000	100.00	0.00
Sep.	2000	1200	800	60.00	0.40	8000	7600	400	95.00	0.05
Oct.	3200	1200	2000	37.50	0.63	9500	5500	6000	57.90	0.42
Nov.	5600	2000	3600	35.76	0.64	10200	4200	0000	58.82	0.41
Dec.	4800	2100	2700	43.60	0.56	11000	4500	6500	40.25	0.60
Annual mean	3733	1558	2175	46.23	0.537	9616	6875	2741	75.15	0.248

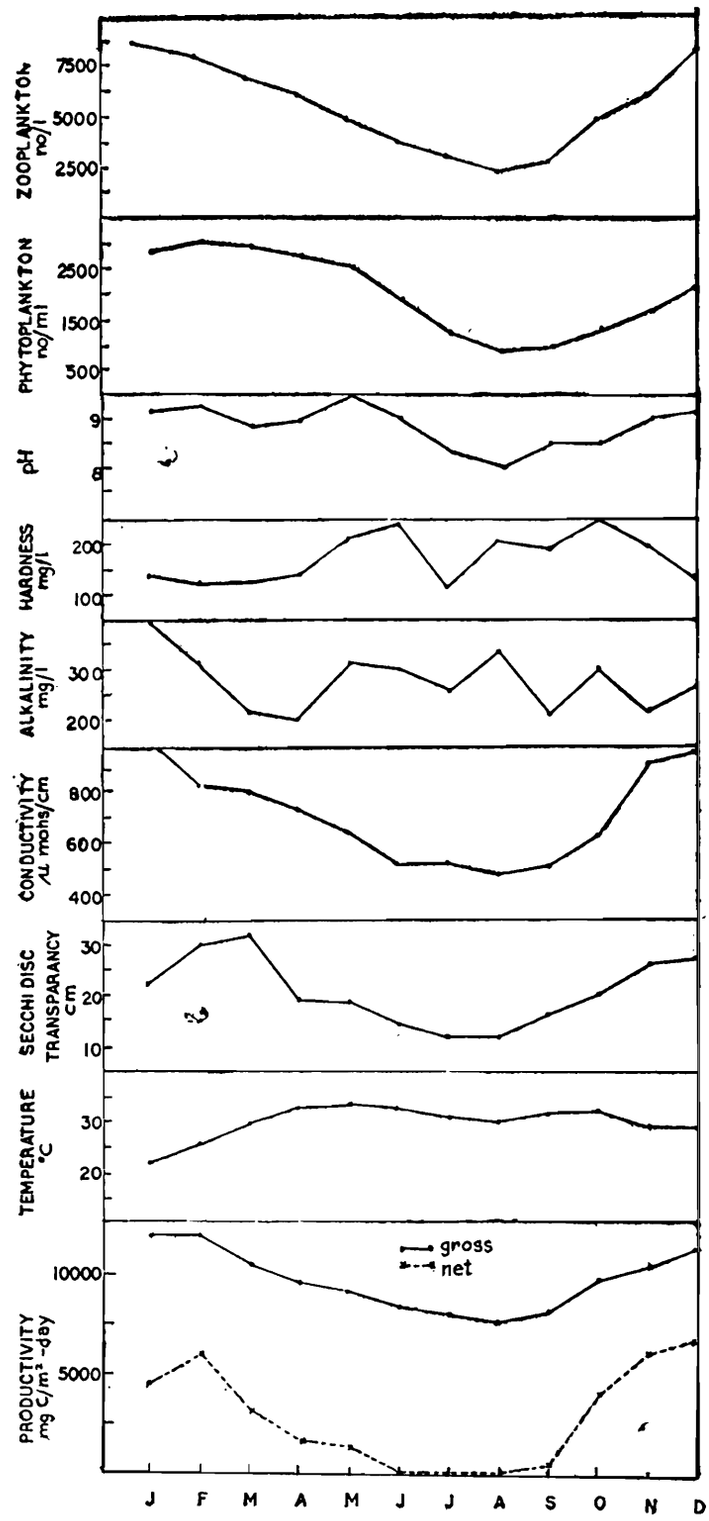

Fig. 2. Seasonal variation in primary productivity and various physicochemical and biological factors in Monohar Das pond.

European water bodies in relation to productivity has been given by Vallenweider (1968) and Rodhe (1969). According to former author, a lake having a primary

productivity rate of 65—300 mg C/m²-day is oligotrophic, 250-1000 mg C/m²-day is mesotrophic and 1000-8000 mg C/m²-day is eutrophic, while latter worker gives the values of 30-100 mg C/m² -day for oligotrophic 300-1000 mg C/m² --day for natural eutrophic and 1500-3000 mg C/m²-day for polluted water bodies. Gessner (194) reported that the gross primary productivity of temperate eutrophic lakes varies between 500 and 5000 mg C/m²-day. With gross primary productivity rate of 3733 (range 1800--5600) and 9116 (range 7600--12000) mg C/m²-day, both Dhakuria lake and Monohar Das pond can be classified as highly eutrophic water bodies. Values are well above the limit fixed by above workers. Very high productivity rate of tropical water bodies have been reported by a number of workers. (Talling 1965, Falconer *et al.* 1970, Ganapati and Sreenivasan 1970, Vijayraghavan 1971 and Ganf 1972). It appears that in general extremely high productivity is an important feature of tropical eutrophic water bodies. These may be due to uniformly high temperatures, greater intensity of solar radiation and absence of a critical winter season. In fact, temperature and light are never a limiting factor under tropical conditions and the addition of small amount of nutrient will greatly increase the productivity (Marshall and Falconer 1973).

High production rates have been recorded both from temperate as well as tropical regions under specialized conditions, *e.g.* sewage ponds (Bartsch 1960), fertilized ponds (Hepler 1962) and refinery ponds (Copeland and Dorris 1962). The highly eutrophic nature and high productivity of Monohar Das pond can be attributed to its small size and high load of organic pollution caused by sewage as well as indiscriminate and intensive use made by the dense human population surrounding it. The presence of permanent bloom of blue-green algae in the pond also signifies its highly eutrophic nature. The effect of human activities is not as marked in Dhakuria lake as in the pond. This is due to the fact that Dhakuria lake covers a relatively larger area and is well managed. Human interference is very much restricted.

Contrary to the temperate waters where the seasonal variations in the primary productivity are considerably high, and maximum values, during summer being as high as fifty times ; in tropical water production remains moderate throughout the year with little oscillation (Hulbart *et al.* 1960, Prasad and Nair 1963 and Qasim *et al.* 1969). This is clearly evident from the present study also. Inspite of clear pattern of seasonal fluctuations in the two water bodies, production was fairly uniform throughout the year except during few monsoon months and the maximum values were not more than 3 and 1.5 times higher than minimum values in Dhakuria lake and Monohar Das Pond respectively. The low values during monsoon months were probably due to heavy rain which resulted in the increased turbidity and considerable dilution of the water. Similar effects of heavy rain on phytoplankton and zooplankton density have been reported by Ray *et al.* (1966).

In the absence of marked change in the temperature in tropical region different patterns of seasonal variations in productivity have been observed in different water bodies depending upon the local conditions and a generalization seems to be difficult. However Ganapati and Sreenivasam (1970) have tried to generalize the seasonal variations in the productivity of few south Indian water bodies and observed that the order of magnitude of production seasonwise was almost same in different water bodies, maximum during hot season and minimum

TABLE 2. Relationship between gross primary productivity and variation physicochemical and biological factors.

Factors	Dhakuria lake			Monohar Das Pond		
	Correlation coefficient	Degree freedom	Probability	Correlation coefficient 'r'	Degree of freedom	Probability
1. gross primary productivity and Zooplankton	0.080	10	more than 0.1*	0.009	10	more than 0.1*
2. gross primary productivity and Secchi disc transparancy	0.723	10	less than 0.01	0.621	10	less than 0.05
3. gross primary productivity and conductivity	0.765	10	less than 0.01	0.980	10	less than 0.001
4. gross primary productivity and total alkalinity	0.887	10	less than 0.001	0.377	10	more than 0.01*
5. gross primary productivity and hardness (Caco$_3$)	0.786	10	less than 0.01	0.547	10	more than 0.05*
6. gross primary productivity and pH	0.578	10	less than 0.05	0.672	10	less than 0.05
7. gross primary productivity and phytoplankton	0.972	10	less than 0.001	0.846	10	less than 0.001
8. gross primary productivity and zooplankton	0.963	10	less than 0.001	0.900	10	less than 0.001

* Not significant

during cold season. This is in contrast to present observations where minimum values were recorded during monsoon months.

The annual net productivity and respiration of freshwaters have been found to vary considerably. While Ganapati and Sreenivasan (1970) found that the gross productivity was more in smaller water bodies as compared to large man made lakes, the order is found to be reverse in the present case, productivity being higher in Dhakuria lake than the pond. Similarly respiration rate in the pond was high throughout the year and during monsoon months, when dark clouds and heavy rains were common, it was cent percent of the gross production. Similar conditions have also being reported from other tropical water bodies (Prowse 1969, Ganapati and Sreenivasan 1970 and Vijayraghavan 1971). Ganapati and Sreenivasan (1970) suggested that such condition indicates a shift in photosynthetic oxygen production where respiration exceeds production.

Among the factors affecting productivity temperature has been reported to be the most important. This may be true in temperate waters, where it is detrimental, but in tropical waters, at least in this region of the country, it does not seem to play any important role. During present study it was found that rate of production increased and decreased irrespective of the fluctuations in temperature. A highly significant correlation coefficient between temperature and productivity in both the water bodies further supported the view.

Relationship between transparency, electricical conductivity and pH and primary pro-

ductivity are well known Juday, *et al.* 1924, Philip (Rodhe 1949, Vallenweider 1963. 1927). Similarly during present study high productivity and direct significant correlations were observed in both ponds during the period when conductivity transparency and pH were high. Alkalinity was only significant in Dhakuria lake. Though considerably high alkalinity was observed in the pond throughout the year, it was not related to the productivity. It appears that alkalinity was always well above the required limit. Phytoplankton and zooplankton were also found to be significantly related to the productivity but a definite conclusion can not be drawn as the relationship was established between the number of plankton and productivity, not the biomass or chlorophyll content. This requires further investigations.

It is not easy to correlate the productivity with any single physical, chemical or biological factor as productivity of an ecosystem is governed by a complex of factors acting simultaneously. However, a gross idea can be obtained.

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