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POPULATION DYNAMICS, BIOLOGY AND PRODUCTION ECOLOGY OF A LITTORAL ZOOPLANKTER, *CHYDORUS SPHAERICUS* (O. F. MÜLLER) (CLADOCERA : CHYDORIDAE)

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ABSTRACT

The population dynamics, biology, biomass, production and turnover ratio of a littoral chydorid cladocera, *Chydorus sphaericus* (O. F. Müller) were studied in a large man made lake of Calcutta for 2 years (1978, 1979). The population density was high throughout the year with two peaks, during April-May and November-December, in both years. Minimum values were recorded in August which were related to heavy rain flooding of the lake resulting in the displacement of vegetation from the littoral zone. Reproduction took place by parthenogenetic females throughout the year and juveniles always dominated the population composition. In laboratory the total life span of 14.1 days was completed in 12 instars producing at an average 51.3 eggs/female.

Biomass and production values ranged respectively between 54-523 ($\bar{x}$ 271) mg dw/m^2 and 5.3–98.1 ($\bar{x}$ 57.83) mg dw/m^2-day in 1978 and between 220–380 ($\bar{x}$ 276) mg dw/m^2 and 19.6–43.6 ($\bar{x}$ 60.79) mg dw/m^2-day in 1979. The mean turnover ration for both years were very close (0.190 in 1978 and 0.205 in 1979).

INTRODUCTION

Whereas, among cladocera, daphnids have been the subject of numerous investigations during the last 3 decades and considerable work has been carried out on their population dynamics, life cycle, bioenergetics and impact of complex environmental factors both in field and laboratory (McArther and Baillie 1929, Berg 1934, Banta *et al.* 1939, Ingle *et al.* 1937, Brooks 1946, Edmondson 1955, Green 1956, Richman 1958, Regler 1961, Hall 1964, Schindler 1968, Beukema 1973, Vijverberg 1976, Murugan and Sivramakrishna 1976), not much attention has been given to other groups of cladocera, specially to littoral Chydorids. Few accounts which are available deal with general taxonomy and ecology of chydorids in littoral zone (Smyly 1952, Smirnov 1963a, b, 1974, Goulden 1971).

Chydorids as a littoral taxocene are ecologically diverse and play an important role in the productivity of littoral zone of freshwater impoundments, which is the most productive zone. Because of abundance of submerged vegetation, reduced penetration of light and reduced temperature, the condition in littoral zone are different from open water.

The present study which is a part of a detailed investigation on population and

production ecology of tropical littoral fauna, describes the population dynamics, biology, biomass production and turnover, ratio of *Chydorus sphaericus* (O. F. Müller) in a large man made lake of Calcutta, India. Laboratory studies have also been carried out to determine instar duration, life span, growth rate and reproduction. *C. sphaericus* is the most common cladocera found all over the world (Brooks 1959).

Materials and Methods

The study was carried out in Dhakuria lake, Calcutta, a large man made lake already described by Khan (1979, 1981). The samples were collected at fortnightly intervals from the littoral zone at 3 different centres of the lake. Hundred litres of water were filtered from the plant bed through a plankton net made of No. 21 cloth. In the laboratory, the chydorids were separated from detritus by settling the samples in a beaker and slightly heating the bottom. Chydorids swam up into the overlying water which was decanted from the beaker and concentrated with a net. Filtered samples were preserved in 4% formalin and adjusted to 100 ml. Identification and enumeration were done simultaneously under a binocular microscope with varying magnifications (SM × 20) by taking several 1 ml subsamples. After general counting, each individual of *C. sphaericus* was separated and measured from the crown of the head to the posterior border of the carapace with the help of an ocular micrometer. Eggs (including embryos) in the brood pouch were counted after dissecting the brood pouch. Laboratory studies were carried out in December 1978-February 1979 when the conditions were most favourable and laboratory temperature fluctuated around $25 \pm 3°$ C. Stock culture was maintained by keeping several parthenogenetic females collected from Dhakuria lake in a 3 litre Jar containing lakewater filtered through No. 25 net so as to remove all other zooplankton but include all phytoplankton, bacteria and detritus. All experiments were carried out in such water. Neonates, after their release, were taken out and cultured separately in small petridishes containing 80 ml water. Petridishes were examined daily and records of developmental duration, growth, number of youngones produced and total life span were made. Four successive generations of each original parent were studied.

For the determination of biomass and production, the animals were divided into 5 groups, *viz.* eggs, neonates, juveniles, adult I and II and biomass was determined by multiplying the number of each group present in the sample to the mean dry weight of the group and summing up. Mean dry weight of each group was determined only once in the beginning. About 500 animals of each group were dried at 65° C for 3 days and weighed on a microbalance and the mean individual weight was calculated.

Production was determined by the method of Petrovich *et al.* (1964) and Ivonova's given in Edmondson and Winberg (1971) as :—

$$P = \frac{N_i\ W_i}{t_i} + \frac{N_{ii}\ W_{ii}}{t_{ii}} + \frac{N_n\ W_n}{t_n}$$

where P is production in dry weight per day, N_i , N_{ii} and N_n are mean number of individuals in each group, W_i , W_{ii} and Wn are the mean dry weight of the group and t_i , t_{ii} and t_n are the development time of each group. The results obtained under

laboratory conditions on instar duration were used.

Daily production can be raised to production rates over longer times :—

$$\frac{P_1+P_2}{2}(t_2-t_1)+\frac{P_2+P_3}{2}(t_3-t_2)$$

$$\frac{+P_{n-1}+P_n}{2}(t_n-t_n-1)$$

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

RESULTS

Population Cycle

Chydorus sphaericus was the most abundant chydorids of Dhakuria lake and occurred abundantly throughout the year. Except for a brief period of monsoon months (July and August), its density was always high. It surpassed in density to all other littoral cladoceran species and contributed at an average 38% and 42% of total littoral cladoceran population in 1978 and 1979 respectively (Fig. 1b). Its density fluctuated between 6/L (August) to 150/L (April) with an average of 80/L in 1978 and 25/L (August) 140/L (May) with an average of 85/L in 1979. Though several small and large peaks were visible, two peaks in each year (April and November in 1978 and May and December in 1979) were most conspicuous (Fig. 1a). The juveniles always dominated adults in both years and contributed about 71.5% and 76% in 1978 and 1979 respectively. In fact the population maxima of the total population were directly caused by the production of large number of juveniles in the population (Fig. 1c).

Reproduction

Only parthenogenetic reproduction occurred in Dhakuria lake and neither males nor ephippial females were observed. Reproductive activity was considerably high throughout the year, except during July and August, with two periods of heavy reproduction (Fig. 2a, b), resulting in high population density during both years as already mentioned.

The brood size expressed as egg number per brood varied between 3.5-6.6 ($\bar{x}$ 5.35) in 1978 and 3.3-7.0 ($\bar{x}$ 5.37) in 1979 (Fig. 2a). The size of breeding individuals was also not found to vary much between the two years and ranged between 3.8 to 5.0 ($\bar{x}$ 4.0) in 1978 and 3.6 to 5.2 ($\bar{x}$ 4.2) in 1979 (Fig. 2b).

Laboratory Studies

The parthenogenetic eggs were laid in brood pouches immediately after molting. Within a few hours, eggs swelled in brood pouches and became oval and started developing. The development took place in 3 major phases (1) egg phase (no segmentation), (2) first embryo stage (segmentation but no eye) and (3) second embryo stage (appearance of eye). The entire development was divided into six stages following Green (1956) with some modifications.

		Duration of Stage
Stage I	—Egg roundish or slightly flattened, transparent outer margin.	2 hours
Stage II	—Egg slightly enlarged and flattened with a creak.	3 hours

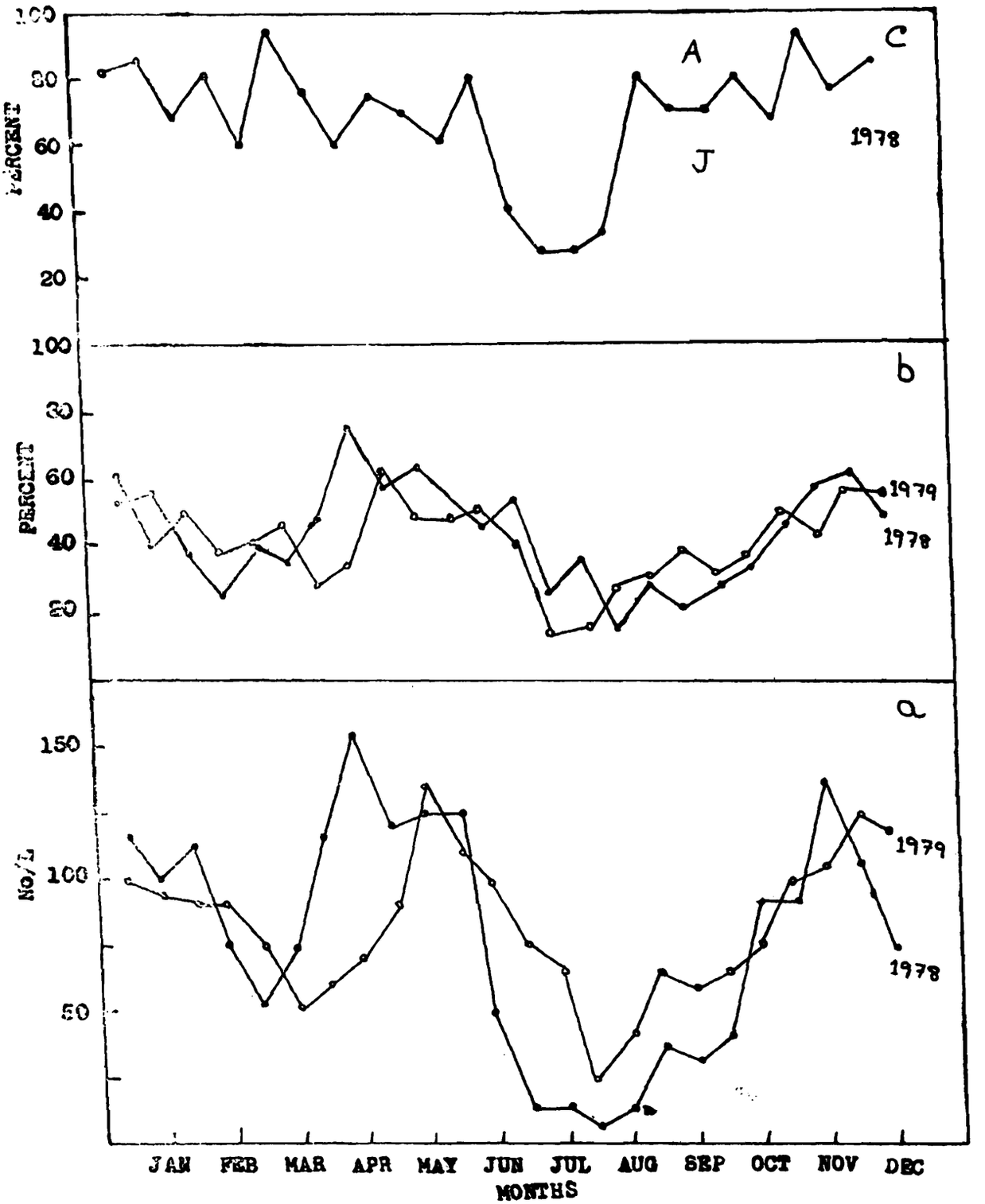

Fig. 1. Seasonal fluctuation (a) mean density (b) percentage of total littoral cladocera, (c) percentage of juveniles and adults of *C. sphaericus*.

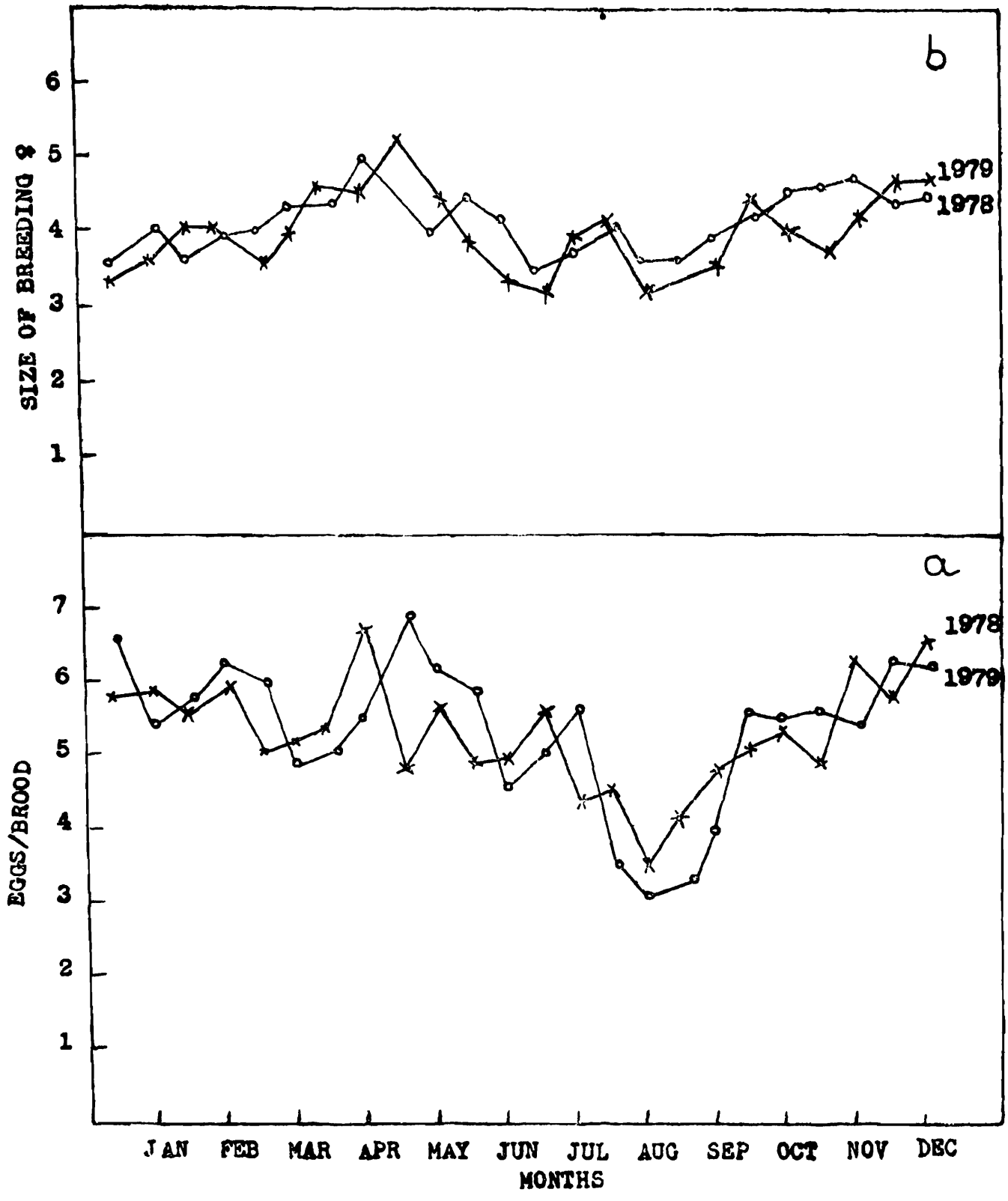

Fig. 2. (a) Eggs/brood of *C. sphaericus* in different months.
(b) Size of breeding females of *C. sphaericus* in different months.

		Duration Stage
Stage III	—Elongated with head rudiments, second antennae became separated.	4 hours
Stage IV	—Head bulge distinct, antennae elongated.	5 hours.
Stage V	—Antennae elongated, thoracic appendages developed, eye spot appeared.	6 hours.
Stage VI	—Fully developed embryo with dark eye, like adults.	8 hours.

Instar duration, growth rate and life span

Neonates released from mother resemble in every respect to adults, except that their sizes were small and they did not possess eggs in egg sacs. Each individual passed through at an average 2 preadult and 10 adult instars (Table 1). The average size at the time of birth was 1.4 mm Growth took place after each molting Growth rate was rapid at earlier stages and gradually slowed down as age increased but continued throughout the life. The maximum size of the females observed was 0.51 mm. The durations of instars were small in preadults and early adults but increased afterwards and finally became almost constant. The mean total life span covering 12 instars (pre- and post-) was found to be 14.1 days. The duration of first adult instar was longer than any of the preadult instars.

Egg production, size and age

The first batch of eggs were laid into brood pouches immediately after the individuals molted into adult instar. The number of eggs per brood was few at the beginning and increased gradually during successive instars (Table 1). The Maximum number of egg/ brood was found to be 6.8 produced by the

TABLE 1. Instar duration, size, age, brood size and cumulative fecundity of *C. sphaericus*

Instar	size (mm)	Duration (hours)	Age (days)	No. of youngone produced	Cumulative fecundity
1	1.4	20	0.833	—	—
2	2.1	22	1.750	—	—
3	2.7	26	2.830	2.0	2.0
4	3.2	28	4.000	3.2	5.2
5	3.6	28	5.170	4.2	9.4
6	4.0	30	6.420	4.8	14.2
7	4.4	30	7.970	5.4	19.6
8	4.7	32	9.000	5.8	25.4
9	4.9	30	10.250	6.1	31.5
10	5.0	32	11.580	6.4	37.9
11	5.1	30	12.83	6.6	44.5
12	5.2	3.0	14.08	6.8	51.3

oldest female (12th instar). The total number or eggs produced by an individual female was 51.3. A gradual increase was observed, when cumulative egg production was plotted against instar number. When a log/log plot was made by converting into logerithms, a straight line relationship was observed.

Length weight relationship

Length weight relationship of individuals obtained from Dhakuria lake was determined. The relationship was exponential. Regression analysis of the Log weight on Log length gave a straight line relationship with 'b' value of 2.707, significant at 5% level. The length weight relationship equation was :—

$$\text{Log } W = -0.865 + 2.707 \text{ Log } L$$

where W and L are weight and length respectively.

Biomass, productivity and turnover ratio

Like density, the biomass was also high throughout the year, in both years, except in July and August when the values were minimum. While in 1978, the biomass fluctuated widely, in 1979 it was somewhat constant and fluctuated narrowly, except in June and November when small peaks were noticed (Fig 3). Biomass ranged between 54-523 ($\bar{x}$ 271.4) mg. dry weight/m^3 in 1978 and between 220-380 ($\bar{x}$ 276) mg dry weight/m^3 in 1979. It is very surprising to note that inspite of variations in the biomass patterns of the two years, the mean values were very similar.

Since the biomass pattern was chiefly influenced by the abundance of young ones in the population, the pattern of productivity was almost similar. Mean daily productivity values ranged between 5.3-98.1 ($\bar{x}$ 57.83) mg dry weight/m^3-day in 1978 and between 19.6-43.6 ($\bar{x}$ 60.79) mg day weight/m^3-day in 1979. While the contribution of juveniles in the biomass was only 30% in 1978 and 33% in 1979, they contributed to the bulk of production (72% and 79% in 1978 and 1979 respectively). The turnover ratio (P/B) varied between 0·098-0.276 ($\bar{x}$ 0.190) in 1978 and between 0·082-0.344 ($\bar{x}$ 0.205) in 1979.

DISCUSSION

The consistant occurrence of *C. sphaericus* in sufficient numbers throughout the year, with continuous active reproduction, revealed that the species is well adjusted to Dhakuria lake. The little variations in population fluctuation and mean density from year to year also indicated its stability. Among many factors governing the zooplankton cycle in littoral zone, the submerged vegetation has been reported to play an important role (Keen 1976). The dominant littoral vegetation of Dhakuria lake was the alga, *Chara fragilaris*, which was present abundantly throughout the year except during monsoon months (July-August) when heavy rain caused flooding of the lake and its removal from littoral zone. This has resulted in the reduced density of *C. sphaericus* in monsoon months of both years.

No indication of competition between *C. sphaericus* and other littoral chydorids was found as the occurrence of all other species followed their own course. Probably, as Fryer (1968) observed, because of greater diversity of habits of chydorids, the competitive interaction was reduced.

Temperature, the most important factor governing the cyclic occurrence and abundance

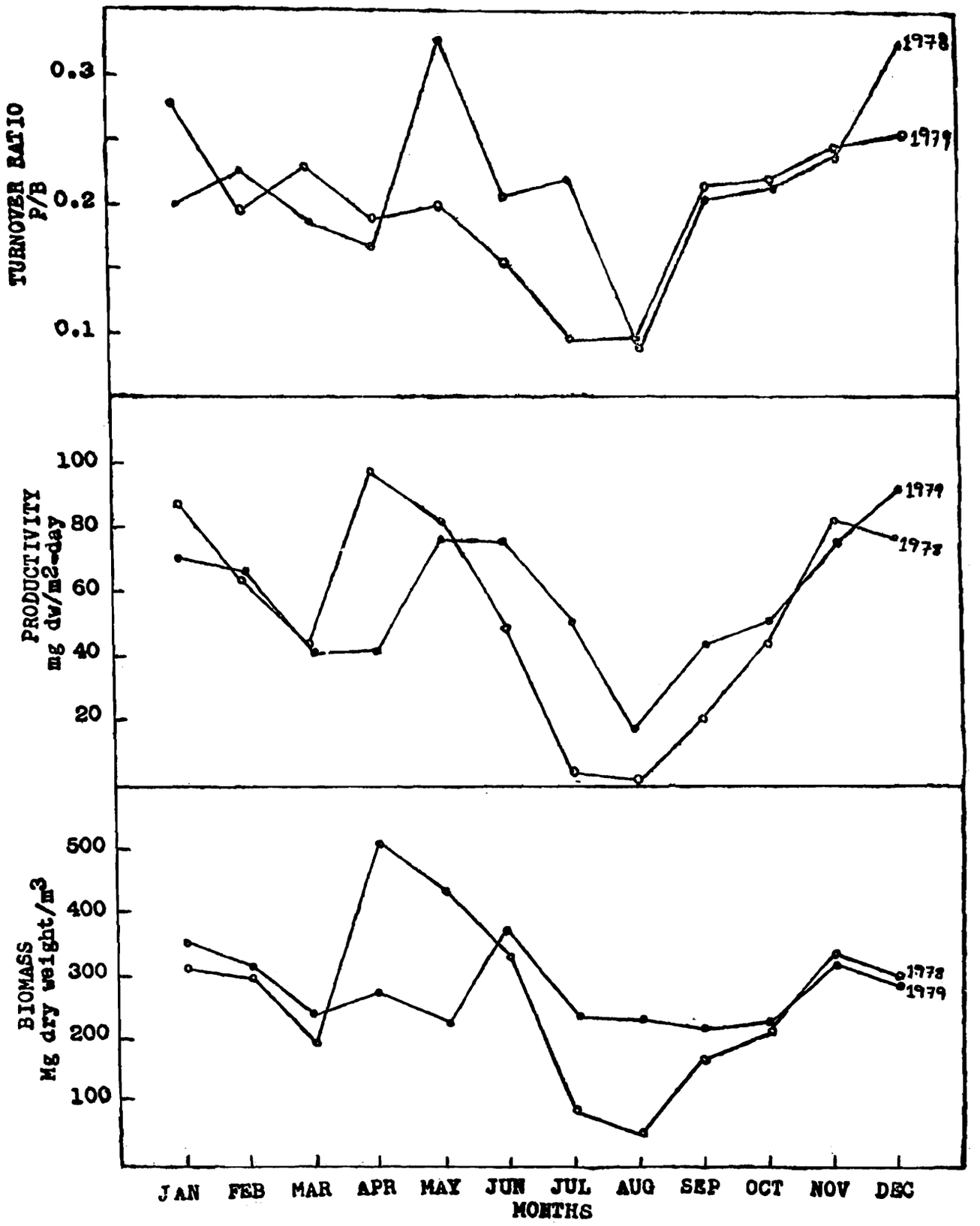

Fig. 3. Biomass, production and turnover ratio of *C. sphaericns*.

of zooplankton in temperate waters (McArther and Baillie 1929, Hall 1964), was of not much significance to *C. sphaericus* in Dhakuria lake. The population density and biomass increased and decreased irrespective of mean monthly temperature. As already discussed in case of primary and secondary productivity of Dhakuria lake (Khan 1979, 1981), the temperature in this region of country did not fluctuate much from season to season, so as to become limiting at any time of the year.

The fact that population density of *C. sphaericus* has never gone down considerably except during monsoon months, following the loss of suitable vegetation bed, suggests that sufficient food was available all the year round and the carrying capacity of the lake in term of food (of *C. sphaericus*) was never reached. This was quite expected. Being a highly eutrophic water body having rapid rate of primary production and continuous decay, the phytoplankton and detritus were available all the year round in abundance. The peak production of phytoplankton during April-May and November-December also resulted in increased density and biomass of *C. sphaericus* during the period suggesting its relationship with food. Most probably the predation pressure was the factor which kept the population of *C. sphaericus* in size and did not allow it to grow enormously.

The absence of either male or epihippial females also suggests that conditions were always favourable since only under unfavourable conditions like temperature above and below the optimum range, food shortage and overcrowding, the sexual reproduction and encystment occur in cladocera (Berg 1931).

The pattern of embryonic development and instar duration was almost similar to general pattern as seen in cladoceran (Edmondson 1955, Green 1956, Murugan 1975). However, the duration of instars and total life span was considerably shorter than that of most of the temperate as well as tropical limnetic species of cladocera. The littoral chydorids have probably shorter life span. The pattern of growth rate was also basically similar to those in other species of cladocera in the respect that growth was rapid at early ages and decreased gradually as the age increased. (McArther and Baillie 1929, Anderson *et al.* 1937, Ingle *et al.* 1937, Banta *et al.* 1939, Green 1956, Richman 1958, Hall 1964, Vijverberg 1976, Murugan and Sivaramakrishna 1976) but it continued till death and no cessation of growth was found as reported in some species (Banta *et al.* 1939, Richman 1958).

The production and turnover ratio of *C. sphaericus* in Dhakuria lake was considerably higher than many of the species studied in temperate waters. The high production rate was due to rapid and continuous reproduction and availability of juveniles in the population throughout the year which accounted for 75% of the production rate.

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