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THE POPULATION AND PRODUCTION ECOLOGY OF THE CYCLOPOID COPEPOD, *MESOCYCLOPS LEUCKARTI* (CLAUS) IN A SMALL POND

RASHID A. KHAN

Zoological Survey of India, Calcutta

ABSTRACT

The population structure, dynamics, biomass and secondary productivity of a cyclopoid copepod, *Mesocyclops leuckarti* (Claus) have been studied in a eutrophic pond and in the laboratory. The species occurred abundantly throughout the year with the dominance of copepodite stages and nauplii always ranking second inspite of high birth rate. The developmental duration, as determined in the field (egg 3, naupliar 11, copepodite 20, adult 33 and total life span 67 days) did not differ much from the laboratory data (egg 3, naupliar 8, copepodite 18, adult 46 and total life span 75 days). Maximum growth of active instars took place at copepodite I. Reproductive activity, as determind by size of the breeding population, egg stock, clutch size and population birth rate, was continuously high throughout the year and four generations, spread over the entire year, could be detected. Reproduction and development did not appear to be affected by any of the prevailing environmental factors in the pond which revealed the high adaptibility of the species.

Mean daily biomass and daily production were also high throughout the year and mean values were 61.6 mg dw/m^3 and 4·775 mg dw/m^3 $^-$day for biomass and production respectively, Mean daily P/B ratio fluctuated between 0·037 and 0·102 with a mean of 0.062.

INTRODUCTION

Inspite of the fact that researches on dynamics of zooplankton have long been shifted from merely descriptive study of their numerical fluctuations with seasons or their simple relationship with some physicochemical factors of the environment, to the exact structure and dynamics of the population of each species and its contribution to the production and energy flow to the ecosystem abroad, in India researches are still in preliminary stages. This has necessitated the detailed study of the population and production ecology of various zooplankton species in our tropical freshwaters, which differ markedly from temperate waters in several aspects. The present work has been carried out in a typical small pond of Calcutta in eastern India in order to work out in detail, the developmental duration, annual cycle, structure of population, reproductive activity, biomass and secondary productivity of a cyclopoid copepod *Mesocyclops leuckarti* (Claus). Laboratory studies were also carried out on instar duration, growth and fecundity.

Mesocyclops leuckarti is a cosmopolitan freshwater copepod species distributed widely throughout the world. Inspite of differences in salinity, temperature and associated organisms in waterbodies of different regions, this species seems to be well established over a very large part of its range indicating its high adaptibility (Hutchinson 1967, Gophen 1978b).

MATERIALS AND METHODS

Studies were carried out in Monohar Das pond of Calcutta, a small highly eutrophic pond already described (Khan 1979). Though studies were carried out for many years, the present report deals with the period November 1976 to October 1977. During November and early December sampling was done at alternate days in order to trace the development of various instars, and thereafter at fortnightly intervals. Zooplankton were collected by filtering 100 litre of water through a standard plankton net made of No. 21 cloth from 3 different centres of the pond. Samples of all the three centres were mixed together so as to obtain only one sample for particular sampling day and screened through several cloths of varying mesh sizes in order to facilitate species or sizewise separation. Samples were preserved in 4% formalin. In laboratory, samples were appropriately diluted and several 1 ml. sub-samples were examined under a binocular with varying magnifications. Identification and enumeration of total zooplankton and separation of each of the *Mesocyclops leuckarti* were done simultaneously. The size of each of stages was measured with the help of an ocular micrometer. Stages were recognised by the appearance and state of development. Since no other cyclopoid was present in sufficient number, When *M. leuckarti* dominated, not much difficulty was encountered. The development and duration of various instars in the field were determined by calculating the time interval between occurrence of peaks of two subsequent stages (Comita 1956). In laboratory pairs of adult *M. leuckarti* were kept in small petridishes containing 50 ml filtered water. Water was filtered so as to remove only crustacean zooplankton and rotifers and protozoan remained. Immediately after their release, eggs were taken out and as soon as first nauplii appeared, they were separated and kept in separate petridishes. Petridishes were examined daily and records of developmental duration of egg and various instars, total life span and fecundity were made. The temperature range in the laboratory was 28±3°C, very close to that found in the pond water for major part of the year.

The size of breeding population was recorded by establishing the ratio of ovigerous female to the total female population, clutch size was established by counting the number of eggs/sacs for atleast 20 animals, egg stock of the population was calculated by multiplying the mean clutch size to mean number of ovigerous females and number of eggs in each clutch were recorded in laboratory and individual fecundity was worked out. Number of clutches produced by females in the pond was recorded indirectly by dividing the number of ovigerous females to egg development time (Chapman 1969). The reproductive rate was determined by calculating the eggs/female/day as suggested by Edmondson *et. al.* (1962) by formula $B=\frac{E}{D}$, where B is population birth rate, egg/♀/day, E is egg ratio observed in population as egg/♀ and D is duration of development. Egg ratio was derived by dividing the number of eggs by total number of ovigerous females.

The mean dry weight ($\overline{W}$) of each individual belonging to various developmental stages was determined by drying at least 300 individuals of the particular stage at 50°C for 2 days and weighing on a microbalance. The mean individual weight ($\overline{W}$) was worked out. All precautions were taken as suggested by Winberg (1971). For biomass and production studies, various instars were grouped in following 7 categories, egg, nauplii I-III, copepodite I—III.

TABLE I —Occurrence of peak, estimated duration, size and weight of various stages of *M. leuckarti* in pond and in laboratory.

Stages	Pond Animals			Laboratory Animals		
	Occurrence of Peak	Duration (days)	Size in mm	Duration (days)	size in mm.	Mean individual dry weight mg$\times 10^{-3}$
Egg	4.11.76	3	0.078	3	0.080	0.026
NI-III	7.11.76	3	0.175	2	0.185	0.055
N-IV	10.11.76	3	0.220	2	0.240	0.082
N-V	13.11.76	2	0.285	2	0.300	0.120
N-VI	15.11-76	3	0.330	2	0.370	0.160
CI	18.11.76	3	0.400	2	0.430	0.290
CII	21.11.76	3	0,522	3	0.580	0.410
CIII	24.11.76	4	0.680	4	0.700	0.540
CIV	28.11.76	6	0.860	5	0.880	0.780
CV ♂	4.12.76	4	1.010	4	1.050	0.930
♀			1.090		1.180	1.600
CVI ♂	8,12.76		1.100		1.160	1.300
♀			1.210		1.250	2.900
(Adults) Subsequent minimum in adult population of pond or period after which lab. animals died.	10.1.77	33		46		
TOTAL LIFE SPAN		67		75		

copopodite IV-V, adult male and female. The daily biomass was obtained by multiplying the number of individuals in each group (N) and mean dry individual weight ($\overline{W}$) of that group and summing up all groups. Daily production was determined by the method of Greze and Baldina (1964) as described by Winberg (1971). Absolute growth increment and specific growth rate (CW) in length and weight were calculated as described by Winberg (1971).

RESULT

Life cycle and instar duration :

Six nauplii and six copepodite stages were recorded in the life history of *M. leuckarti*, in addition to eggs. Sixth copepodites were adults. When studies started on November 4, 1976, adults and copepodite V dominated the pond population along with abundant egg bearing females. Though naupili N I—III started to increase in number but they formed peak on November 7 (The first 3 molts N I-III could not be separated as each of the stages took very short time to develop and therefore have been grouped together). Thereafter successive instar started forming peaks either at 2 or 3 days intervals (Table 1) until copepodite III, which took 4 days and cope-

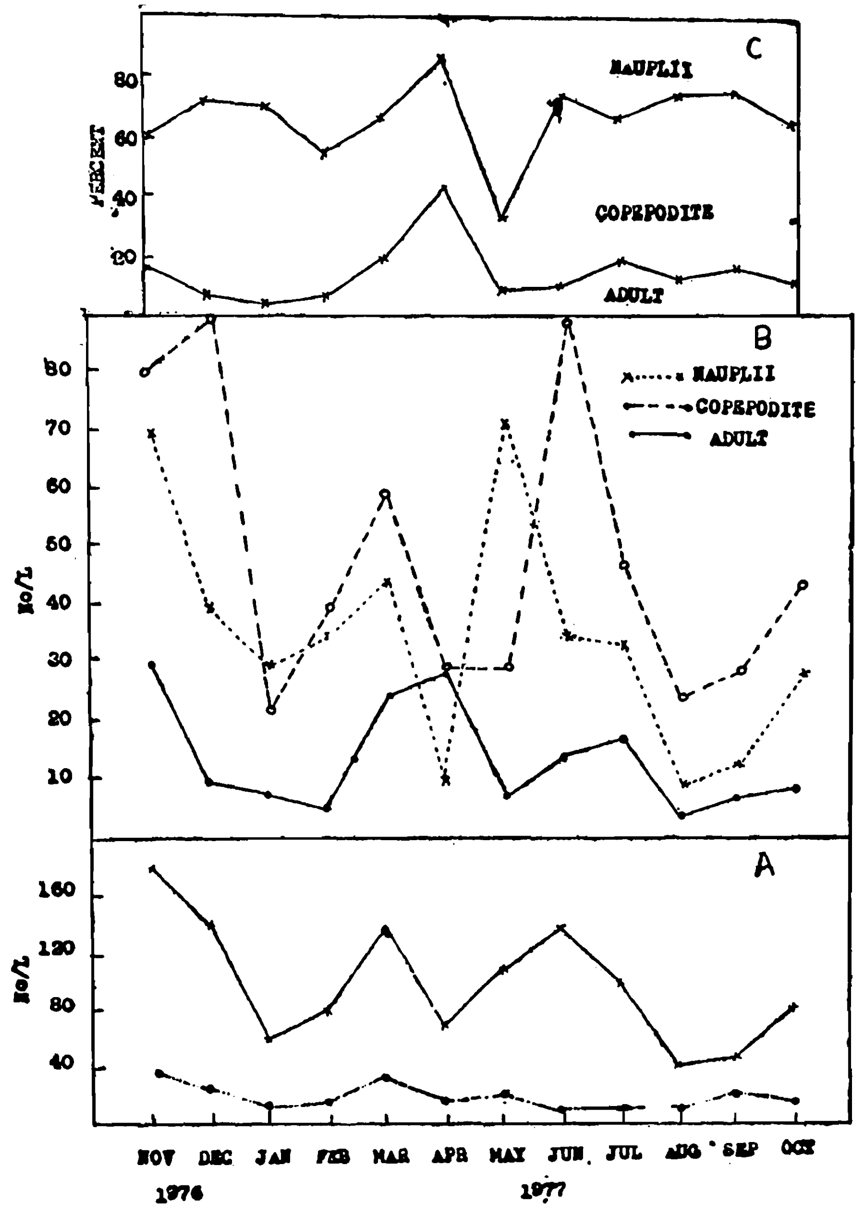

Fig. 1. Seasonal variations in the density of *M. leuckarti* (A) upper curve—Total, (except eggs), lower curve—eggs, (B) Nauplii, Copepodite and Adults (C) percentage composition of nauplii, copepodites and adults.

podite IV which took 6 days. Adults formed peak on December 8. The life of adults was computed indirectly by observing the subsequent minimum in their population which has been assumed to coincide with heavy mortality of the individuals of the aforesaid generation. Such minimum occurred on 10 January 1977 giving total adult duration of 33 days. If the development time of egg is taken as 3 days, as determined in laboratory, the total life span of pond animals (Table 1) is computed to be 67 days (eggs 3, nauplii 11, copepodites 20, adult 33 days). These results were very close to laboratory data (Table 1) where total life span was found to be 75 days (eggs 3, nauplii 8, copedite 18, adults 46 days).

The annual cycle :

Mesocyclops leuckarti were present throughout the year in fairly large numbers. Maximum concentration was found in November

TABLE 2—Absolute and specific growth rate in weight (mg × 10^{-3}) and length of various stages of *M. Leuckarti*

Stages	Dry weight (mg× 10^{-3}) Absolute growth increment (dw/dt)	Dry weight Specific growth rate (1/w w/t)	Length (mm.) Absolute growth increment (dl/dt)	Length Specific growth rate (1/l l/t)
Egg	0.0096	0.3686	0.035	0.4725
NI-N_{III}	0.0090	0.1638	0.015	0.0850
N-IV	0 0126	0.1537	0.021	0.9940
N-V	0.0200	0.1660	0.022	0.0787
N-VI	0.0400	0.2480	0.023	0.0710
C-I	0.0400	0 1360	0.046	0.1120
C-II	0.0400	0.0960	0.043	0.0780
C-III	0.0600	0.1080	0.045	0.0660
G-IV	0.0800	0.1020	0.031	0.0366
C-V	0.0920	0.0980	0.025	0.0247
	0.3250	0.2030	0.030	0.0260

when it was 180/L (all nauplii, copepodites, adults) and minimum in August when it was 49/L (Fig. 1A). Three distinct peaks of total population were recorded first in November, second in March and third in June. Copepodites were found to dominate the population throughout the year with three distinct peaks similar to total population. Nauplii were also in sufficient number throughout the year (Fig. 1B). Copepodite constituted 49.8% of the total population followed by nauplii 35.7% and adults 14.5% (Fig. 1C). The eggs were also present throughout the year and their density ranged from 40/L in November to 6/L in August (Fig. 1A lower graph). When eggs were also included in the total population the percentage composition of eggs ; nauplii., copepodite and adult came to be 13.2%, 30.9%, 43.3% and 12.6% respectively. In every case the contribution of copepodite was highest.

Growth rate :

The absolute growth increment (dw/dt) and specific growth rate (1/W) (dw/dt) in dry weight and length (l) are given in Table 2. Besides eggs, maximum specific growth rate in length was noticed in case of copepodite I (0.1120 mm.). However, the naupliar (I—III) growth rate as a whole was higher than copepodite and adults. The growth rate of adult (CVI) was nearly lowest.

Like length, overall maximum growth in weight occurred in naupliar stages, highest being in nauplii VI (CW, 0.248 × 10^{-3}mg), excepting eggs. The growth in terms of weight of adult female was extraordinary (0.203 × 10^{-3} mg) which was due to appearance of eggs sacs. Besides all these, the growth rate, both in length and weight was highest in eggs.

Reproduction :

Active and continuous reproduction took place throughout the year as revealed by the abundance of eggs and ovigerous females during all months. The size of breeding population (ratio of ovigerous females to total population) ranged between 60 in November

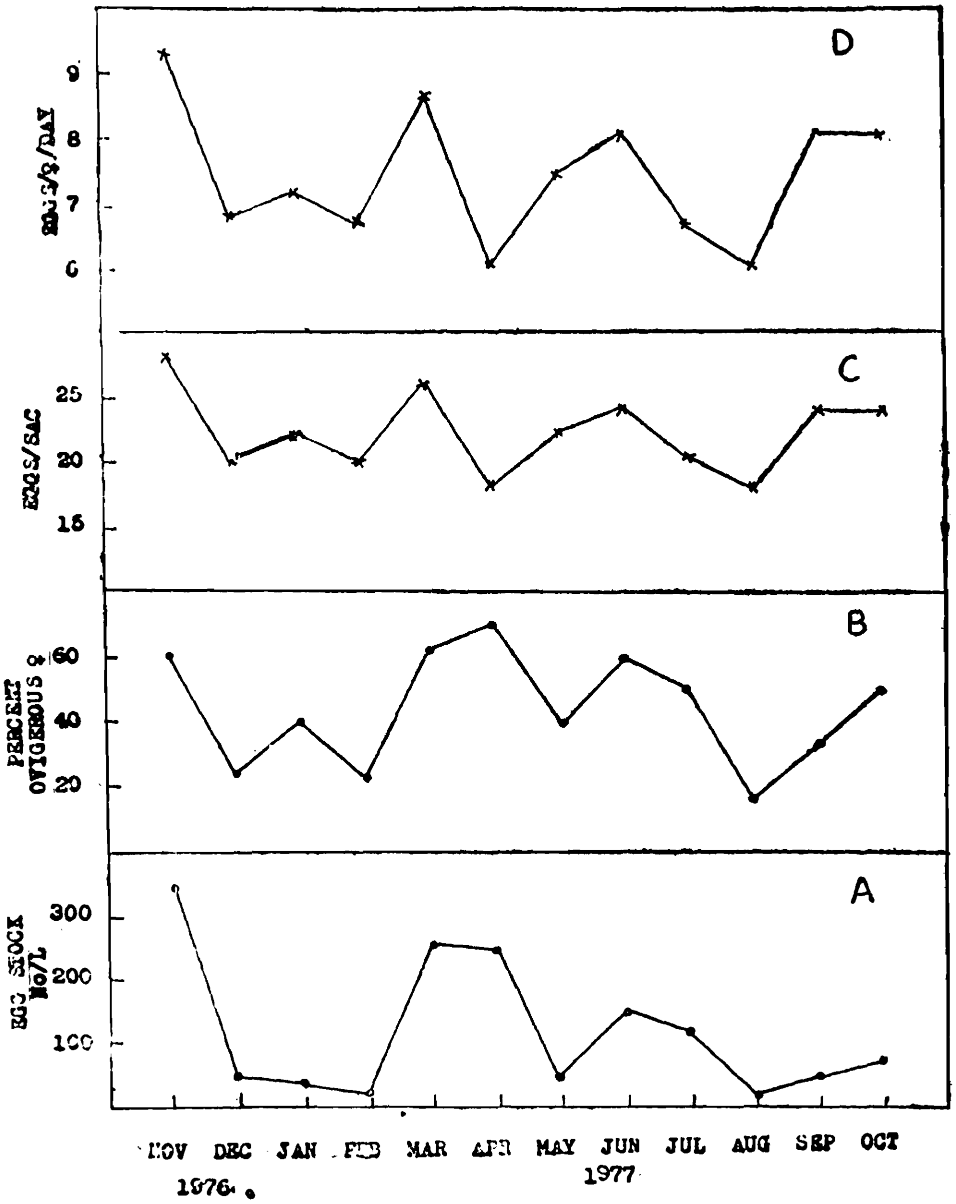

Fig. 2: Seasonal variations in egg ratio of the population (A) size of breeding population (B) clutch size (C) and reproductive rate (D) of *M. leuckarti*..

to 16 in August (Fig. 2B) with 4 peaks, in November, January, April and June, January peak being the smallest and April being largest. Similarly the egg stock of the population (Fig. 2A) also exhibited 4 peaks almost during the same months when size of breeding population formed peaks. These 4 peaks, probably denote the 4 generations of *M. leuckarti* which developed in one complete year.

Almost similar results were obtained when reproductive rate or population birth rate B was calculated in terms of egg/♀/day (Fig. 2D). 4 peaks are clearly visible almost during the same months except that there was a slight shift of 3rd peak which was recorded in March instead of April. This may be due to different calculation procedures. Like size of breeding population, the reproductive rate (egg/♀/day) was also high throughout the year.

The mean clutch size as egg/sac (Fig. 2C) was sufficiently high and did not vary much

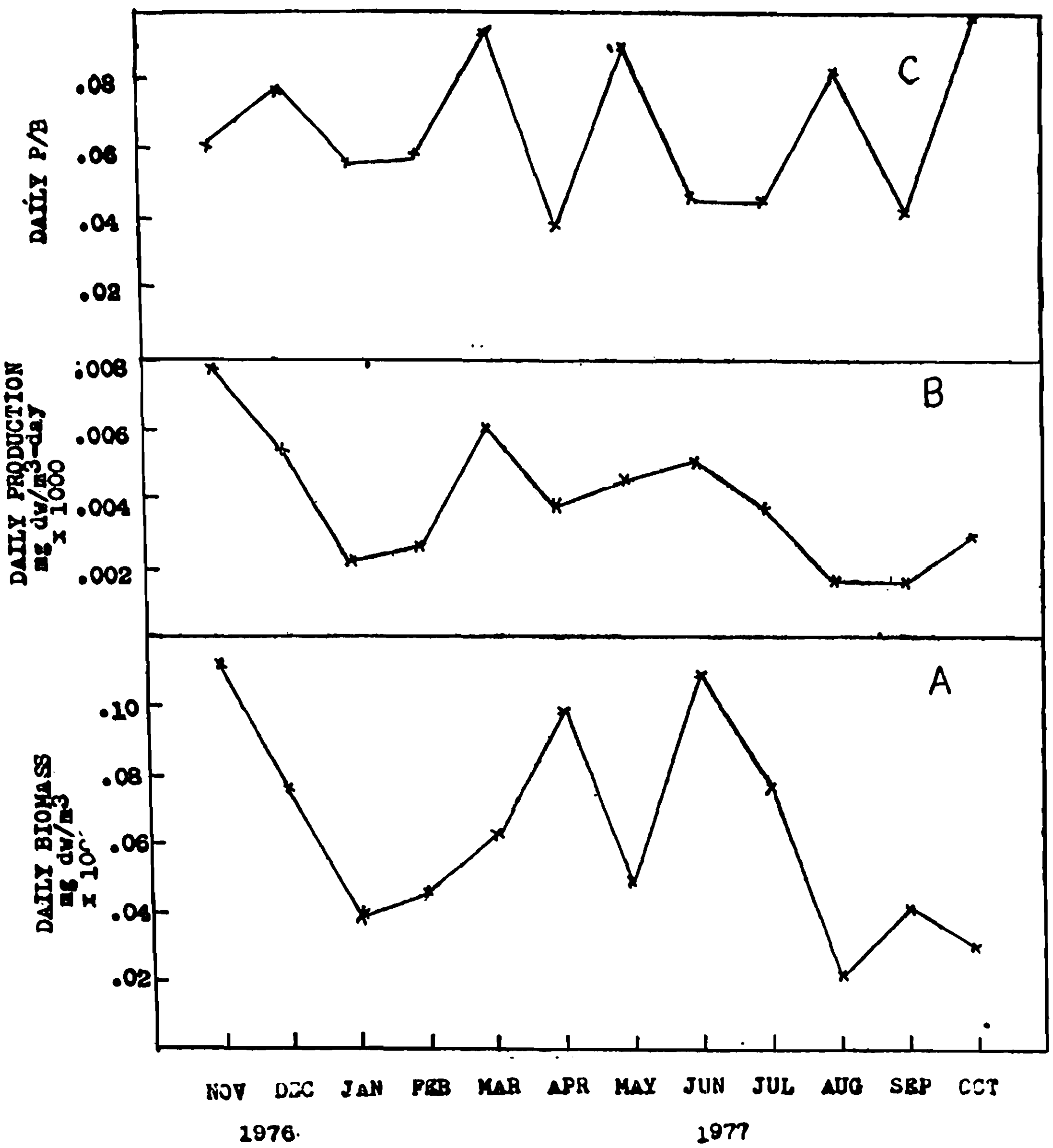

Fig. 3. Seasonal variations in Biomass (A) Daily secondary production (B) and Daily P/B (C) of *M. leuckarti.*

during different seasons (22.16±6). It appears that clutch size increases during the period of rapid reproduction as evident by 4 similar peaks as derived from other reproductive parameters.

Total number of egg/♀ (individual fecundity) was determined in laboratory. It was found that each female at an average produced 2.58 clutches with a mean of 52.8 eggs (range 20—93).

Biomass, secondary production and P/B :

Mean daily biomass, daily production and P/B ratio of *M. leuckarti* during November 1976—October 1977 are shown in Fig. 3. The daily biomass ranged between 21.51 mg dw/m^3 to 113.5 mg dw/m^3 with a mean of 61.6 mg dw/m^3, with 4 peaks, in November, April, June and September. The daily production varied from 1.756 mg dw/m^3-day to 7.930 mg dw/m^3-day (mean 4.775 mg dw/m³-day). Mean daily P/B ratio also fluctuated throughout the year (range 0.037 to 0.102, mean 0.062). Four peaks were also recorded here. Mean monthly P/B ratio was found to be 1.89.

DISCUSSION

The occurence of all stages of *M. leuckarti* in fair numbers throughout the year reveals that species reproduced and flourished continuously in the pond without being affected by any of the prevailing environmental factors. In fact the most important factor governing the population cycle of animal in general, the temperature, was not of much importance as it varied only between 28±3°C throughout the year. Further being an eutrophic waterbody, food was always in abundance as rotifers and cladocerans, early stages of which are the chief food of *M. leuckarti*, also reproduced continuously. The drop in population during August, which is the peak monsoon month may be due to flooding and great dilution of water. As far as the effect of other physicochemical factors are concerned, it appears that *M. leuckarti* has well adjusted. This successful adaptation of *M. leuckarti* in the pond strengthens the view of Hutchinson (1967) and Gophen (1978b) that the species has high adaptability and has successfully adjusted over a major part of its range, inspite of great regional differences in environmental conditions.

The population of *M. leuckarti* was always dominated by copepodites and nauplii contributed less inspite of high reproductive rate and egg stock of the population. This low availability of nauplii may be attributed to high mortality of early stages as reported in copepods by Odum (1959), Burgis (1971) and Gehrs and Robertson (1975). Such heavy mortality of naupliar stages may probably be due to heavy predation upon them and their greater susceptibility to adverse conditions.

Most of the copepod species reported from temperate regions produce only one or two generations in a year. This is because reproductive activity is confined to a short time during summer and development is hampered during winter season (Ravera 1954, Comita 1956, McLaren 1969, Chapman 1969) Obviously such conditions do not occur in tropical waters, atleast in this region of the country and *M. leuckarti* found it convenient to reproduce and develop throughout the year. With the result four definite generations, spread over the entire year can be detected.

The development time of copepods has been found to vary from region to region depending upon different environmental conditions, particularly at different temperature. Eckstein (1964) observed that while *Diaptomus gracilis* took 115 days to develop at 5°C, it took only 38 days at 15°C. From that standard it appears that *M. leuckarti* has a higher developmental duration and life span, even at sufficiently high temperature as that of the pond.

Copepods and other crustaceans are often stated to increase their length by about the same proportion at each molt and follow Brooks law which reveals that such increase is about 25% at each molt. *M. leuckarti* was also found to follow the law as increase in length at each molt from NI — NIII onwards upto CIV ranged between 15.8 — 37.5%. The highest growth occurred at CI which was probably due to sudden increase in length as the animals took copepodite form. Like any other animal, the growth of *M. leuckarti* was found to decrease gradually as age increased.

Inspite of abundance of *M. leuckarti* throughout the year, its biomass and production rate were considerably lesser in Manohar Das Pond as compared to Lake Kinneret, Israel, where Gophen (1978a) found that its biomass and monthly production were 15500 mg. d.w/m² and 5000 mg. d.w./m^{-month}.

Similarly the monthly P/B ratio in Manohar Das Pond (1.89) was also lesser than the Lake Kinneret (3.1).

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