POPULATION DYNAMICS OF A CLADOCERAN ZOOPLANKTER, *DAPHNIA MAGNA*, IN TWO POULTRY-CUM-FISH (DUCK-FISH & CHICKEN-FISH) INTEGRATED PONDS.

Arachana[1], A. P. Sharma[2] and M. Das[2]
[1]*S.V.B.P. University of Ag. & Tech., Meerut, U.P., India*
[2]*College of Fishery Sciences, G.B.Pant University of Ag. & Tech., Uttaranchal, India*

ABSTRACT

The population dynamics of *Daphnia magna* was studied in two integrated fish-cum-poultry ponds (duck-fish and chicken-fish). The seasonal changes in the population of *D. magna* were recorded. Peak population of the zooplankter was recorded in the month of January in both ponds. The birth rate (b), growth rate (r) and death rate (d) of *D. magna* were studied in field as well as in the laboratory. Three temperatures and three different food concentrations were selected for laboratory study. The maximum values of (b) and (r) were recorded during December January in field. Under laboratory conditions, highest birth and death rate occurred at lowest temperature (15 °C). Both food and temperature were found to affect the population dynamics of the species; longest life span and maximum population were recorded at lowest temperature and maximum food concentration.

Keywords: Population dynamics, Cladocera, *Daphnia magna*, Integrated fish -cum -poultry ponds.

INTRODUCTION

Zooplankton constitute one of the most important component of secondary production in a water body. They are mostly represented by mixed population of cladocerans, rotifers and copepods, of which the cladocerans are more important as food for both young and adult fish (Lewis, 1979). The dynamic properties of cladocerans population like growth rate, birth rate and death rate can be used to estimate the production of the particular species (Mailer, 1993).

The population dynamics of cladocerans has been studied in detail by various researchers and found to be influenced strongly by predation and food supply (Hall, 1964, Vijverberg, 1976, Glazier, 1992, Mailer, 1996, Saunder *et.al.,* 1999). Korpelainen, (1980) and Monaghan and Bond, (1993) have evaluated the effects of photoperiod and temperature on the population structure of cladocerans. Fundel *et.al.,*(1998), studied the effect of grazing of *Daphnia* on population dynamics. The present study was carried out to examine the dynamic properties of a common cladoceran, *D magna,* which was found to be the most important cladoceran species in the present integrated fish-poultry ponds. The study was done both in natural as well as in laboratory conditions.

MATERIAL AND METHODS

The present investigation was carried out for a period of 12 months from July 2000 to June 2001, in two completely integrated fish-duck and fish-chicken farming ponds (0.05 ha). High growth variety of broiler chicken (Bab cock) and egg laying exotic variety of duck (Khaki Campbell) were used for integration with polyculture system of Indian major and

exotic carps. The ducks and chicken were raised in wooden houses made up of split bamboo, erected directly over the ponds. The stocking density in both the ponds was 10,000 fingerling/ha, while the stocking density of ducks and chicken was kept as 700 and 500 no/ha, respectively. No fertilizer or manure was added in the integrated ponds; artificial feeding of fish was also not resorted to. Ponds were managed as per standard farm management practices. For the study of population dynamics of *Daphnia magna,* being the most important species in terms of biomass was selected.

Field Methods

Samples of *D. Magna* (concentrate of 5 litre constituted a single sample) were collected at weekly intervals from both the integrated ponds. All adult specimens of *D. magna* were separated from the sample and preserved in 90% alcohol. Length and width of *Daphnia* was measured with ocular micrometer calibrated to stage micrometer. The density of each size group was estimated using the equation given by Welch (1948).

Laboratory methods

The culture of *D. magna*, collected from integrated ponds, was maintained at room temperature in the laboratory. Population dynamics of the zooplankter was studied at three different temperatures (15±1; 25±1 and 35±1°C) and 3 food concentrations (25,000; 50,000 and 75,000 cells/ml). For studying the population attributes, new born *D. magna* were raised in petri dishes at three experimental temperatures.

Chlamydomonas sp., used as food for the zooplankter, was collected from the ponds and cultured in laboratory in Beizerinck's nutritive medium. Moulting time, length after each moult, number of eggs in brood chamber, hatching time of eggs and number of young produced, were recorded at each experimental temperature and food concentration. Birth rate (b), growth rate (r) and death rate (d) were calculated as follows:

1. $b = \ln(1+B)$

Where, b is the instantaneous birth rate and B is the finite birth rate.

The finite birth rate 'B' was calculated as:

$$B = \frac{N_e}{Dn_i}$$

Where, Ne and Ni are number of eggs and number of animals, respectively and D is the egg development time for the species.

2. $r = \ln Nt - \ln No/t$

Where, ln Nt is the observed value of N (Number of individuals) after an interval of 't' days

3. $d = b - r$

Seasonal variations in birth rate, death rate and growth rate values were also calculated in both the ponds.

RESULTS

Field Studies

a) Population density

Only one peak (during January) was observed in the population of *D. magna* in both the ponds (fig 1). In duck-fish pond, the

species was recorded from November (20.50 ind/l) to April (22.05 ind/l). The population rose rapidly in December attaining maximum value in January (175.5 ind/l), after which it again declined till April. The trend of population variation was similar in chicken-fish pond. Starting from an initial value of 26.88 ind/l in November, the *Daphnia* population increased sharply in December (189.84 ind/l) and reached a maximum value in January (257.04 ind/l). The population decreased thereafter and disappeared in April and May in chicken and duck-fish ponds respectively.

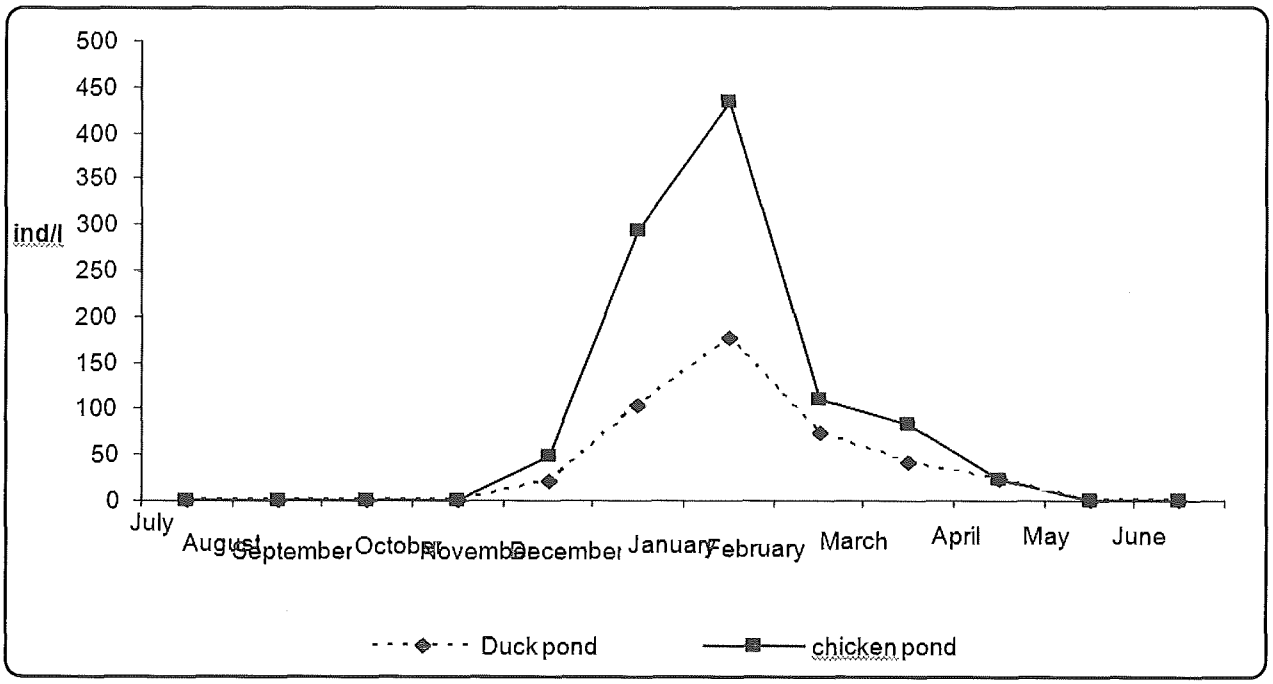

Fig. 1. Seasonal variation in population density of *D.magna* in duck-fish and chicken-fish ponds

The maximum number and individuals carrying ephippia were recorded in February and March in chicken and duck ponds respectively (fig 2).

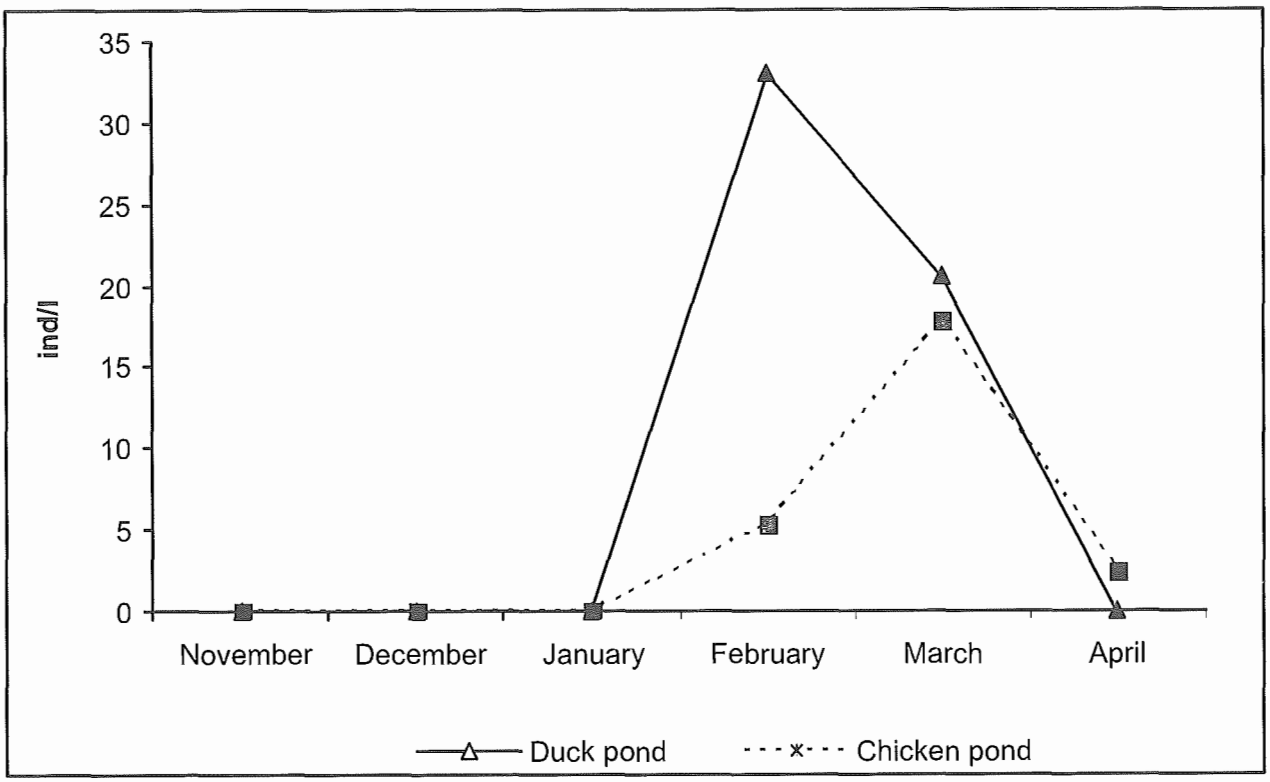

Fig. 2. Seasonal variation in the density of ephippial females in duck and chicken fish ponds.

b) Size structure:

The individuals collected from the ponds were examined and differentiated according to their size:

Size group I Neonates (0.76-0.96 mm)

Size group II Pre-adults (0.96-1.50 mm)

Size group III Adults (1.50-2.48 mm)

All the size groups were represented in the samples, but their proportion varied from time to time (fig 3). The individuals of size group I peaked during November in both the ponds contributing 60.5% and 62.0% to the total population in duck-fish and chicken-fish ponds, respectively. The size group II had its maximum contribution in December with 54.6 and 58.3% in duck and chicken ponds respectively; while the individuals of size group III had a maximum percent contribution during April (82.4%) in duck-fish pond and March (81.0%) in chicken-fish pond. The time series pattern of birth rate (b), growth rate (r) and death rate (d) in both duck and chicken ponds is illustrated in figures 4 (a) & (b).

c) Birth rate

The highest birth rate value was recorded in December (0.093), whereas the calculated value of 'b' was nil during February in the chicken-fish pond. The highest and lowest values of b were observed in January (0.084) and April (0.005), respectively in the duck-fish pond.

d) Growth rate

The maximum growth rate (r) in chicken-fish pond was recorded in December (0.095) and lowest in March (-0.047). In the duck-fish pond, the highest growth rate value, r = 0.075 was recorded in December, it got decreased till April attaining the lowest value of r = -0.07.

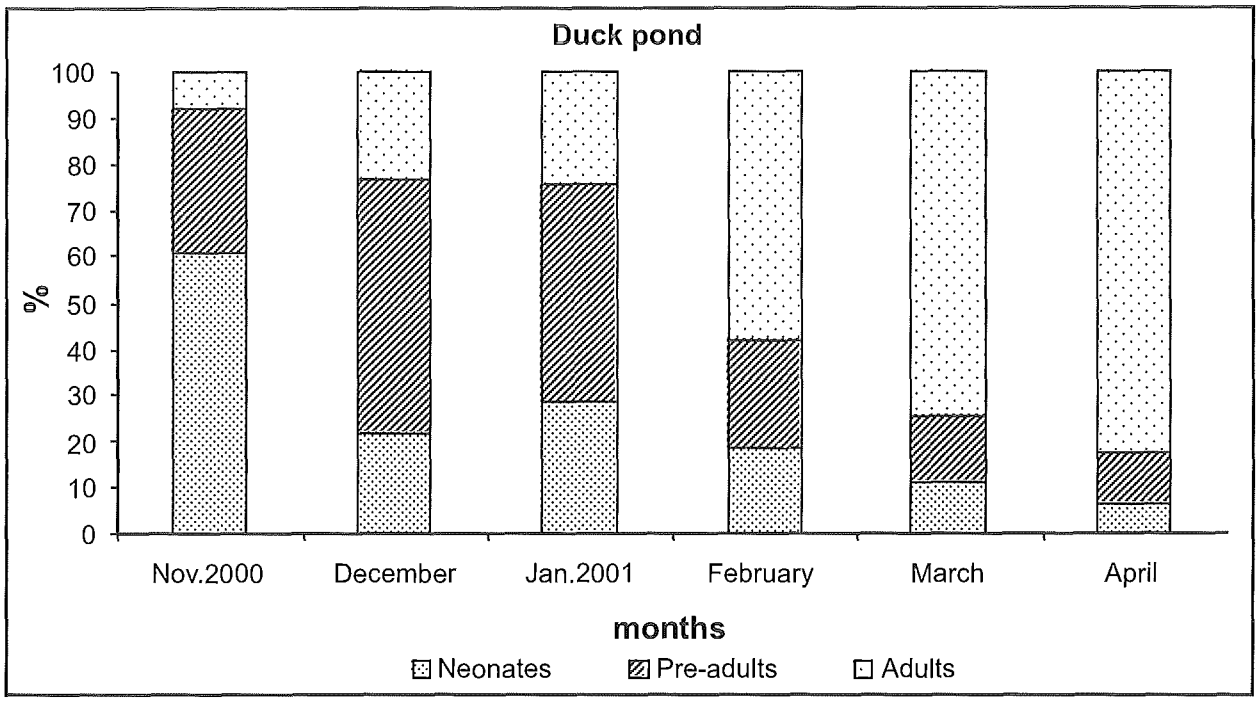

Fig. 3. Percent composition of different stages of *D. magna* in duck and chicken-fish ponds.

e) Death rate

The death rate value of *D. magna* was highest in March (0.041) and in April (0.054) in chicken-fish and duck-fish pond respectively. In the chicken-fish pond the death rate was lowest in December (d = -0.002). In the duck-fish pond, the death rate value, which was initially 0.002 in November, eventually became negative (d = -0.007) in December. There was a considerable increase in January (d =0.052) followed by slight decrease in February (0.046).

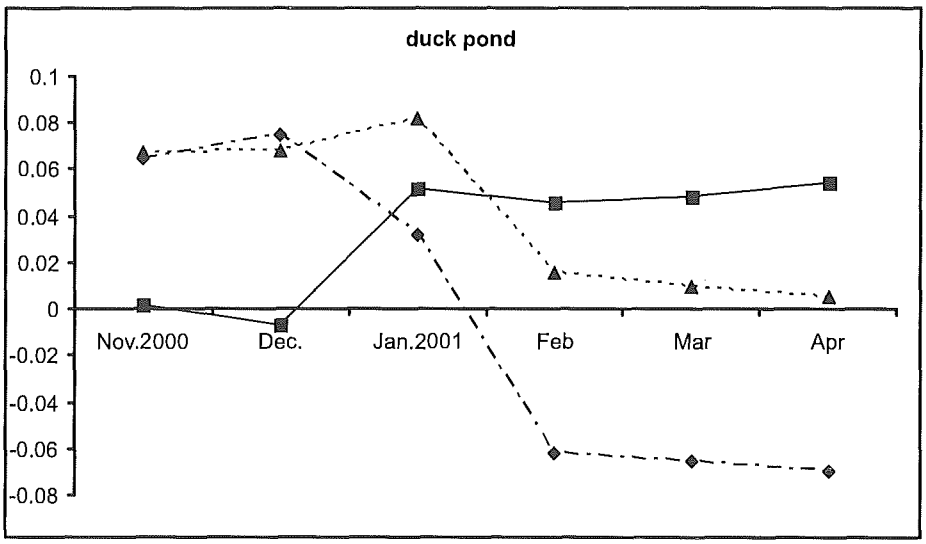

Fig. 4(a). Variations in the growth (r), birth (b) and death (d) rate values of *D. magna* in duck-fish pond

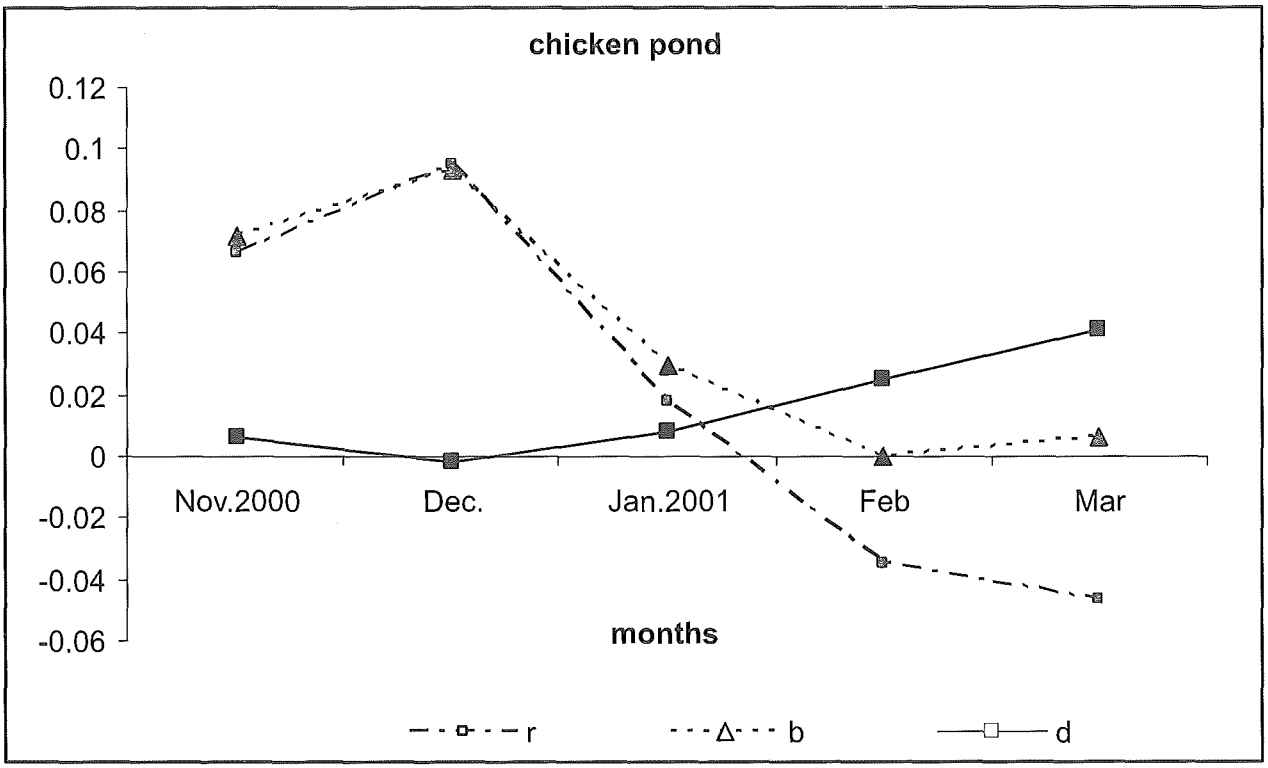

Fig. 4(b). Variations in the growth (r), birth (b) and death (d) rate values of *D. magna* in chicken-fish pond

Laboratory (Experimental) Studies:

Population traits at selected temperatures:

Table 1. gives an account of the time devoted to various life-span activities and total number of juveniles produced by *D. magna* at the 3 experimental temperatures. The longest survival (22 days) was recorded at the lowest temperature *i.e.* ,15 ^{0}C followed by 14 and 8 days at 25^{0}C and 35^{0}C. The pre-adult and post-adult development time was observed as 7, 4, 2 and 15, 10 days respectively at the selected experimental temperatures of 15^{0}C, 25^{0}C and 35^{0}C. A female produced maximum number of juveniles (58.04) at 35^{0}C, while the least number of juveniles (33) were produced at 15^{0}C. The average time taken by an egg for development was 4.6 days at lowest temperature while at 35^{0}C it took 2.55 days. The highest birth, growth and death rate values were recorded at the lowest temperature (15^{0}C) (Table 2).

Population traits at selected temperatures and food concentrations

Time devoted to various life span activities by *D. magna* at 3 selected temperatures and 3 selected food concentrations (25,000, 50,000 and 75,000 cells/ml) are given in Table 3.

Table 1. Time devoted to various life span activities by *D. magna* at three selected temperatures.

	15^0C	25^0C	35^0C
Total life span (days)	22	14	8
Pre-adult development time (days)	7	4	2
Post-adult development time (days)	15	10	6
Average number of juveniles produced by female	33	54	58.04
Dev. Time of egg (days)	4.6	3.4	2.55
Average number of individuals at the end of experiment	396	864	1109.6

Table 2. r,b and d values at different temperatures.

	r	b	d
15 ± 1^0C	0.270	0.290	0.561
25 ± 1^0C	0.083	0.174	0.257
35 ± 1^0C	0.127	0.051	0.178

Table 3. Time devoted to various life span activities and average number of individuals produced by *Daphnia magna* at different food and temperature levels.

Temperature	**15 ± 1^0C**			**25 ± 1^0C**			**35 ± 1^0C**		
Food concentration (cells/ml)	**25,000**	**50,000**	**75,000**	**25,000**	**50,000**	**75,000**	**25,000**	**50,000**	**75,000**
Total life span (days)	22	24	27	14	15	15	8	8	8
Pre-adult development time (days)	7	7	8	4	2	3	2	2	2
Post-adult development time (days)	15	17	19	10	12	12	6	6	6
Developmental time of egg (days)	4.6	4.6	4.6	3.4	3.4	3.4	2.55	2.55	2.55
Average number of juveniles produced by one female	33	42	38	54	58	55	58.4	56	62
Average number of individual at the end of experiment	396	412	418	864	887	901	1109	1122	1140

It was observed that an organism had the longest life span (27 days) at lowest temperature (15°C) and highest concentration of food (75,000 cells/ml). The shortest life span of only 8 days was recorded at 35°C at all the food concentrations. Similar traits were observed for the pre-adult and post-adult development time of *Daphnia.* On an average, an egg took the least time for development at 35°C (2.55 days) while the development time was longest at 15°C (4.6 days). Maximum number of juveniles (62) were produced at highest temperature by feeding at highest food concentration; minimum offsprings were produced at 15°C (33) when the organisms were fed at 25,000cells/ml food concentration.

The observed values of birth: death: growth rate at the food concentrations of 25,000, 50,000 and 75,000 cells/ml were 0.073:0.189:0.178,0.0539:0.188:0.116 and 0.0567:0.124:0.132, respectively.

DISCUSSION

In general, the cladoceran population consisted mostly of parthenogenetic females for most part of the year. In the present study, parthenogenetic females carrying eggs at different stages of development were observed during the occurrence of *Daphnia* in both ponds. The presence of ephippial females coincided with the lowest population density of the species. The maximum density of such females was recorded before the complete disappearance of *D. magna* population from the ponds during March/April. Similar observations were reported by Edmondson (1955). The population of groups II and III increased after the decrease of size-group I (fig. 3).

The studies in the natural population of *D. magna* in both the integrated ponds revealed rapid increase in the population from December to January, coinciding with the highest growth rate values in both ponds. This probably is indicative of the hatching of resting eggs on getting favorable environmental conditions. In chicken-fish pond, the highest birth rate coincided with the highest growth rate (December) preceding the highest population density of *D. magna*. Similar results have been reported by Smyly (1979) for *D. magna* in a productive fresh water ecosystem. During a three and a half years study of *Daphnia* population dynamics in a small subtropical water body, Saunders *et. al.* (1999) obtained highest biomass of *Daphnia* during winter season, coinciding with the lowest temperature; the population was scarce during most of the summer. The constrained population during summer was attributed to temperature, food and predation. In the present study, *Daphnia* population declined with increase in temperature with the onset of summers and disappeared thereafter. The grazing of *Daphnia* by fishes with the increase in temperature can also be considered as a major factor for the disappearance of its population. The carps stocked under polyculture system in the ponds either do not feed or have very low feeding intensity during winter months (personal observation). The phytoplankton population during summer was also found to be very low (Singh, 2002). It can be inferred from the data collected in the present study that since *Daphnia* occurred only during the period of low temperature, therefore water temperature was the most important factor determining the abundance of *D. magna* in comparison to the other factors.

On the other hand, the maximum birth rate coincides with the highest population during January in duck-fish pond. During the phase of maximum growth and birth rate, the death rate was either lowest or attained negative values *i.e.,* natality exceeded mortality. Hulsmann and Weiler (2000) also reported that a quick increase in

Daphnia abundance leads to the formation of a strong "peak cohort" of about the same age.

In the present study death rate, birth rate and growth rate values of D. *magna* do not seem to be affected by availability of food. This is in contrast to the findings of Wu and Culver (1994) who found that food limitation is the major cause of decline of *Daphnia* populations, although temperature had a considerable effect on population. The *D. magna* population increased with the decrease in temperature in both the ponds and rose to peak values in January. Similar trend of variation is observed in birth rate of the species in the both the ponds under study. A sudden reduction in fecundity values of *D. magna* during summers has also been reported by Gliwich (1977) and Mailer (1992). According to Vijverberg and Richter (1982) this seems to be a common feature of all large sized *Daphnia* species.

Under varying temperature conditions, when surplus food was provided to the test animals, it was observed that lowest temperature favoured the longest life span. However, the production of eggs into juveniles was more at higher temperature.

When both temperature and food concentration were taken into consideration, maximum population was recorded at highest temperature (35°C) and highest food concentration (75,000 cells/ml). Longest life span of D. *magna* was also recorded at highest food concentration but lowest temperature.

Sterner *et. al.* (1993) and Wu and Culver (1994) also hypothesized that food quality affects the cladoceran population. Cox (1993) concluded that more supply of food resulted in greater number of neonates produced. In the present study also the overall population increased with increasing food concentrations at all experimental temperatures.

Similar trend of variations in birth rate and growth rate values is observed for both laboratory and natural population with highest 'b' and 'r' values being recorded at lowest temperatures. The birth and growth rate values are generally higher in laboratory at all temperatures as compared to natural populations. It may be due to the fact that food concentrations as well as temperature were kept constant throughout the study under laboratory conditions.

ACKNOWLEDGEMENTS

One of us (Arachana) is grateful to U.P. Council of Agriculture Research and Indian Council of Agriculture Research for award of J.R.F. and S.R.F., respectively. Thanks are also due to Dean, College of Fishery Sciences and Director, Experiment Station, G.B. Pant University of Agri. & Tech. Pantnagar, Uttaranchal, India for providing necessary facilities to conduct the present study.

REFERENCES

Edmondson, W.T., 1955. The seasonal life history of *Daphnia magna* in an arctic lake. *Ecology. 439-455.*

Hall, D. J., 1964. An experimental approach to the dynamics of natural population of *Daphnia magna mendotae. Ecology. 45:94-112.*

Vijverberg. J., 1976. The effect of food quality and on the growth, birth rate and longevity *Daphnia hyalina* Leydig and *Daphnia cucullata* Sars in Tjeukemmeer. *Hydrobiologia. 95:235-259.*

Gliwicz, Z. M., 1977. Food size selection and seasonal succession of filter feeding zooplankton in an eutrophic lake. *Ecology Pol. 25 (2): 179-225.*

Lewis, W. M. Jr., 1979. Zooplankton community analysis: Study on a tropical lake. Springer Verlag, New York: 163d.

Smyly, W. J. P., 1979. Population dynamics of *Daphnia hyalina* Leydig (cerustacea : cladocera) in a productive and an unproductive lake in the English lake district. *Hydrobiologia. Vol. 64:269-178.*

Korpelainen, Helena, 1980. The effects of temperature and photoperiod on life history parameters of *Daphnia magna* (crustacean: cladocera). *Freshwater Biol.* 16: 615-620.

Vijverberg, J. and A. F. Richter, 1982. Population dynamics and production of *Acanthocyclops robustus* sars and *Mesocyclops leuckarti (claus)* in Tijeukemeer. *Hydrobiologia 95: 261-274.*

Glazier, D. S., 1992. Effect of food, genotype and material size and age on off spring investment in *Daphnia magna. Ecology. 73 (3): 910-992.*

Mailer, G., 1992 Development, reproduction and growth patterns of two coexisting, pond dwelling cladocerans. *Int. Rev.* Ges. *Hydrobiol. 77:621-632.*

Cox, E. J., 1993. The effect of manipulating algal food source on animal growth and fecundity. *J. Phycol. 29 (3):20.*

Maier, G., 1993. The life histories of two temporarily coexisting, pond dwelling cladocerans. *Int. Rev. Ges. Hydrobiol. 78: 83-94.*

Monaghan, C. R. and J. A. Bond, 1993. Different expression if protein in *Daphnia magna* raised at 3 different temperatures. *In*: Stegeman, J.

J., M. N. Moore, M. E. Hahn (*eds*). Response of marine organisms to pollutants. Part 2. 35 (1-2):222 pp.

Sterner, R. W., D. P. Hagemeir, W. L. Smith and R. F. Smith, 1993. Phytoplankton nutrient limitation and food quality for *Daphnia. Limnol. Oceanogr.* 38:857-891.

Wu, Lin and David A. Culver, 1994. *Daphnia* population dynamics in Western lake Erie: regulation by food limitation and Yellow Perch predation. *J. Great Lakes. 20 (3): 537-545.*

Maier, G., 1996. *Daphnia* invasion: Population dynamics of *Daphnia* assemblages in two eutrophic lakes with particular reference to the introduced alien *Daphnia ambigua. J. Plankton Research. 18:2001-20015.*

Fundel, B., Stitch, H. B., Schimd, H. & Maier, G., 1998: Can phaeopigments be used as markers for *Daphnia* grazing n lake Constance? *J. Plankton Research. 20:1449-1462.*

Saunders, P., Porter and B. Taylor, 1999. Population dynamics of *Daphnia* spp. and implications for trophic interaction in small, monomictic lake. *J. Plankton Research. 21: 1823-1845.*

Hulsman, Stephen and Winried Weiler, 2000. Adult, not juvenile mortality as a major reason for the midsummer decline of a *Daphnia* population. *J. Plankton Research. 22: (1). 151-168.*

Singh, V. K., 2002. Nutrient dynamics in duck-fish integrated farming system. Ph.D. Thesis. Kumaun University, Nainital. India. pp. 247.